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ORIGINAL ARTICLE

Cereal chaff used as temper in loom-weights: new evidence from a Slovenian Eneolithic pile-dwelling site (ca. 3100 cal BC)

Tjaša Tolar[1] · Stefanie Jacomet[2] · Anton Velušček[1]

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Abstract We present new evidence of the intentional use of cereal by-products at Stare gmajne, an Eneolithic pile-dwelling site in Slovenia, dated approximately 3160–3100 cal BC. The chaff material, which had been used for tempering, was discovered inside one of the largest discovered loom-weights and analysed. Clay, which was used by the dwellers to make the weight, was tempered with cereal chaff to reinforce it. The practice of tempering, not necessarily for loom weights, has already been proven for earlier settlements, mostly in arid areas where firewood, grazing and building material were scarce. However, tempering has rarely been found in European prehistoric sites. More than 1,800 carbonised and half-carbonised, excellently preserved and well identifiable cereal plant macroremains in less than 1 l of waterlogged clayey material were sorted and counted. Among the recognized plant macroremains, barley rachis fragments and glume wheat (emmer and einkorn) by-products such as spikelet forks and glume bases prevailed. A few grains were also found. Cultivation of the main crops of emmer, einkorn and barley at Slovenian Eneolithic pile-dwelling sites was confirmed again. Among the chaff, a new "strange type" of *Triticum dicoccum* (emmer) spikelet forks was discovered. The size of the weight and the intentional local use of cereal by-products as temper suggest that late Neolithic (Eneolithic) pile-dwelling societies all around the Alps were highly organized and developed due to expansion of crop production and processing.

Keywords Eneolithic · Waterlogged preservation · Cereal by-products · "Strange type" of emmer

Introduction

The Stare gmajne site is an Eneolithic or copper Age pile-dwelling site from the 4th millennium cal BC in Slovenia. The excavated cultural layers were dendrochronologically dated to 3160–3100 ± 14 cal BC (Čufar et al. 2009, 2013). Tolar et al. (2011) have recently discovered the six main crops that were cultivated there: *Triticum monococcum* (einkorn), *T. dicoccum* (emmer), *Hordeum vulgare* (barley), *Linum usitatissimum* (flax), *Papaver somniferum* (opium poppy) and *Pisum sativum* (pea), which show evidence of the agricultural activity of the inhabitants. Several grinding stones have been discovered at the site as well, which were most probably used for making flour (Velušček 2009b; Turk 2009).

On the basis of the archaeobotanical research, barley, emmer and einkorn were the main cereals at the Stare gmajne site (Tolar et al. 2011). With the exception of barley, all identified cereals belong to glume wheats (einkorn and emmer), which, in contrast to naked wheat, has thick gripping glumes that enclose the grain tightly, therefore the grain cannot be easily extracted from the spikelets and the ears usually break into spikelets (Wilkinson and Stevens 2003; Jacomet 2007, 2010). To obtain naked grains, the spikelets must be processed

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✉ Tjaša Tolar
tjasa.tolar@zrc-sazu.si

[1] ZRC SAZU, Institute of Archaeology, Novi trg 2, 1000 Ljubljana, Slovenia

[2] Department of Environmental Sciences, Institute of Prehistory and Archaeological Science IPAS, Basel University, Spalenring 145, 4055 Basel, Switzerland

(Hillman 1984a, b; Meurers-Balke and Lüning 1992; Anderson and Peña-Chocarro 2014). During the processing of cereals, many different by-products were produced: chaff, straw, weed seeds as well as some grains (Hillman 1981, 1984a; Anderson and Peña-Chocarro 2014). Ethnographic evidence in present-day societies as well as archaeobotanical evidence of past societies indicates that these by-products were used as fuel, fodder or temper (Watson 1979; van der Veen 1999; Henn et al. 2015). Nevertheless, some of these by-products, especially those of free-threshing cereals, are rarely found in charred seed assemblages from European sites (Green 1981; Hillman 2001; Henn et al. 2015), in contrast to sites in arid regions like North Africa where one can find desiccated preservation. Van der Veen (1999) provided evidence for the use of chaff and straw at some of the North African sites and reviewed the situation in Europe. She discussed the role of cereal by-products as an economic resource. An example of the use of cereal by-products in the Eneolithic/late Neolithic was seen from plant impressions at many European sites (Hopf 1977, 1980; Bakels 1984; Borojević 2006; Henn et al. 2015). These were the imprints of wheat chaff from einkorn and emmer which were used together with fine culm fragments of wild grasses for tempering daub and ceramics (Kohler-Schneider 2007). At the Opovo site in Serbia, dated from 4700 to 4500 cal BC, for example, mineralized (silicified) chaff from domesticated glume wheat, probably of emmer and einkorn, and straw remains and their omnipresent impressions were found in house daub (Stevanović 1997; Borojević 2006). Although there are no available techniques to identify the actual quantity of straw and chaff used (Henn et al. 2015), an attempt was made to estimate the amount, function and importance of chaff and straw used for tempering house daub at Opovo (Borojević 2006). Some *Triticum monococcum/dicoccum* spikelet impressions on a large pot from Opovo were also noticed, but a more precise identification and counting of the remains was impossible due to the lack of techniques to identify the actual quantity of straw and chaff preserved in burnt and dried pottery.

