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ORIGINAL PAPER

Botanical evidence of malt for beer production in fifth–seventh century Uppåkra, Sweden

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Abstract

The excavation of a low-temperature kiln structure at an affluent Iron Age regional center, Uppåkra, located in southern Sweden, revealed from archeobotanical samples and its context evidence of malting in the process to make beer. Carbonized germinated hulled barley grain (*Hordeum vulgare*) was recovered from the kiln structure itself and from the surrounding occupational surface. Located somewhat from the central area of the site, where previous excavations have uncovered hall-buildings, a ceremonial structure, and several smaller houses, the investigated kiln was situated in an area on the site that is absent of remains to indicate a living quarter. Activities using kilns have instead primarily been linked to this area and archeological finds are mainly of charred crops remains. In this paper, we argue that the germination of grain was deliberate and that the kiln was used to stop the germination process by drying or roasting the grain. If the malting process for large-scale beer production was carried out at a designated area of the site is discussed, as well as if this activity area was part of a structural organization observed elsewhere on the settlement.

Keywords *Hordeum vulgare* ssp. *vulgare* · Beer production · Malting · Kiln · Scandinavian Iron Age · Uppåkra · Sweden

Introduction

Our knowledge of the preparation and consumption of beer in ancient times depends on archeobotanical evidence and non-botanical archeological evidence such as written and iconographical documentation. The importance of beer in society is well documented in inscriptions and legal documents dating back to the fourth millennium BC from Mesopotamian cultures (Wartke 1998; Damerow 2012) and ancient Egypt (Samuel and Bolt 1995; Samuel 1996, 2000). In Scandinavia, written and iconographical sources of beer are absent prior to the Middle Ages (before ca. AD 1200) and knowledge of prehistoric beer making is limited to finds of plant remains involved in the process of making beer.

The recently discovered germinated grain from the Iron Age settlement Uppåkra in southern Sweden (Scandinavian Iron Age 500 BC–AD 1000) presented in this paper provides evidence of malt from the fifth to seventh centuries AD and gives insights to the malting process in Scandinavian society (Fig. 1). The Uppåkra settlement—a large affluent regional center during most of the first millennium AD—is thought to have had a spacial organization for several buildings, including hall-buildings, ceremonial houses, and workshop areas, as well as, grain storage and areas for ritual activities (Larsson 2011; 2015). The new find of germinated grain was recovered by a kiln structure, located in an area on the settlement with several other kiln structures, but absent of remains from houses (Stilborg 1998; Lindell 2001). Contextually, this indicates how the kilning in the malting process for making beer was an activity allocated to a specific area on the settlement and that it was part of the structural organization observed elsewhere on the settlement.

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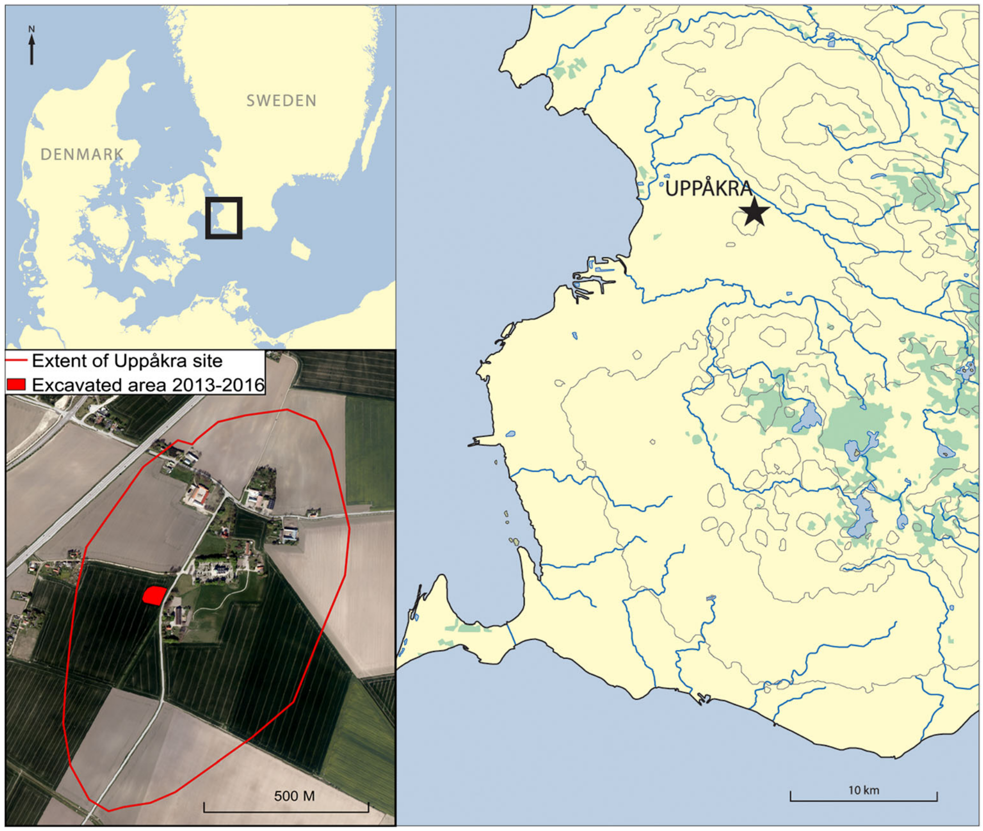

