Archaeobotanical Studies from Hierakonpolis: Evidence for Food Processing During the Predynastic Period in Egypt

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Abstract. This paper discusses recently obtained archaeobotanical evidence from locality HK11C of Predynastic Hierakonpolis, Upper Egypt, and in particular, information on plant foods and their processing. The excavations at this locality have revealed industrial food production activities dating to the Naqada II period (c. 3800–3300 BC). From one structure (Operation C) dedicated to the processing of meat and fish, plant remains were extracted through flotation of sediment from burned debris obtained from hearths. A sample from another structure, reused for refuse disposal, was also studied. The finds indicate discarded waste of cereal crop processing, fuel residues (wood and vegetative parts of herbaceous vegetation), herbivore dung and other plant remains deriving from crops (flax, melon) or representatives of the wetland and desert vegetation. The most frequent plant remains recovered from this food processing zone are crop cleaning by-products of emmer and barley, the principal cereal crops of the period (c. 75% of the total frequency of identifiable plant remains). In much smaller frequencies are remains of weeds, found as seeds and/or vegetative parts, which represent the wild growing vegetation from ruderal places, river banks or the desert. Further archaeobotanical evidence from the site HK11C comes from an installation (Operation B) where large ceramic vats were found containing charred residues. Close examination of the charred residue revealed remnants of emmer processed for food. Whole and fragmented grains were distinguishable under low magnification (10–40x). Although no longer recognisable without magnification, the presence of ground grain was demonstrated by numerous cereal pericarp fragments and aleuron cell layers visible under higher magnification (100–400x). Starch grains with perforations observed under Scanning Electron Microscope (SEM) suggest that fermentation had taken place. This processing, with subsequent heating, must have resulted in a more or less homogenous mass suggesting that this matter was wet when charred. It may represent dough for bread making or more probably, considering the

A. M. Mercuri et al. (Eds.): *Plants and People in the African Past*,
https://doi.org/10.1007/978-3-319-89839-1_5

archeological context, for initial stages of beer production. Other samples found inside the vats and their surroundings also indicate processed emmer probably for beer production.

Keywords: Archaeobotany · Ancient brewing · Emmer · Plant macroremains Predynastic Upper Egypt

Introduction

Archaeobotanical studies at Hierakonpolis, a major town in Predynastic Upper Egypt (Fig. 1), have provided crucial evidence for reconstructing the plant economy and resources used during the time of emergence of Egyptian civilization (c. 3800–3200 BC). The site includes diverse localities related to activities of daily life (settlement areas and industrial quarters where, for example, beer brewing and pottery production took place) as well as several cemeteries and a ceremonial centre (Friedman 2011). Activities that took place at the site left numerous plant remains relating to food production, processing, consumption and the dumping of refuse. The excellent preservation conditions in the arid environment at the site have allowed archaeobotanical research at Hierakonpolis to obtain detailed information on the past environment, agricultural practices, crop processing, human and animal diets, and the use of plants in architecture and ritual contexts (Fadl et al. 2013; Fahmy 2005, 2008; Fahmy et al. 2008a, b, 2011; Fahmy and Fadl 2009; Marinova et al. 2013).

In this paper we discuss recently obtained archaeobotanical evidence from locality HK11C at Hierakonpolis and in particular, new information on plant food resources and their processing. In addition to the identification of plant remains, a study of the microstructure of charred residues found in what are interpreted as brewing vats was conducted in order to observe alterations in tissues and cells of processed (cooked or/and fermented) emmer grains.

Materials and Methods

Excavations at locality HK11C, situated on the south bank of the Wadi Abu Suffian (Fig. 1), have revealed several installations dedicated to industrial food production, activities dating to the Naqada II period, c. 3800–3300 BC (Baba and Friedman 2016).