Henn et al. (2015) found out that mudbrick is extremely rich in plant materials, especially chaff, straw, fruits and seeds. Recovery of these remains would enable us to gain a comprehensive insight into the contemporary floras of past settlements and their surroundings. Hundred- and fifty-year old mudbricks from Hungary, used as natural building material, were investigated and processed with different techniques to examine the desiccated archaeobotanical material in the mud.

Loom-weights are present at many Eneolithic settlements throughout Slovenia (Velušček 2011). They are also sporadically known from the pile-dwellings at Ljubljansko barje (Bregant 1975). It is widely accepted that they were used for the weaving of textiles. The loom-weights are pyramidal in shape. Especially because they are simple in form it seems that they were less carefully made than the other pottery objects. They consist of a full body with a horizontal shaft-hole in the upper part. Hollow or inadequately burnt bodies of loom-weights are also known (Tomaž 2012).

The present paper discusses new evidence of the use of cereal chaff as temper in Slovenia, where in the cultural layer, the original waterlogged unburnt clay with organic material for tempering for making the loom-weight was discovered and analysed in detail. The plant remains from the loom-weight confirm and complement existing knowledge on the intentional use of cereal by-products in European late Neolithic/Eneolithic settlements.

The main aim of the present research is to produce new evidence of cereal chaff use in Slovenian prehistory and to investigate in more detail the practice of tempering loom-weights with cereal chaff. The primary objective of the research is therefore to identify and count the cereal by-products that were preserved in an incompletely burnt clayey loom-weight and which were used as temper. As the chaff inside the loom-weight is excellently preserved, it also allows us to do detailed morphological studies on the chaff and to compare these results with the recently discovered "new" wheat taxa like "new glume wheat" (Jones et al. 2000; Kohler-Schneider 2003; Kenéz et al. 2014; Toulemonde et al. 2015). A further goal is to reconstruct the way in which the preservation types of plant remains were formed, and how the weight was fired. On the basis of the archaeobotanical results, an estimation of the clay-straw ratio is attempted.

Results from archaeobotanical investigations in Slovenia are quite scarce due to the inappropriate methodology used until 2006 (Tolar et al. 2010). However, some recent research has given a reliable insight into the plant spectra of the Eneolithic Slovenian lake dwelling sites (Tolar et al. 2011). Therefore, this new research on material from the clayey weight at Stare gmajne attempts to supplement these results.

Materials and methods

During the excavation in 2006 at the site of Stare gmajne, a large loom-weight was found whose outer parts were burnt (Fig. 1a; ESM Fig. 1). In the course of excavation, the bottom of the clayey weight broke or fell off and its interior became visible (Fig. 1b, c).

In total, almost 1 l of wet and clayey material from the inner parts of the weight was obtained. It was very carefully wet sieved with two sieves with 2 and 0.355 mm mesh sizes. Both organic sieve fractions were wet stored

Fig. 1 **a** The pyramid-shaped 1.5 kg heavy well preserved loom-weight, 22.2 cm high, up to 14.4 cm wide, photo: M. Turk; **b**, **c**, weight with burnt outer and inner less burnt part, filled with waterlogged clayey material, analysed in detail; photos by T. Tolar

and their volumes measured before sorting. All recognizable and identifiable botanical macroremains were picked out and counted from the whole fractions. The results of identification, type of remains, preservation state and counts are presented in Table 1. Since cereal chaff provides the most important means for the identification of wheat species on the basis of their morphology (Hillman 1984a; Jacomet 2006a, 2010), a careful morphological study of the different remains, mainly chaff, was made and the proportions of different cereal types were calculated. Based on this, an estimation of the clay-straw ratio used for making the clayey objects was made and the proportions of chaff remains of the different crops were estimated.

Finally, an experiment was performed in order to reconstruct how the chaff became carbonised and half-carbonised inside the weight, although only its outer parts were completely burned. Was the chaff already carbonised before it was added to the clay, or did it become carbonised or half-carbonised during the burning of the clayey object/weight? In order to answer this question, we took clay from one of the natural slow-flowing channels nearby the Stare gmajne site and mixed it by hand with untreated dry plant material from hay (ESM Fig. 2a). We produced two specimens of similar size to the Eneolithic loom-weight, objects A and B (ESM Fig. 2b). For the burning, we made an open fire with hot coals. We put the experimentally produced weights in the fire and left them for 1 h 25 min in the case of (object A and 3 h 35 min for object B. Then, the preservation of the added hay in both objects was checked.