Fig. 1 Location of archeological site Uppåkra in southern Sweden. Insert showing extent of archeological site in present day landscape and area excavated 2013–2016

Background

Archeobotanical evidence of beer making in prehistoric Scandinavia

Prehistoric botanical evidence in Scandinavia for beer making is scarce and rests on a few finds of germinated grain and remains of beer-flavoring plants. The earliest evidence of beer making in Scandinavia have been recovered from Iron Age settlements and are assemblages of germinated barley grain, indicative of malt. At the Danish site Østerbølle dating to the first century AD, germinated grain was recovered from two ceramic pots from a burnt-down house, providing evidence of stored malt (Helbæk 1938). In Sweden, finds of germinated barley grain perceived to be malt were recovered from a stone ringfort site at Eketorp, dating to the sixth century AD (Helbæk 1966), and from a burnt-down ninth century AD Viking Age hall-building, where several liters of germinated grain was recovered (Viklund 1989).

Finds of the beer additive sweet gale (*Myrica gale*), a bush with its natural distribution in northern Europe, preceded hops (*Humulus lupulus*) in Scandinavia. Besides its use in beer, sweet gale was used in various fermented beverages dating back to the beginning of the first millennium AD in southern Scandinavia (von Hofsten 1960; Behre 1999; Balic and Heimdahl 2015). Hops are known in Scandinavia from Viking Age sites (ca AD 800–1050), but the plant increased in use first after ca. AD 1200, and later replaced sweet gale as an additive to beer (Jensen 1985; Hansson 1996; Behre 1999; Lagerås 2003: 256). From the Scandinavian Middle Ages (1050–1536 AD), medieval laws and written accounts are available to show the importance of beer in society, but provides also insights to the malting and brewing process, and beer additives used (Olaus 2010).

Preparation of beer

Production of beer is typically divided into two parts, the malting process and the brewing itself. Archeobotanical evidence from these processes are made up of finds of germinated grain and remains of beer-flavoring plants (van Zeist 1991; Dineley 2004; Stika 2011a). Though indications of beer in archeological excavations, other than botanical evidence, can include residues of the wort and liquid, tools and vessels used for brewing, it falls outside the scope of this article.

Malting process

The process of malting starts by wetting the grain with water, allowing the grains to germinate. During germination, enzymatic activity (mainly alpha- and beta-enzymes) starts to convert both proteins and starches of the grain into fermentable and more easily digestible sugars. After 4–6 days, the germinated grain, "green malt," is dried in an oven or kiln with hot air to drop the moisture level of the grain, arresting the germination process. This last stage of the malting process is the kilning, referring to the kilns that are used to dry batches of sprouted grain. At this stage, by increasing temperature, caramelization and bitterness can be added to the flavors of the malt which can be brought out later during the mashing in the brewing process. After the kilning, the water level in the malt is low, making the malt storable (Keyland 1989:72–84).

Botanical evidence from the malting process is likely to be green malt roasted in a drying kiln. Germinated grain, malt, becoming charred during the kilning may survive in the archeological record and provide indications of the first step in the making of beer. Finds of charred germinated grain on sites can be preserved in large numbers, providing evidence for a whole batch of malt being set ablaze (Helbæk 1966; Stika 1996, 2011b) or from stored malt became charred after a house-fire (Helbæk 1938).

Brewing process

The second stage in the production of beer is the brewing itself. Before the fermentation process starts, the malt, still in granular form, is ground forming a grit. The brewing process begins with the mashing in which ground malt is mixed with hot water. During the mashing, enzymes that were activated during germination start to break down the starch into fermentable sugars. The concentrated solution that is formed of sugar and grain is a mix known as wort. When the conversion of starch to fermentable sugar is developed to a sugary liquid, malt and hulls are removed from the "sweet wort." The next step in the brewing process is the boiling of the sweet wort with additives, primarily hops or sweet gale. With the first use of hops in Europe dating back to the early Middle Ages and before that, sweet gale, with some early, but few finds from the pre-Roman Iron Age (Behre 1999), the routine of boiling the wort in prehistoric times is somewhat ambiguous. Other plant-ingredients for extra flavor or to prepare special beer such as medicinal beer may have been added at this stage. In Scandinavia, this could include parts from plants, such as labrador-tea (*Ledum palustre*), wormwood (*Artemisia absinthium*), St. John's wort (*Hypericum perforatum*), and yellow rattle (*Rhinanthus minor*) (von Hofsten 1960). When the boiling is finished, plant parts are removed from the liquid, the bitter wort. The last stage in the brewing process is fermentation by adding yeast. In Scandinavia, yeast was usually kept from an earlier brewing and originally a wild-yeast type (Keyland 1989; Viklund 2009). When yeast is added to the wort, fermentation begins, where the sugars turn into alcohol, carbon dioxide, and other components. This process could take 2–5 days.

Botanical remains from the brewing process are the by-products removed from the wort, i.e., the crushed malt and the additive. The by-products could be used as animal feed or were discarded; however, these botanical remains are rarely found on prehistoric sites in Scandinavia (Balic and Heimdahl 2015).