In Operation C (Square C3-4), a roughly square mudbrick structure with one rounded wall (Fig. 2a) was found. In this structure meat and fish were prepared and cooked. The interior of the structure was filled with accumulated layers of black burnt debris containing charcoal, ash, stones and potsherds overlying and surrounding numerous hearths. Two sediment samples (each with volume of 2 l) were taken from hearths (nr. 4 and 6) discovered on the floor of the structure and were processed by dry sieving with mesh sizes of 1 and 0.3 mm. Another sample of the same volume was obtained from the ash-filled debris within a larger mudbrick structure in Square C10-11, located 30 m to the south of Operation C. This material probably represents discarded waste from the industrial activities in the area and was deposited in the structure

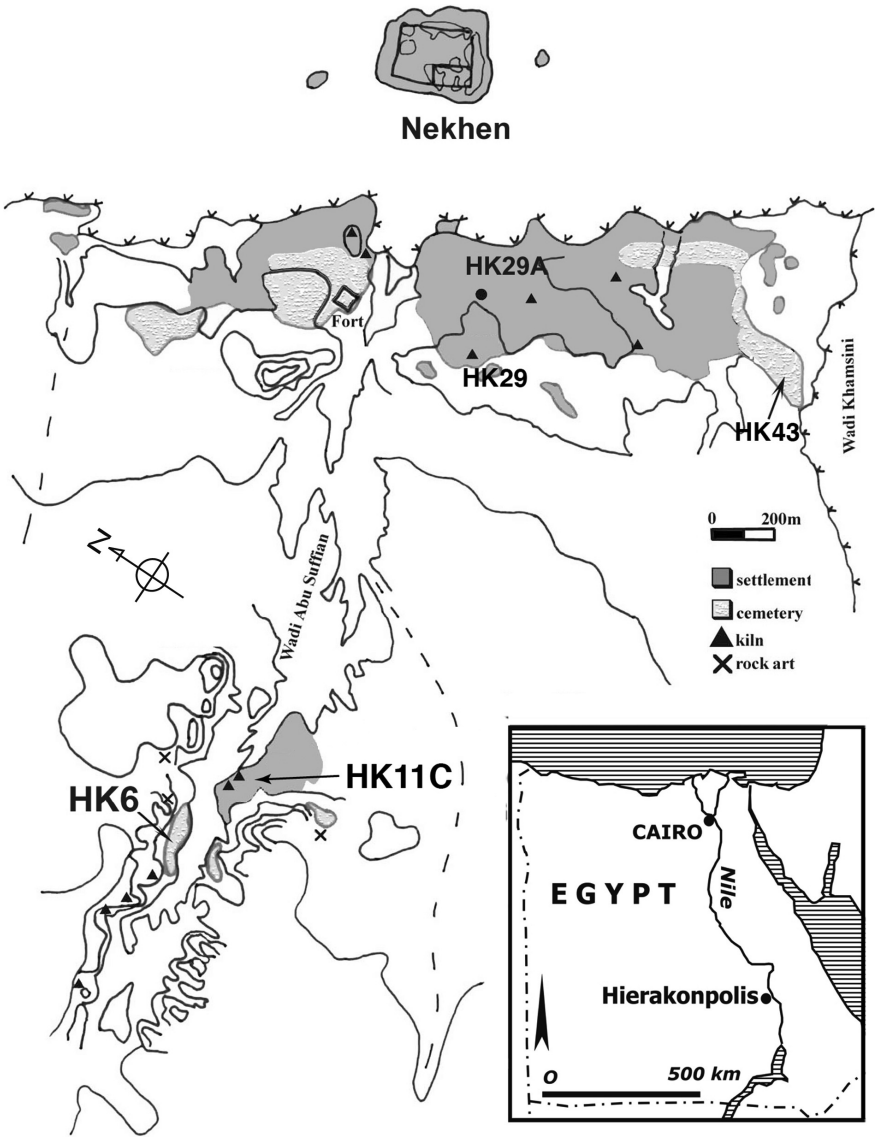


Fig. 1. Location of the study site (HK11C) within the site of Hierakonpolis

after it had fallen out of its original use. The plant remains were also extracted by dry sieving.