The nomenclature of the cultivated plants follows Zohary et al. (2012), by using the traditional classification on pp 17–69.

Table 1 Quantity (numbers) of identified cereal macroremains and other identified seeds/fruits in 1 l of sediment from the incompletely burnt loom-weight

	Rachis frg. carb. (half-carb.)	Grain carb. (half-carb.)	Spikelet fork carb. (half-carb.)	Glume base carb. (half-carb.)	Seed/fruit carb. (half-carb.)	Total grain/seed units
Hordeum vulgare-nudum	392 (71)	8				463
Triticum dicoccum		11 (1)	235 (68)	255 (103)		482
T. monococcum			69 (73)	26 (75)		193
T. monococcum/dicoccum		(2)	43 (31)	306 (94)		274
Papaver somniferum					(12)	12
Bromus sp.					1	1
Panicum cf. *miliaceum*					1	1
Quercus sp.					2	2
Poaceae					23	23
Cyperaceae					2	2
Chenopodium album					(12)	12
Verbascum cf. *blattaria*					(10)	10
Hypericum perforatum					(1)	1

Results of both sieve size fractions added up

Results

From almost 1 l of sediment sample from the Eneolithic weight, a total of 65 ml of organic fractions was caught on the sieves: 40 ml of the large fraction (>2 mm) and 25 ml of the small fraction (>0.355 mm). The density of botanical macroremains was high: in total, 1,950 botanical macroremains per litre of sediment were identified and counted. 566 identifiable plant macroremains were preserved in a half-carbonised state and the rest, 1,384 (71 %), in a carbonised state (Table 1).

Cereals

The majority (97 %) of the identified macroremains were cereals. Among them, three species were identified, namely two glume wheats: *Triticum monococcum*) and *T. dicoccum*, and *Hordeum vulgare-nudum* (Fig. 2).

New "strange" type of *T. dicoccum*

If we have well preserved remains of spikelet forks consisting of glume bases with rachis nodes and grains, it is often possible to distinguish between some of the glume wheat varieties or different ploidy levels (Hillman et al. 1996; Jacomet 2006a, 2010). Since Jones et al. (2000) drew attention to a "new" type of glume wheat from Neolithic and Bronze Age sites in northern Greece, several finds of this morphologically distinct, most probably tetraploid wheat form have been made across central and southeastern Europe (Kohler-Schneider 2003; Kenéz et al. 2014; Toulemonde et al. 2015).

In the loom-weight from the Stare gmajne site we found numerous "strange" type emmer spikelet forks that had been used as temper in this late Neolithic (Eneolithic) pile-dwelling site (Fig. 3; Table 2). They look like an exceptionally big, maybe 3-grained emmer variety (G. Jones, personal communication) and were counted as emmer spikelet forks, because they resemble emmer, but they are much larger (Table 1). In only 9 l of surface sediment samples from the cultural layer of the Stare gmajne site (Tolar et al. 2011) that were properly wet sieved and examined in Slovenia (Tolar et al. 2010), we have not yet found such "strange" type emmer spikelet forks (Fig. 3b; Table 2). Further research on other Slovenian pile-dwelling sites will show whether this is really a special type of glume wheat that was grown by the people south of the Alps.

For a reliable comparison of the proportions of the cereal taxa, the identified remains were converted into comparable units, using the following scheme: 1 spikelet fork corresponds to 1 rachis fragment and/or to 2 glume bases (Fig. 4; Table 1).

Other identifications

Among the cultivars, 12 seeds of *Papaver somniferum* and probably one seed of cf. *Panicum miliaceum* (broomcorn millet) were also found (Table 1). Only 49 (2.5 %) plant remains of seeds/fruits belong to other non-cultivated taxa such as weeds and plants of other vegetation types. Among them, six taxa were identified: various Poaceae, *Chenopodium album*, *Verbascum* cf. *blattaria*, *Hypericum perforatum*, *Quercus* sp. and various Cyperaceae (Table 1). There were also some fungal spores, charcoal fragments, fish bones and scales present.