Site description

Uppåkra is currently the largest Iron Age site known in southern Sweden. Archeological excavations and research based on its material culture reflects a wealthy settlement, thought to have served as a major economic and political center in the region during the Scandinavian Iron Age. (Hårdh 2001, 2003; Helgesson 2002, 2010; Stjernquist 2004; Watt 2004; Larsson 2007, 2011).

Remains from several kilns and oven features were found in the 1990s with GPR survey (ground-penetrating radar) in an area on the western side of the site (Lorra et al. 2001). Although the area was only partially investigated, two low-temperature kiln structures were excavated and the analysis of the remains of the kilns has revealed that this area of the site was in use from the late Roman Iron Age until at least the Vendel Period (ca. AD 300–700) (Helgesson 1998; Lindell 2001). Absent of any by-products from smithing activities, but with plenty of charred cereal grain, particularly of hulled barley and emmerwheat, the kilns were interpreted to be primarily used for baking and food preparation (Stilborg 1998; Lindell 2001; Regnell 2001).

Material and method

Site excavation

Excavations at the Uppåkra site from 2013 to 2016 targeted the area with kilns previously investigated in the 1990s (Helgesson 1998; Lindell 2001). From geophysical mapping by the Ludwig Boltzmann Institute, an anomaly, a probable oven structure was detected, and subsequently an area of 40 m^2 was selected to investigate the feature by excavation. Immediately underneath the plow layer, large amounts of burned daub were located. These daub pieces were the remains of a collapsed kiln structure. Underneath the scattered daub, a wall fundament with an enclosed clay base revealed a horseshoe-shaped kiln, measuring 2.7 × 1.8 m.

The kiln was first excavated, by removing clay packing and a stone packing in stratigraphic sequence (Fig. 2a–c). After the kiln structure had been excavated and removed, a 0.5-m-wide and 8.6-m-long trench was dug through the excavation area, producing a 0.75 m deep cross section (Fig. 2d). From the transect, a build-up of mostly accumulated hard-packed soil mixed with fine charcoal exposed older cultural layers. In the trench, an old destruction layer was found, likely the remains of

Fig. 2 Excavation of the kiln structure. **a** During removal of clay base of oven. **b** Stone packing exposed at the base of the kiln. **c** Removal of stone packing and wall foundation of oven. **d** Oven removed, excavation of trench cut in progress. The large surface in the excavation area is layer 119881

an earlier kiln (Fig. 3). The earlier kiln feature aligned stratigraphically with an older occupational surface (layer 116178/117705). The feature was only partially investigated as it extended beyond the 0.5 m width of the excavated trench. At the bottom of the trench was a thick cultural layer composed of sandy silt with inclusions of fine charcoal (layer 118400).

Most of the archeobotanical remains were recovered in layer 119881, a mixed layer consisting of silt with fine charcoal and some fragments of burned daub that covered most of the investigated area (Fig. 2d). The layer was observed to be contextually contemporary with the kiln. Layer 119881 was partially investigated by excavating the layer in 1 × 1 meter units; a total of 20 m^2 was excavated from the layer.

Archeobotanical material and sample treatment

Forty-four soil samples were collected and analyzed from the excavation area of the kiln. Sampling of layer 119881 was systematically done by collecting soil samples from every 1 × 1 meter unite during excavation. Subjective sampling was used during excavation of the kiln structure and from cultural deposits during excavation of the trench, including layers 118400 and 116178/117705 with sampling in intervals from west to east in the trench, and from deposits of a probable older kiln structure. All soil samples were processed by flotation, with running water and sieved over a 0.4-mm mesh. Identification of plant remains was undertaken using a microscope (× 6.3–63), a modern reference collection of seeds, and relevant literature (Cappers et al. 2006; Jacomet 2006).

Radiocarbon dating

Five charred cereal grains were subject to AMS radiocarbon dating and these were taken from the kiln structure, deposits from a presumed older kiln, a posthole, and two cultural layers, 119881 and 118400 respectively. Results were calibrated using OxCal (Bronk Ramsey 2017).

Results

The kiln structure and its context

The excavation of the kiln structure revealed, underneath scattered daub fragments from the kiln, intermittent layers of burnt and unburnt clay, fine charcoal, and a stone packing at

Fig. 3 South wall profile of trench section (digital image by Sjoerd van Riel). Excavated kiln structure is marked in the figure

the ovens bottom. These layers comprised a build-up from one kiln structure. At the rear of the kiln was a channel-like part, observed in the field to contain fine charcoal, cereal grain, and a spindle whorl, possibly functioning as an air vent in the back of the oven. The scattered daub fragments recovered around the kiln had negative imprints from small wooden sticks. These imprints indicate how the kiln was constructed from a wooden framework, having formed a dome-shaped oven made from clay.

The context around the kiln showed no layers of constructed clay floors, otherwise common in houses excavated from the site (Larsson and Söderberg 2012). Layer 119881, a homogenous earthen floor layer is stratigraphically the youngest occupational surface in the excavation area. From the trench, the remains of a probable older kiln structure showed a similar build-up of layers as the fully excavated kiln. Stratigraphically, this indicates kiln activities across time at the investigated location.

Two postholes, discovered and recorded immediately underneath the scattered daub, are visible in the profile immediately east of the kiln (Fig. 3). These postholes were erected before the clay structure of the kiln collapsed and are contextually connected to the kiln structure. The postholes may have formed part of a roofed construction, suggesting the kiln was housed in a smaller building.