One industrial installation, a beer and pottery production complex dating to the early Naqada II period, was found in the lower level of Operation B (Fig. 2b). There, five large ceramic vats presumed to be for making beer were uncovered in situ (Fig. 3a). They were found within a structure composed of mud. From partly charred

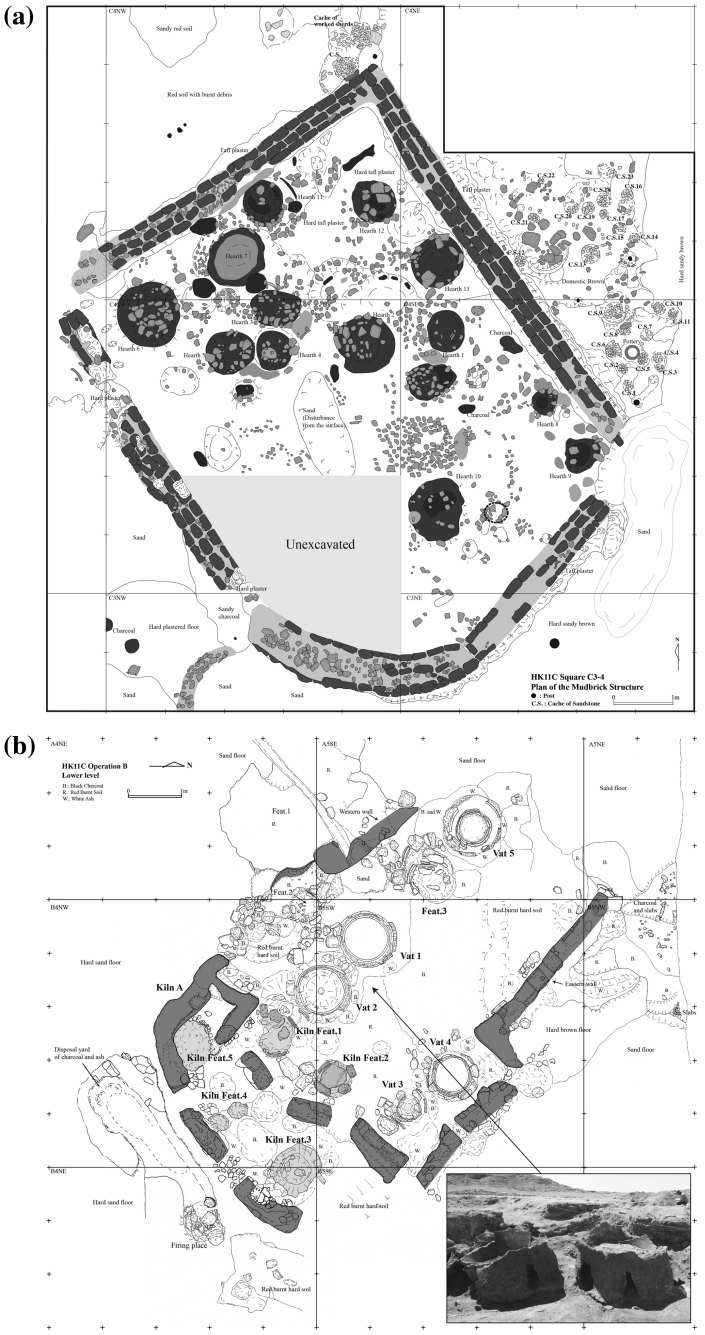
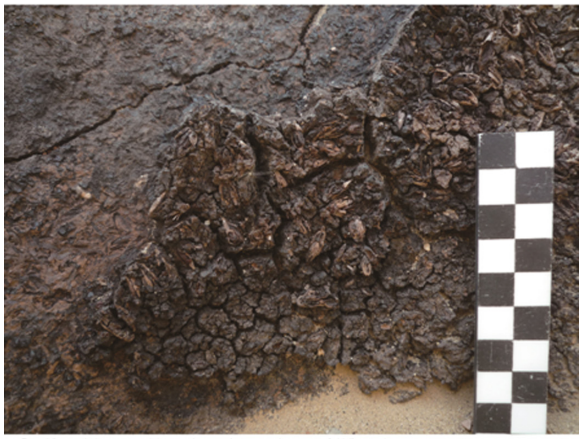


Fig. 2. Plans of the studied features: **a** Operation C (Square C3-4) **b** Operation B.