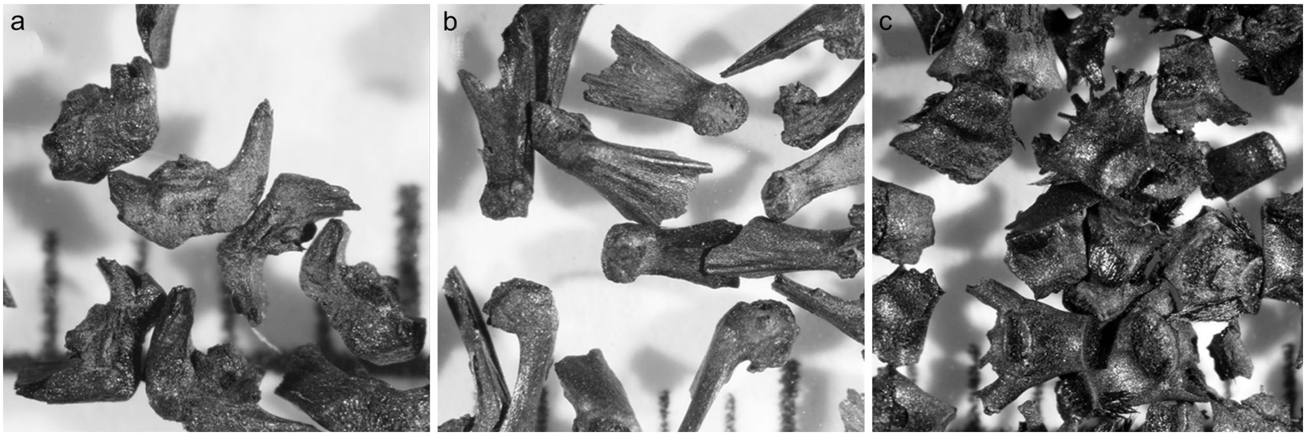

Fig. 2 Carbonised and half-carbonised parts of cereal flowering structures from the interior of the loom-weight of the *Stare gmajne* site: **a** spikelet forks of glume wheats; **b** glume bases of glume wheats; **c** rachis fragments of barley; photos by D. Valoh

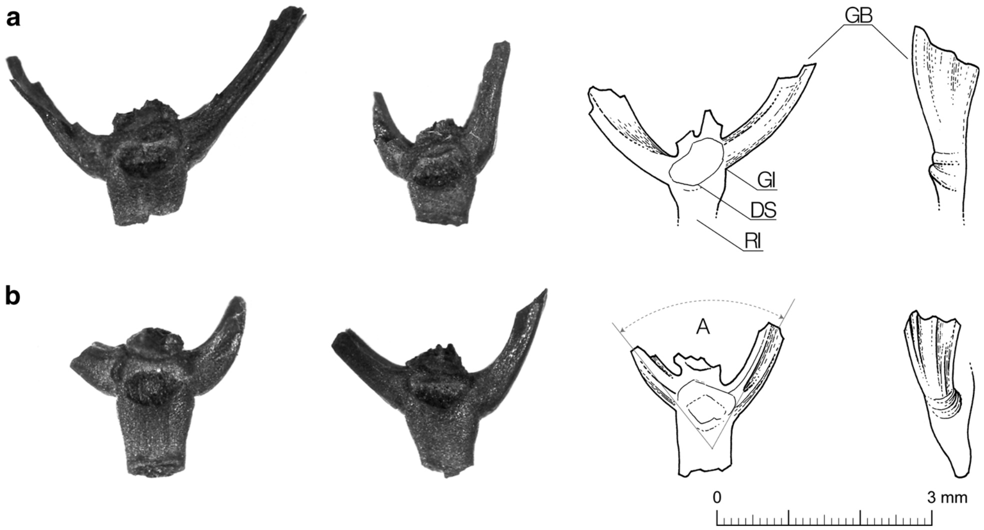

Fig. 3 **a** Typical *Triticum dicoccum* and **b** "strange ones". Diagnostic features (Table 2) are combined from Jones et al. (2000) and own observations. Marked diagnostic features: *GB* glume bases, *GI* glume insertion, *DS* disarticulation scar, *RI* rachis internodes and *A* angle between glume bases; photos by D. Valoh, drawings by T. Korošec

Table 2 Diagnostic features of einkorn, emmer and "new" glume wheat spikelet bases (after Jones et al. 2000; Kohler-Schneider 2003) in comparison with "strange" type of emmer from Stare gmajne

Diagnostic features	*Triticum monococcum*	*T. dicoccum*	»New glume wheat«	»Strange « emmer
Disarticulation scar	Linear, broad and shallow	Round, narrow and deep	Round and deep, rather large	Round and deep, rather large
Glume insertion	At the same height as DS, U-shaped	Below DS, often V-shaped	At the same height as DS; U-shaped; very abrupt	Below DS, rather U-shaped
Rachis internodes	Parallel sided	Tapering towards the base	Rather tapering towards the base	Rather tapering towards the base
Angle between glume bases	Narrow	Wide	Between einkorn and emmer	Between einkorn and emmer
Glume bases cross section	Massive	Less massive	Massive	Massive
Glume bases lateral view	Curved in; not veined	Not curved in; sometimes veined	Slightly curved in; clearly veined	Not or slightly curved in; veined

See also Fig. 3, ESM Fig. 1

DS disarticulation scar

Discussion

The interpretation below focuses on the large amount of cereal remains in the weight, mainly cereal chaff or by-products of crop processing.