Chronology

Results of the radiocarbon dating are presented in Table 1 and calibrated dates in ESM 2. The calibrated 2 sigma intervals show overlap for two different periods: AD 645–655 for the fully excavated kiln and a posthole interpreted to be contemporary with the kiln, and AD 425–635 for the earlier kiln and the two cultural layers. Based on overlap of dates only, these dates could show a rather narrow period for the activities in excavated area. Contextually, there is, however, a build-up of separate layers interpreted as being stratigraphically different (Fig. 3). Radiocarbon dates together with stratigraphic information indicate that the investigated context was in use for a considerable period that could have encompassed the Migration Period and well into the Vendel Period (ca. AD 400–685).

The botanical assemblage

Twelve thousand seven hundred forty-four charred botanical macrofossils were recovered from the samples collected during the excavation. The botanical macrofossil material comprised cultivated plants and wild plants (see ESM 1 for complete list of taxa and quantity for individual samples). Due to varied soil volume of collected and analyzed samples, the proportion of cereal species from each sample was calculated per liter, and these are presented in percent in Table 2.

The cultivated plants were mostly cereal grain. Hulled barley (*Hordeum vulgare* ssp. *vulgare*) was the most abundant cereal, although significant amounts of rye (*Secale cereal*) were also present. While more limited in number, other crops recovered included emmerwheat (*Triticum dicoccum*), bread wheat (*Triticum aestivum*), and oat (*Avena* cf. *sativa*). A small number of chaff remains of hulled barley, rye, and wheat were found in the samples. Flax (*Linum usitatissimum*) and gold of pleasure (*Camelina sativa*) occurred frequently but in small numbers. Other cultivated plants are foremost associated with horticulture, such as herbs and spices, represented by finds of dill (*Anethum graveolens*) and black mustard (*Brassica nigra*). Finds of carrot (*Daucus carota*) typically represent a root vegetable. However, the seeds of carrot have also been used as herb or could have grown as weed.

Findings of seeds from wild plants include typical arable field weeds, such as fat hen (*Chenopodium album*), redshank, (*Persicaria maculosa*), common chickweed (*Stellaria media*), and black-bindweed (*Fallopia convolvulus*). Other seeds are typical of pastures and hay meadows, such as grasses (Poaceae sp.), ribwort plantain (*Plantago lanceolata*), fairy flax (*Linum catharticum*), common sorrel (*Rumex acetosa*), and red clover (*Trifolium pretense*). Alongside these were a range of plant species that can be associated with the local environment. Charcoal was found in all samples, but in small quantities.

Among the hulled barley recovered were a large number of clearly sprouted grains, in total 650 (see ESM 1). Evidence of germination was identified from morphological features on the grain, visible by development of the coleoptiles (shoot sheath or sprout) from the embryo, and by groove-like channels on the dorsal side of the grain (Fig. 4a–c). The length of the sprouts was not uniformed, and ranged in general between one third to two thirds of the grain length, but some coleoptiles had developed along the full length of the grain. The lengthwise groove visible on many of the grains indicates coleoptile development under glumes. Some germinated grains still had glume attached, and it is probable that the hulled barley grain

Table 1 Radiocarbon dates from cultural deposits. OxCal v4.3.2 Bronk Ramsey (2017); atmospheric data from Reimer et al. (2013)

Lab no.	Feature	Sample	Material	^{14}C year BP	Cal. 2σ range
Beta 410194	Kiln	ID14883	*Hordeum vulgare*	1310 ± 30	AD 645–685
LuS 12156	Presumed older kiln	ID216129	*Hordeum vulgare*	1510 ± 35	AD 425–635
LuS 12159	Layer 119881	ID216508	*Hordeum vulgare*	1585 ± 40	AD 395–565
LuS 12157	Layer 118400	ID216192	*Hordeum vulgare*	1515 ± 40	AD 425–625
LuS 12158	Posthole	ID119591	*Secale cereale*	1445 ± 35	AD 555–655

Table 2 Percent of cereal species per sample from excavated contexts

		Layer 119881																				Layer 118400					
	Unite	120003	119993	120056	119973	119998	119983	119963	120061	119957	120066	119941	120029	119934	119988	120014	119948	120046	120051	120009	120019						
	ID no.	216508	216635	216654	216526	216632	216642	216650	216655	216623	216649	216647	216646	216648	216626	216656	216651	216653	216516	216652	216542	216191	216193	216201	216200	216259	216192
Cereal grain																											
Hordeum vulgare ssp. *vulgare*	ungerminated grain	86	66	74	78	62	8	63	59	76	67	83	12	71	50	60	59	60	58	67	82	69	73	64	83	39	86
Hordeum vulgare ssp. *vulgare*	germinated grain	4	2	22	1	5	□	2	24	3	8	3	□	□	□	10	1	1	1	7	4	□	□	□	□	□	□
Triticum aestivum	grain	1	□	<1	□	4	<1	□	1	3	1	1	<1	□	□	□	4	6	3	<1	□	□	□	□	□	□	□
Triticum cf. *aestivum*	grain	□	2	□	□	4	□	□	<1	□	□	□	□	□	□	1	□	□	□	□	□	□	□	□	□	□	□
Triticum dicoccum	grain	2	□	□	1	□	□	<1	1	1	1	□	<1	□	□	□	2	□	3	□	1	□	□	14	□	□	□
Triticum cf. *dicoccum*	grain	□	□	□	<1	1	□	□	□	□	□	□	□	□	□	<1	□	□	3	□	□	□	□	□	6	□	□
Triticum sp.	grain	□	□	□	□	□	<1	□	□	1	□	□	□	□	□	1	□	1	3	□	1	□	□		□	□	□
Secale cereale	grain	3	9	1	2	2	80	3	1	4	<1	1	74	16	26	2	1	4	1	2	□	□	9	□	□	39	□
Avena sp.	grain	1	5	1	1	□	□	10	2	9	1	2	<1	2	3	11	2	□	1	11	8	□	□	□	□	□	□
Cerealia indet.	grain	2	16	<1	18	23	12	22	12	3	23	10	13	11	20	15	31	28	27	13	5	31	18	23	11	22	14