A: Vats 1 and 2 in situ

B: Inside Vat 2 after clearance



C: Residue adhering interior of Vat 2

Fig. 3. **a** Location of Vats 1 and 2; **b** and **c** charred residue in Vat 2 found at Operation B.

residues found inside each of the vats (Fig. 3b, c) and adjacent deposits, six samples were taken for macro-botanical analysis. The charred residue in one of the vats (Vat nr.4) was absolutely dated to 3762–3537 BC (raw date: 4875 ± 40 BP) (Baba and Friedman 2016: 193).

All samples were analysed under low magnification stereoscope (up to 50x) while fine structures, such as the epidermal layers of plant tissues, were examined under higher magnification (up to 500x) using reflected light microscope. Fine microstructures of the residues found in vats were also documented using Scanning Electron Microscope (SEM).

Results

Well preserved plant macroremains, both desiccated and charred, were retrieved from all samples.

Dry-Sieved Samples from Squares C3-4 and C10-11

The three samples retrieved from the two mudbrick structures at locality HK11C revealed good preservation of both desiccated and charred plant macroremains (Table 1). A total of 972 of plant macroremains were identified including: 598 fragments of cereal chaff (rachis fragments of barley and glume bases of emmer); 52 cereal grains (barley, emmer or Cerealia indet.); 58 seeds of potential weeds and ruderal vegetation seeds; 18 remains of species of wetland vegetation; 3 genera of xerophytes (represented by 35 vegetative parts); 145 varia items (not identifiable below family level) seeds and fragments of vegetative parts, as well as 63 indeterminate specimens.

Cereal crops. Barley (*Hordeum vulgare* L.), an annual crop cultivated in autumn/winter, is one of the main cereals of ancient Egypt. It is present in the archaeological record from Neolithic times onward, and was favoured because it can resist drought conditions and is a suitable crop for arid regions. A total of 12 grains and 275 rachis fragments of the studied botanical assemblage at HK11C was attributed to *H. vulgare*. The majority of the identifiable fragments are chaff either charred (n = 33) or desiccated (n = 242) (Table 1). The highest number of grains was separated from the sample obtained from the structure in Square C10-11 (11 charred grains).

Emmer wheat (*Triticum dicoccum* Schrank) is an annual winter crop, which is no longer cultivated in Egypt today. Isolated grains number eight in total, and they are concentrated in the sample from the debris in Square C10-11. There is only one charred grain from the structure in Square C3-4. On the other hand, charred chaff from emmer wheat dominates (n = 282 glume bases in total) the assemblage from this area, and may represent the remains of dung cakes used as fuel for the hearths. In contrast, only 18 glume bases of emmer occur in the sample from Structure C10-11.

Other crops. One unripe desiccated capsule of flax (*Linum usitatissimum* L.) was isolated from the sample from Square C10-11 and a fragment of a charred capsule from Square C4. Flax is an annual herb that is cultivated in the winter. At present, it is

Table 1. Results of the archaeobotanical analysis of three samples from the mudbrick structures in Square C3-4 and Square C10-11.