Clay-chaff ratio

The clay-straw ratio in temper depends on the availability of straw and the properties of the clay, and probably also on the local traditions. Many attempts have been made to calculate that ratio (Ginder 1996; Borojević 2006; Henn et al. 2015), but the results were never straightforward. In contrast, the ratio of clay and chaff used for making the loom-weight at the Stare gmajne site can be quite precisely estimated (ESM Fig. 1). From almost 1 l of sediment sample from the incompletely burnt loom-weight, 65 ml of organic fractions, mainly botanical-cereal macroremains, were caught on the sieves. The clay-chaff to straw volume ratio is therefore around 93:7, thus in 93 % of clayey material, 7 % of cereal by-products were added. Almost 1 l of clayey material contained at least 1,841 cereal by-products (Table 1). The ratio of clay to organic material might be, however, somewhat higher, as cereal straw and small charcoal remains were not taken into account, since only identifiable cereal macroremains consisting of chaff and grains were picked out and counted (Table 1). Bahor (2010) performed an experiment to determine which and how many organic materials should be added to the clay in order to obtain solid and durable pottery. He found out that some types of plant material such as grains get burnt or break during the firing of the pottery, and are therefore not suitable for adding to the clay since small holes are formed in the vessel walls, making them less strong. He also found

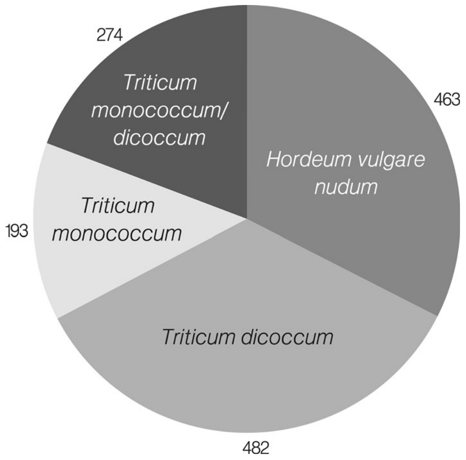

Fig. 4 Relative proportions (numbers) of comparable units of the chaff remains (comparable units: 1 spikelet fork = 1 rachis frg. = 2 glume bases) in 1 l of sediment from the loom-weight

that pottery fired at higher temperatures, 1,050 °C, became very fragile. A temperature around 700 °C proved to be suitable for the production of solid ceramic vessels that are shock and breakage-resistant.

The proportions of chaff remains of the different crops

A comparison of the counted items converted into comparable units shows similar proportions for barley and emmer, about 33–34 %, while the proportion for einkorn is significantly lower, about 14 % (Fig. 4). About 19 % of the units could not be precisely identified because their characteristics overlap (Fig. 4).

It is interesting to compare the quantitative results of different cereals represented in the loom-weight with results of earlier archaeobotanical research of the surface sediment samples from the younger cultural layer, dated approximately 3110 cal BC, of the Stare gmajne site (Tolar et al. 2011). There, barley rachis segments/internodes at 387 units/l of sediment sample absolutely outnumber spikelet forks/glume bases of emmer at 67/l and einkorn at 72/l.

The record from the single loom-weight is not sufficient for definite conclusions on the differences in utilisation of the identified cereal types, however it appears that the proportions of glume wheat (einkorn and emmer) remains in the incompletely burnt loom-weight, in comparison with the wet soil samples from the cultural layer of the same archaeological site, are higher than those of barley rachis fragments. There could be two or three reasons for this, all of them taphonomical:

(1) The dwellers may have simply used the chaff available as temper and apparently without any cultural or technological selection towards a specific chaff type, and therefore the taphonomy played the main role; see the discussion and the references in the section "How did the plant macroremains in clayey material become carbonised?". Here, differential carbonisation rates among different cereal types are described, such as hulled or glume wheat versus free-threshing barley. The nature of carbonisation of included cereal chaff that happened during burning, during the last phase of making the loom-weight, led to higher proportion of glume wheat chaff remains.

(2) Alternatively, the difference may be because archaeobotanical remains in the waterlogged sediment samples from the cultural layer were not carbonised (Tolar et al. 2011), while the chaff remains from the loom-weight were mostly carbonised, which means that the taphonomy of the compared sediment samples was not the same and therefore the results are not comparable. Boardman and Jones (1990), for example, found that the first components that are lost through charring are those which are only rarely represented archaeologically and which are characteristic of early crop processing stages, such as straw and free-threshing cereal rachis. Therefore glume bases of glume wheat survive better than the rachis of free-threshing cereals.