		Kiln structure							Presumed older kiln structure								Layer 116178/117705		
	ID no.	116164	113824	114586	113823	114730	114733	114732	216138	216130	216140	216146	216131	216129	216139	216132	216135	216133	216136
Cereal grain																			
Hordeum vulgare ssp. *vulgare*	ungerminated grain	81	65	70	75	67	43	50	73	84	93	77	85	89	83	91	85	74	87
Hordeum vulgare ssp. *vulgare*	germinated grain	15	6	5	8	□	29	8	17	9	4	20	5	5	6	9	1	□	□
Triticum aestivum	grain	1	<1	□	□	□	□	□	3	□	□	□	1	□	□	□	□	□	□
Triticum cf. *aestivum*	grain	□	<1	□	□	□	□	□	□	□	□	□	□	□	□	□	1	□	□
Triticum dicoccum	grain	□	<1	□	□	□	□	□	□	□	1	□	1	2	□	□	4	8	3
Triticum cf. *dicoccum*	grain	□	2	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Triticum sp.	grain	□	□	□	□	□	□	□	1	1	1	3	1	□	□	□	□	3	1
Secale cereale	grain	□	□	□	□	□	□	□	□	□	1	□	1	3	□	□	6	□	□
Avena sp.	grain	2	2	□	□	□	□	□	1	1	□	□	□	□	□	□	□	□	□
Cerealia indet.	grain	□	24	25	17	33	29	42	6	5	□	□	6	1	11	□	4	16	8

from Uppåkra germinated in their glumes. During the germination process, some grains may only partly germinate with no clear sprouting developed. Such grains are, however, morphologically difficult to separate from grain not processed for malt. For that reason, only grain with clear development of coleoptiles or with groove-like channels on the dorsal side of the grain was sorted as germinated.

Despite good preservation of the charred seeds and cereal grain in general, many barley grains specifically were eroded at the base, other barley grains were slightly puffed-up, and many were fragmented (Fig. 4c). The preservation of carbonized germinated grain has in experiments by Stika (1996) shown how germinated grain may puff-up due to damp grain being rapidly heated and how grain can break in half during the charring, leaving the upper half of the grain intact while the lower half is eroded. If the excavated kiln in this study was used also to dry grain before storage, a similar puffing or fragmentation of the grain may have occurred. For the purpose of this study, complete or fragmented barley grain showing no morphological evidence for germination was sorted as ungerminated grain. Detached sprouts were found in all samples having clearly germinated grain during analysis, but these were not sorted and counted.

The finds of clearly germinated grain were widely recovered from layers comprising the kiln and from layer 119881. The spacial distribution of the germinated grain in layer 119881 was concentrated around the kiln (Fig. 5). The percent of germinated grain among the cereals in individual samples from the kiln ranged from 5 to 29% and from 1 to 24% among samples from layer 119881. From the trench, germinated grain ranged from 5 to 20% in layers comprising the presumed older kiln, as well as 1% in layer 116178/117705. No germinated grain was recovered from the oldest layer 118400.