Site			HK 11C				
Sample number			1	2	1		
Feature			C3-4	C3-4	C10-11		
Sample volume (l)			2	2	2		
Total nr. plant remains			76	526	370		
	Type of record	*Preservation*				*Total nr.*	*%*
Crops							
Cereal grains						**52**	**5.3**
Hordeum vulgare undiff.	Seed/fruit	Charred	1		10	11	1.1
Hordeum vulgare undiff.	Seed/fruit	Desiccated			1	1	0.1
Triticum dicoccum	Seed/fruit	Charred		1	7	8	0.8
Cerealia indet.	Seed/fruit	Charred	3		29	32	3.3
Cereal chaff						**598**	**61.5**
Hordeum vulgare undiff.	Rachis fragment	Charred	3	101	138	242	24.9
Hordeum vulgare undiff.	Rachis fragment	Desiccated			33	33	3.4
Triticum dicoccum	Glume base	Charred	2	280	18	300	30.9
Triticum dicoccum	Glume base	Desiccated			23	23	2.4
Others						**5**	**0.5**
Cucumis melo/sativus	Seed/fruit	Desiccated		3		3	0.3
Linum usitatissimum	Capsule	Charred		1	1	2	0.2
Potential weeds						**58**	**6.0**
Avena sp.	Seed/fruit	Desiccated		1		1	0.1
Lolium cf. *temulentum*	Seed/fruit	Charred		2	10	12	1.2
Phalaris cf. *minor*	Seed/fruit	Charred	1	3	38	42	4.3
Rumex cf. *dentatus*	Seed/fruit	Desiccated		1		1	0.1
Solanum sp.	Seed/fruit	Desiccated		1		1	0.1
Vicia sp.	Seed/fruit	Charred			1	1	0.1
Desert plants						**35**	**3.6**
Acacia	Wood	Charred	12			12	1.2
Pulicaria	Inflorescence	Charred			1	1	0.1
Tamarix	Branch	Charred		1		1	0.1
Tamarix	Wood	Charred		10	11	21	2.2
Riparian/Floodplain Vegetation						**18**	**1.9**
Ceruana pratensis	Seed/fruit	Charred	1		2	3	0.3
Cyperaceae	Seed/fruit	Charred			10	10	1.0
Cyperaceae	Seed/fruit	Desiccated		1		1	0.1
Cyperaceae	Culm fragment	Charred		2		2	0.2
Desmostachya bipinnata	Culm fragment	Charred			1	1	0.1
Portulaca sp.	Seed/fruit	Charred		1		1	0.1
Varia						**145**	**14.9**
Fabaceae	Seed/fruit	Charred			1	1	0.1
Lamiaceae	Seed/fruit	Desiccated			1	1	0.1
Poaceae	Seed/fruit	Charred			1	1	0.1
Poaceae	Culm fragment	Charred	20	20	24	64	6.6
Poaceae	Culm fragment	Desiccated		78		78	8.0
Indeterminated						**61**	**6.3**
	Seed/fruit	Charred		2	9	11	1.1
	Vegetative part	Charred	8	13		21	2.2
	Vegetative part	Desiccated	25	4		29	3.0

mainly cultivated in the Nile Delta and at Abu-Tig in the Assiut governorate (c. 375 km south of Cairo). It requires moderate climatic conditions for the production of a good yield.

Three desiccated seeds of melon (*Cucumis melo/sativus* L.) were found in Square C3-4. According to current knowledge (see Zohary et al. 2012) most probably the seeds represent *Cucumis melo*, a prostrate annual herb that grows in sandy loamy soils. It was a valued vegetable since Predynastic times and is attested also in the stomach contents of Predynastic humans at Hierakonpolis (Fahmy 2008).

Potential weeds and ruderal vegetation. This ecological group includes 58 seeds (55 charred and 3 desiccated) representing six species. They represent 6.2% of the recorded plant remains in the studied samples. It is observed that the weed flora of HK11C is characteristic of winter farming as both *Phalaris* cf. *minor* and *Lolium* cf. *temulentum* represent the highest percentages of weed taxa (4.3% and 1.2% respectively). Other field weeds were also recorded, for example: *Portulaca* sp., *Vicia* sp., *Rumex* cf. *dentatus, Solanum* sp., which could have originated in ruderal habitats and *Rumex* cf. *dentatus* which also may have grown along the margins of wetlands.

Reeds/wetland vegetation. The water-loving species identified in the samples are: *Desmostachya bipinnata* Stapf, *Ceruana pratensis* Forssk., and several specimens of the family Cyperaceae that cannot be identified to the genus level. These remains were concentrated mainly in Structure C10-11. The presence of such an assemblage of water loving taxa suggests the occurrence of damp soils along natural water channels that would have run through cultivated fields especially during the winter. *C. pratensis* is an annual herb which grows on the muddy banks of the Nile, major irrigation canals in cultivated fields and the inundated ground in their vicinity. Today, this taxon is an endangered species in Egypt (Boulos 2002). Its use in wattle and daub construction or incorporated in wooden architecture, such as fences, is well documented at Hierakonpolis (Fahmy et al. 2008a, b).