(3) The third possibility is that the pile-dwellers really did select glume wheat by-products (spikelet forks and glume bases) rather than barley rachis fragments for tempering clay objects because they knew about differential carbonisation and destruction rates of different components of the cereal plants (Bowman 1966; Hillman 1981; Boardman and Jones 1990; Bahor 2010).

The question could be settled with further similar research.

How did the plant macroremains in the clayey material become carbonised?

71 % of the plant macroremains in the unburnt clayey material of the inner parts of the incompletely burnt loom-weight were carbonised, and the remaining 29 % half-carbonised. In order to reconstruct the possible ways of charring or half-charring, an experiment was performed ("Materials and methods" section; ESM Fig. 2). After the dry plant material had been added to the clay (ESM Fig. 2a), it became easier to mould, which might be, besides tempering, another reason for adding the plant material to the clay. Two objects (A and B), about the same size, were made (ESM Fig. 2b). After burning, 1 kg of

water evaporated from object A. The interior of object A was not completely burnt (Fig. 5a, c). From object B, 1.2 kg of water evaporated and it was completely burnt (Fig. 5b, d). We checked then how the added hay was preserved in both objects (Fig. 5c, d).

Plant macroremains originating from the added hay in object A, which was not completely burnt, were variously preserved, carbonised, half-carbonised and uncarbonised (Fig. 5c). In contrast, plant macroremains added to object B, which was completely burnt, were very scarce and completely carbonised (Fig. 5d). The length of the exposure to heat of object B probably led to the disintegration of the hay in its inner parts.

The experiment confirmed the hypothesis that fresh, not carbonised cereal by-products were added to the clay before the weight was baked. This is expected since moulding of the clay would break the carbonised cereal chaff (or most of it) beyond identification and additional exposure to heat of already carbonised plant material might have led to its reduction to ash.

Most probably, the temperatures inside the weight were high enough, while the oxygen content was very low, to carbonise the organic tempering material in it, but not high enough to fire the inner parts of the clay. The tempering material was exceptionally well preserved since it was protected from post-depositional influences and it was waterlogged.

Experiments on the effects of charring on cereal plant components have already been done by several researchers. Hillman (1981) has pointed out that in household fires, the lighter chaff and straw components of cereal plants are usually completely burnt away. Wilson (1984) demonstrated that seeds of different weed species are differentially preserved under different charring regimes. Jones et al. (1986) suggested, on the basis of archaeological evidence, that even the denser chaff fragments may sometimes be destroyed under conditions which allow the preservation of grains by charring. So it is clearly necessary to establish to what extent differential preservation of cereal components by charring takes place (Boardman and Jones 1990). Bowman (1966) did a direct experiment in which whole emmer spikes were heated to 250 °C for 16 h and suggested that the glumes, paleas and lemmas require higher temperatures than grains for charring. Jenkinson (1976) found that barley spikes heated at the same temperature were perfectly preserved after 6 h, but after 10 h a complete destruction of all parts of the spike other than grains was recorded. Jacomet et al. (2002) found during an experiment with pomegranates that temperatures of 150–200 °C lasting for many hours can lead to complete charring and excellent preservation. All these experiments suggest differential carbonisation rates for grains and glumes as well as differential destruction rates for rachis and grain, and they suggest that temperature and time have the most significant effects on seeds of both cereals (Bowman 1966) and weeds (Wilson 1984). Other variables such as a limited supply of oxygen appear to have a marked, often "dampening", effect at low temperatures