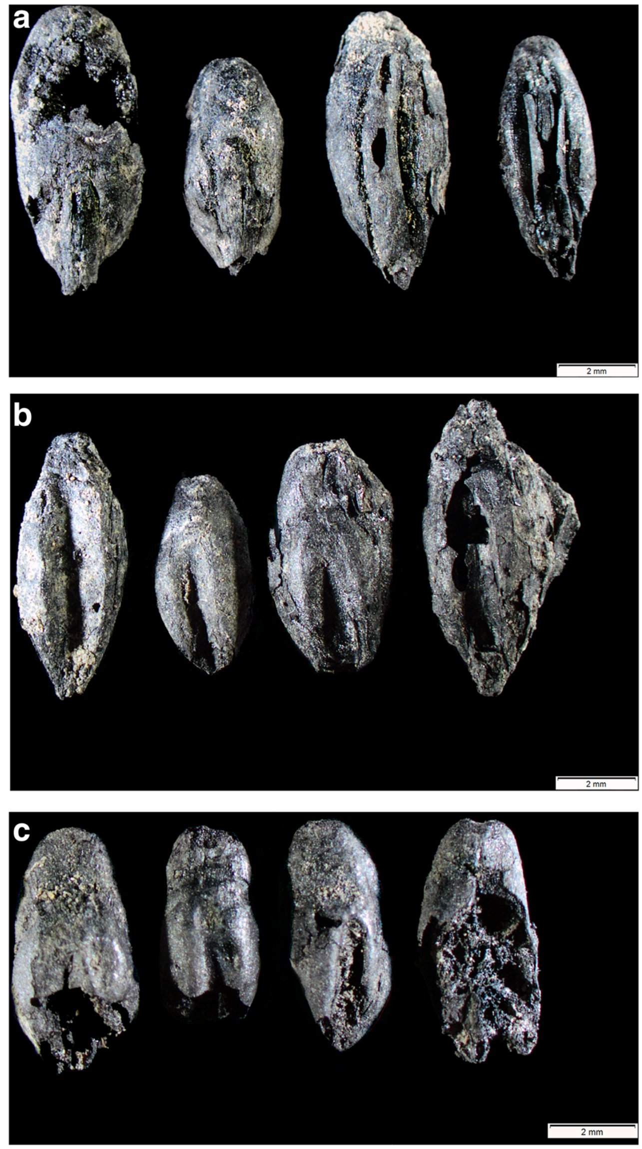

Fig. 4 Germinated barley grain with **a** coleoptiles still attached, **b** groove-like channels on dorsal side of grain, and **c** groove-like channels on dorsal side of grain with eroded and slightly puffed-up base

Discussion

Botanical remains from the malting process

Deposits of germinated grain are rare in the archeological record and make the find at Uppåkra of great interest. Sprouting can be triggered when suitable moisture and temperature levels occur and finds of germinated grain on archeological sites can originate from both accidental and deliberate circumstances (van Zeist 1991). Accidental germination could take place if grain was stored in damp conditions, or during wet summers, sprouting of the grain in the ear could have occurred. As a pre-treatment for beer brewing, germination was induced intentionally in the process to make malt by wetting the grain. Germination activates enzymes that covert the starch of the grain into digestible sugars. Other uses of germinated grain, even if less common, has been for various dietary uses including eating the malt raw or used to make bread (Bouby et al. 2011). Parts of the wort from the beer brewing could be used and added to the bread dough to make a sweet bread.

The germinated barley grain found in this study at Uppåkra are thought to be relevant to the kilning in the malting process and represent the first stage in the making of beer. The clearly germinated grain is relatively low in number compared to ungerminated barley grain found from the excavation. A low quantity of germinated grain in an assemblage could be the result of accidental germination and represent grain being dried to halt further spoilage of a crop. An arbitrary percentage of germinated grain in such grain assemblage has been estimated to be less than 15%, while an assemblage with germinated grain above 75% is regarded as a reliable evidence of malt (van der Veen 1989). Sound evidence of malt, such as the finds of thousands of germinated grain found at Hochdorf in Germany (Stika 1996) and Østerbølle in Denmark (Helbæk 1938) consisted almost entirely of germinated grain. These finds of malt represent a single depositional event as preservation occurred after a batch of germinated grain accidently got charred during the kilning process or carbonized during storage from a house-fire. The germinated grain found at Uppåkra are, in contrast, not a closed find from a single event, but occur spread out around the kiln and in the kiln itself, probably as spill accumulated from several roasting events of green malt. It is likely that occasionally, some grains close to the heat source got charred when green malt was placed to dry and be roasted by the hot air in the kiln. After repeated use of the kiln for roasting malt, rake-outs and cleaning from several firings could produce spill of germinated grain around the kiln and explains the low percentage of germinated grain in the investigated context.

A low amount of relatively uniform sprout length in germinated grain, as observed in the present study, have been used by authors to argue against deliberate and controlled germination for malt (i.e., Hillman 1982; Jones 1983). However, producing a uniform germination might be a fairly recent development in the brewing industry with sample selection by the brewers (Briggs 1978). Even if sprout length was relatively uniform in a given batch of green malt, repeated use of the oven for roasting malt could by cleanings from firings produce spill from different malting occasions to accumulate in the soil around the kiln. Germinated grains recovered from different batches are thus likely to have grain with variable coleoptile development.

Germinated grain recovered in layers pre-dating the investigated kiln and the contemporaneous layer 119881—remains from a presumable older kiln structure and the occupational layer 116178/117705—show chronologically different depositional contexts of malt across time. This points to a continuity of malting that can be traced to this area of the site.

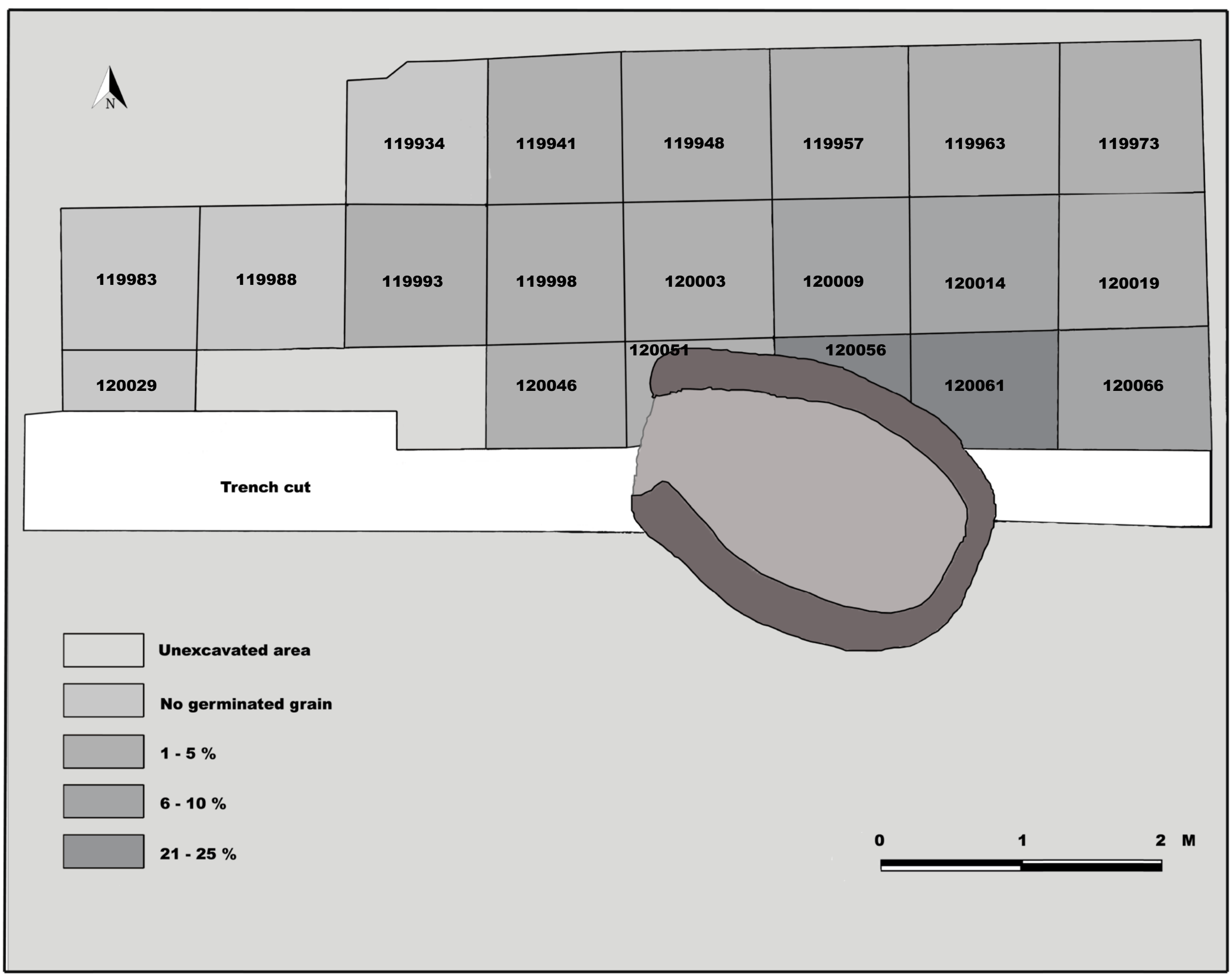

Fig. 5 Spacial distribution of clearly germinated grain from layer 119881. Gray scale indicates percent of germinated grain in each 1 × 1 meter excavation unit. For full details on charred botanical remains from individual units, see ESM 1

Multi-functional kiln

The kiln excavated was constructed to be used as a low-temperature oven, not exceeding temperatures above 5–600 °C, making it unsuitable for smithing activities or for firing pottery. Typically, in Scandinavia, this type of kiln is regarded to have been used for baking and drying, and possibly for smoking meat (Stilborg 1995). The design of the kiln in this study, the indication for low-temperature use, and the recovery of mostly deposits of botanical material and some zooarcheological remains have led archeologists to interpret the kiln to have served as a multi-functional oven, primarily used for baking and preparation of food. This type of kilns has been found from the Younger Bronze Age to Vendel Period (1800 BC–AD 750) in Scandinavia (Stilborg 2002:144). Although this type of kiln is rarely found on excavations, 13 kiln or kiln-like structures was recently recovered on a large settlement dated to AD 250–650, at the site Östra Odarslöv, located about 10 km northwest of Uppåkra (Brink and Larsson 2017a: 107). These kilns had a size spanning from 0.6 to 1.9 m in diameter, compared to the excavated kiln in this study at Uppåkra, measuring 2.7 m. Though the kilns at Östra Odarslöv display a variety in terms of construction, size, and overall shape, they provide a comparative example to Uppåkra, in part by their horseshoe-shaped clay-built kilns and in part by their location a distance from but adjacent to the houses on the settlement (Brink and Larsson 2017b: 134). Similar to Uppåkra, the kilns at Östra Odarslöv were all constructed as low-temperature ovens interpreted to be used in connection to roasting and other processing of grain (Brink and Larsson 2017b: 138–148). Charred crop remains from the contexts of the site revealed dominantly grain of hulled barley and bread wheat, but no remains of germinated grain were found.

The charred grain recovered around the kiln in this study represents cereals typical of the agriculture in southern Scandinavia during the Migration Period and Vendel Period (Robinson et al. 2009; Grabowski 2011). Hulled barley was the principle crop followed by rye, emmerwheat, bread wheat, and oat, and these correspond with other archeobotanical findings from previous excavations on other areas at Uppåkra (Hjelmqvist 1955; Regnell 2001; Larsson 2015).