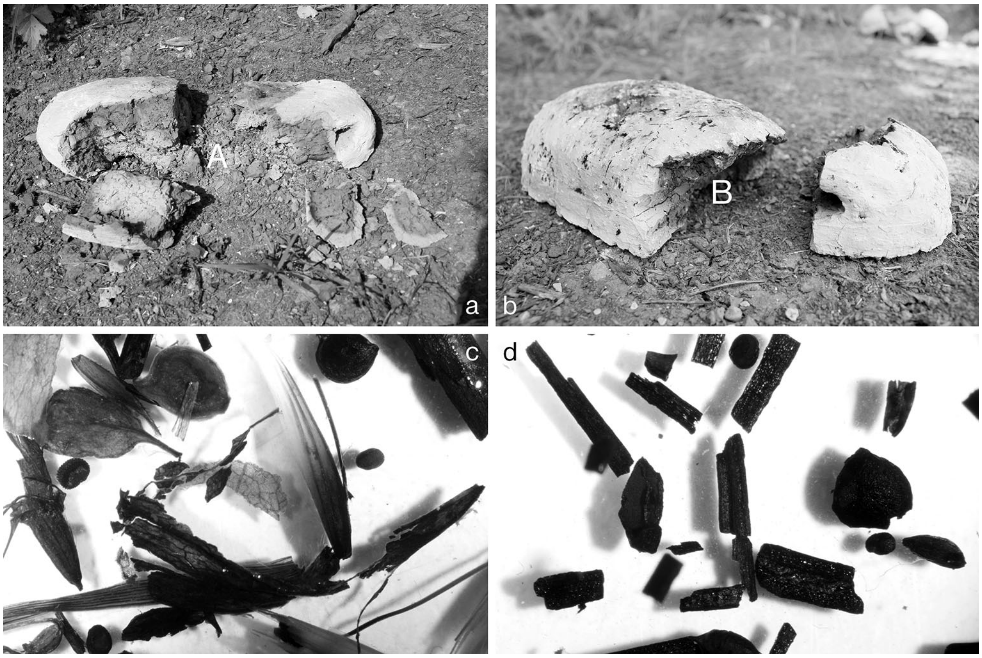

Fig. 5 **a**, **b** Broken objects A and B after burning; **c** differently preserved plant macroremains (hay) found in the incompletely burnt object A; **d** very few and completely carbonised plant macroremains preserved in the completely burnt object B; photos by D. Valoh

(Bowman 1966), but less so under fierce heating conditions (Wilson 1984). Hillman (1984a) has observed that large-scale archaeological destruction events, where oxygen was largely excluded, may result in the preservation of a far greater variety of plant components including the very light chaff not normally seen archaeologically. Experiments by Boardman and Jones (1990) on the effects of charring of different cereal species and remains confirm these conclusions. They have found that glume bases of glume wheat survive better than the rachis of free-threshing cereals. Grains always survive charring as well as or better than glumes. Grain preservation and distortion may be used as indicators of the likelihood of chaff and straw survival and are also affected by depositional and post-depositional factors. The same conclusions can be drawn from our experimental work (Fig. 5) and the results of our investigation of the plant macroremains from the incompletely burnt late Neolithic (Eneolithic) loom-weight (Table 1). Carbonised and half-carbonised remains of cereals, especially glume bases and spikelet forks of glume wheat species and barley rachis fragments, survived the heating during baking of the clayey object, and we may therefore conclude that this object was not exposed to fire for longer than 1.5 h, or only to a low temperature, oxygen-poor fire, as suggested by object A, which was heated for a little less than 1.5 h and where most of the added hay was preserved in a carbonised or half-carbonised state.

Social/technological implications of the plant content from the loom-weight

The pyramid-shaped loom-weight is 22.2 cm high and it has a maximum width at the bottom of 14.4 cm. Its discovery confirms the existence of weaving at the Eneolithic site of Stare gmajne. Recently discovered fibre remains from there show that high-quality yarn of plant origin, probably spun from fibres that are found in fruits, such as awns and stems of plants belonging to the family of grasses (Poaceae), was produced at this site (Pajagič et al. 2009). The third possible proof of textile production at the site could also be the discovery of *Linum usitatissimum* (flax) seeds/fruits in 2007 (Tolar and Velušček 2009; Tolar et al. 2010). These pieces of direct evidence of textile production could also serve as proof that the loom-weight was made locally.

According to van der Veen (1999), the use of chaff in casual use, intentional local use or use as a commercial commodity can be linked to various scales of production and organization in the agricultural system. She suggested that different types of use can be broadly correlated with three developmental stages of agricultural production: (1) casual use which is connected to small-scale domestic production and processing, where the fine sieving by-products of the glume wheats are tossed into domestic fires and are therefore not "used" in the true sense, but thrown away; (2) intentional local use which is associated with the expansion of production and bulk processing of crops; and (3) use as a commercial commodity which is connected with agricultural production in market economies.

Based on the concentrated chaff finds in the clayey weight and other archaeological features (Velušček 2009a), the Eneolithic pile-dwelling society at Stare gmajne can be placed in the second stage of development where the by-products of threshing are located at the place of production. This is firmly supported by the composition of the cereal content of the loom-weight presented here, along with the results of the analysis of the waterlogged/non-carbonised cereal remains from cultural layers of the site; they both show a mixing of the residues from cereal types with different processing requirements. In the archaeological layers, barley absolutely prevailed over emmer and einkorn. Cereals were here mostly represented by waterlogged chaff remains, whereas grains were rare and preserved in a carbonised state. Until now no stores of chaff have been found at the site, most probably due to the method of excavation, in a trench of 3 × 5 m (Velušček 2009b).

The loom-weight from Stare gmajne indicates one of the earliest intentional local uses of cereal by-products in Europe (Jacomet et al. 2004; Velušček 2009a; Schlichtherle et al. 2011; etc.). Cereal by-products were used probably as fuel, surely for fodder (Kühn et al. 2013), or as temper at sites where by-products were produced. So this tradition is much older in Europe than suggested by the known examples from the Roman period (Hillman 1982; Murphy 1989, 1997; van der Veen 1989, 1999).

Conclusions

The addition of straw and chaff to clay is documented archaeologically, ethnographically and in historic documents (the Bible; Exodus 5: 6–9). It was shown for example by van der Veen (1999) that ancient people in arid areas used the by-products, especially cereal chaff and straw, extensively as fuel, as material for tempering clay used as building material and for fodder. The presence of these late processing phase by-products at an archaeological site is usually interpreted as evidence that the processing stage was carried out at or near the site, and that cereals were produced locally (Hillman 1981, 1984a; Fuller and Stevens 2015; Anderson and Peña-Chocarro 2014). To what extent early farmers in temperate parts of the Old World also used such by-products as an economic resource is not so well known. The main reason for this is often the lack of studies of the tempered materials, although daub and pottery tempered with chaff, straw etc. is widely found at prehistoric sites in Europe as in Michela Spataro (2013), on Neolithic pottery from southeast Europe, and Henn et al. (2015). The plant macroremains in mudbrick buildings or in pottery are always well preserved through desiccation (Henn et al. 2015) or carbonisation but are hard to extract and/or count. In our case the remains of the tempering material are preserved by waterlogging while they were protected and preserved inside a large incompletely burnt clayey loom-weight found in waterlogged sediment. Such good preservation of plant material is rather rare and therefore not adequately investigated.

The discovery presented here and the detailed analysis of numerous cereal chaff remains in the incompletely burnt Eneolithic loom-weight provides new definitive evidence of the use of cereal cleaning by-products in temperate parts of Europe, for instance as temper for larger clayey objects. Similarly preserved remains were observed by Jacomet in a clayey loom-weight from the excavation AKAD-Seehofstrasse, Zürich, Switzerland, in 1979, in a layer of the late Neolithic Pfyn Culture, around 3700 cal BC; however, these were never properly investigated.

The research presented here is important since it contributes to the discussion of the following points:

(1) The discovery of a relatively large pyramid-shaped loom-weight with an incompletely burnt interior confirms the existence of textile-related activities at the Eneolithic site of Stare gmajne.

(2) The size of the weight (Velušček 2011) and, according to van der Veen (1999), the intentional local use of cereal by-products as temper in the weight can be associated with the expansion of the production and bulk processing of crops in the Ljubljansko barje area in the late 4th millennium BC. This is suggested by the strong presence of remains of crops, especially cereals, such as pollen, grains and chaff remains in the cultural layers of pile-dwellings (Andrič et al. 2008; Tolar et al. 2011; Tolar and Andrič 2013; Golyeva and Andrič 2014).

(3) Spikelet bases of a so-called “strange type” of *Triticum dicoccum* (emmer) were discovered (Fig. 3; Table 2). In the future, more attention should be given to the appearance of this type. It is possible that it is a new type of glume wheat, not previously detected due to the scarcity of modern archaeobotanical investigations which have so far been made south of the Alps (Jacomet 2006b, 2009; Jeraj et al. 2009; Tolar et al. 2011).

(4) For the Stare gmajne site, we can say that large quantities of cereal crops were processed and cleaned, while specific parts of cereal ears like barley rachis fragments and wheat spikelet forks and glume bases, but only 19 grains were used, or preserved after burning, as temper (Table 1). Weed seeds, straw culms and stems were found in quite small numbers or were completely absent. Beside efficient crop cleaning or processing, the taphonomy of different remains could also be the reason for the appearance of such an assemblage of cereal macroremains in the incompletely burnt loom-weight, for example from differential carbonisation and destruction rates.

(5) At Stare gmajne, by-products of all three main cultivated cereals, barley, emmer and einkorn, were used for tempering. Barley rachis fragments and emmer spikelet forks/glume bases outnumber einkorn grains. However, among cereal macroremains from the cultural layer, barley rachis fragments absolutely outnumber glume wheat spikelet forks and glume bases (Tolar et al. 2011), while the carbonised or half-carbonised remains from the loom-weight show about the same proportions for barley and glume wheat by-products. Is this observation, that there were fewer barley and more glume wheat chaff remains used for tempering in comparison with the assemblages in the cultural layer, connected to different destruction rates for different types of cereal remains or to the pile-dwellers’ selection of a specific type of by-products for tempering? It still remains an unsolved question due the insufficient record from only 1 l of sediment which was gained from one loom-weight and investigated.

(6) The experiment showed that plant macroremains were most probably added to the clay in a fresh, uncarbonised state and they became carbonised or half-carbonised probably during a very short exposure to fire. Plant macroremains added to object B, which was completely burnt after exposure to heat for 3 h and 35 min, were very scarce and completely carbonised (Fig. 5d). The length of the exposure to heat of object B probably led to the disintegration of the hay in its inner part. Differential destruction rates for rachis and grain were confirmed (Bowman 1966; Wilson 1984; Boardman and Jones 1990; Bahor 2010).

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