The staple cereals were commonly first dried or roasted before consumption, and then boiled and eaten as porridges, gruel, and soups, brewed as beer, or ground into flour to make bread (Ellison 1983: 146; Hansson 1994; Viklund 1998: 90–94; Bergström 2007). Drying the harvested crops in the sun was not always sufficient in regions in northern Europe with a humid climate. Prior to storage, the crop could be dried by a heat source to prevent grain from being damaged by mold and accidental sprouting if later stored under moist conditions (Hillman 1982; Viklund 1998). Hulled grain species could become charred during roasting undertaken to facilitate the dehusking of the grains used for baking or to give the food made from cerealia better taste or make it make digestible (Helbæk 1964; Lagerström and Wernhart 1980). Accidental charring during a drying or roasting process may have created many of the archeobotanical finds of charred plant material around the investigated kiln at Uppåkra. With all cereal species represented among the charred grain, it indicates that the kiln was used for different drying and roasting activities. Few chaff remains were, however, recovered suggesting dehusking processes were not a common activity by the kiln.

The abundance of charred germinated hulled barley grain found around the kiln is, however, of particular interest. This type of plant remains is rarely found on archeological sites, and it indicates a step in the preparation of making beer was carried out using the kiln. Finds of charred germinated barley grain scattered around the kiln point to accumulated spill from the kilning in the malting process after repeated drying and/or roasting of the green malt. A medieval documentation of the kilning in Scandinavia describes how the germinated grain was, after drying, roasted in an oven by placing them by low-temperature heat, with the purpose of adding a sweet flavor to the beer (Olaus 2010). A similar process may have been practiced at Uppåkra. If the germinated grain found by the kiln was only dried to stop germination or, also roasted for adding a sweeter taste, is not possible to say.

If other steps in the malting process, such as the steeping or germination, took place on the floor adjacent to the kiln, it would be not possible to say. Plant remains from the brewing process, such as additives or by-products removed from the wort, were neither found. Additives are not exposed to fire during the brewing process, decreasing these plant parts to be carbonized during the brewing, and are therefore rarely preserved and found on prehistoric settlements. The absence of grinding tools and remains of crushed malt suggests that also the crushing of the malt, prior to the brewing, was carried out elsewhere.

Malting and spacial organization

Hall-buildings, several smaller houses, and workshop areas have over the years been archeobotanically investigated at Uppåkra, while to date, remains of germinated grain are restricted to the recent finds presented in this paper. Subsequently, the finds of germinated grain in the context of the investigated kiln, probably from activities of kilning malt, suggest that steps in the malting process for making beer was allocated to a specific area of the settlement. Probably, there might have been malting also in household level; however, that is much more difficult to detect, if normal hearths were used to dry malt in small scale.

Cumulative dates from kilns and contemporaneous surfaces in the western area of the site, from the recently investigated kiln context in this study and previous investigations in the 1990s (Lindell 2001), show that activities tied to using kilns span over, at least, 400 years, from the late Roman Iron Age until the Vendel Period (ca. AD 300–700). Germinated grain recovered in this study from two separate stratigraphic layers and kiln contexts further indicates malting activities in this area across time.

Long-term trends for several other functions to specific areas at Uppåkra are observed also elsewhere on the site, and can in many respects, be seen as being part of a structural organization. This includes repeated reconstruction of buildings at the same location over time—such as community structures with monumental and ceremonial architecture, several multi-phase houses, workshop areas for craft production, but also designated areas for ritual activities—all show continuity over time, both in respect to how they were used and to their fixed location at the settlement (Larsson 2011). Together they illustrate spacial organization for specific functions across time at Uppåkra.

There appears to be several structural parallels to how also crops were handled at the site, both specially and over time. From a large multi-phase hall-building, crop remains found in the layers show a long-term tendency, about 800 years, for handling and storing barley (Larsson 2015). Similarly, several smaller houses with multiple phases show repeated handling of large quantities of barley over time. Some of these contexts have been linked to specific functions, including grain storages for seeding or consumption (Larsson 2015, 2018). In contrast, a ceremonial building with multiple-phases, in use for over 700 years, is characteristic for being largely absent of crop plants, probably due to its use for ritual activities (Grabowski 2008).

In line with previous observations for some fixed building patterns and functions on the site, it is probable that also kilning to produce malt was carried out at a designated area, and for as much as several centuries. If so, this points to a specialized malting activity in this area of the settlement, and in contrast to household level, this was likely aimed for large-scale beer production. With the status of the Uppåkra site as a major economic center in the region, it is possible that large-scale beer production was intended for feasting or/and trade.

Conclusion

The carbonized germinated hulled barley grain found in the excavated area of the kiln structure have proved a contextual relationship to indicate that the low-temperature oven of the kiln was used for drying and roasting germinated grain to produce malt used for making beer. The recovered germinated grain is rather low in quantity but reflect accumulated spill from repeated heating events. Germinated barley grain was found also in layers predating the investigated kiln, suggesting continuity across time of malting at this location of the site. To date, germinated grains have previously not been recovered from households archeobotanically investigated at Uppåkra. This indicates that kilning in the malting process was an activity allocated to a certain area of the site, likely produced in large scale intended for feasting and/or trade.

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