Xerophytes. The plant macroremains of three taxa were grouped under xerophytes and are indicative of desert habitats in the surrounding area. The remains were attributed to: *Pulicaria* sp. (represented by only one charred seed), *Acacia* sp. and *Tamarix* sp. (represented by a vegetative part).

Wood charcoals. This group includes only *Acacia* sp. and *Tamarix* sp. The studied charcoal fragments from Square C3-4 included *Acacia* sp. (12 fragments) and *Tamarix* sp. (10 fragments) while in the sample from Square C10-11 contained only *Tamarix* sp. (11 fragments). Due to the low taxonomic diversity only the half charcoals from each sample was studied.

Dung remains. Desiccated sheep/goat dung pellets were recovered in two samples from Square C3-4. They were examined for seeds and other plant remains that might have passed through the alimentary canal tracts without morphological deterioration. The analysis revealed the desiccated residues of processed cereal crops which had been used as animal fodder.

Charred Residue Samples from the Vats in Operation B

The residues found adhering to the interior side and base of three vats were examined (Fig. 3). The sample from Vat 2 was the best preserved and richest in number of identifiable plant remains. It is composed of a layer of porous charred matter up to 3 cm thick. The thickness of residues available for analysis in the other vats did not exceed 1 cm. Close examination under the microscope showed that some parts of the residue from Vat 2 are not completely charred. They are brownish in colour, indicating limited exposure to heat. The exposed surface of the residue appears rich in plant materials, especially emmer grains and chaff (Fig. 4a).

The inner surface of the residue, which adhered to the vat surface, shows a more homogenous porous structure, with few recognisable plant macrofossils (Fig. 4b). The charring on this side of the residue seems to be more intensive, as very little brownish-semi-charred plant matter was observed. This indicates greater exposure to heat from contact with the lower sides of the vat, since the fire was placed around the base (see Baba and Friedman 2016: 188). Analysis of the crust in cross section (Fig. 4c) indicates that the upper layer is rich in recognisable cereal remains (mainly chaff), while the lower part, which was adhering to the vat surface, is homogenized porous matter.

The samples from inside Vat 4 resemble those from Vat 2, but it seems that there was greater exposure to heat, as certain areas are strongly charred. On the surface some fragmented emmer grains are recognisable (Fig. 4d). There is a high frequency of partly charred and uncharred organic matter and plant remains visible in the sample (Fig. 4e, f). From one of the residue samples it was possible to isolate a single, slightly damaged grain of emmer (Fig. 5a). Most probably the damage is due to the fact that the grain was wet and softened prior to charring.

A sample was recovered from debris found around Vat 4, which was not adhered to the vat walls. It has the appearance of dried bread and has contents similar to the residue sample, but is dominated by desiccated plant remains instead of charred materials. The desiccated fragments represent most probably the same type of matter as the charred remains, but the grains inside have undergone degradation, possibly due to insect activity, to judge from the remains of insects found within this sample. Material that seems to be similar was found in a roughly contemporary brewery complex at Tel el Farkha where it was interpreted as the discarded material removed from the brewed liquid by sieving (Kubiak-Martens and Langer 2008). The uncharred matter from the Vat 4 sample was very brittle and apart from the emmer chaff it was possible, using a brush, to extract from it several seeds of possible weed plants such as *Lolium* sp., *Digitaria* sp. and other specimens not further identifiable. Especially interesting is the find of desiccated rachis of possibly free threshing wheat (cf. *Triticum durum* Desf., Fig. 5b). Free threshing wheat is rather rare in the Predynastic period of Egypt, but contemporary finds are known for Hierakonpolis (see Fahmy et al. 2011). Nevertheless, it is possible that this rachis fragment is an artefact produced by the fragmentation of emmer chaff heated in lower temperature.

The samples from Vat 5 show nearly identical consistency and composition to those from Vat 2, however the thickness of the residue is much less (c. 1 cm). The upper part of the residue contains higher amounts of coarser plant remains (mainly

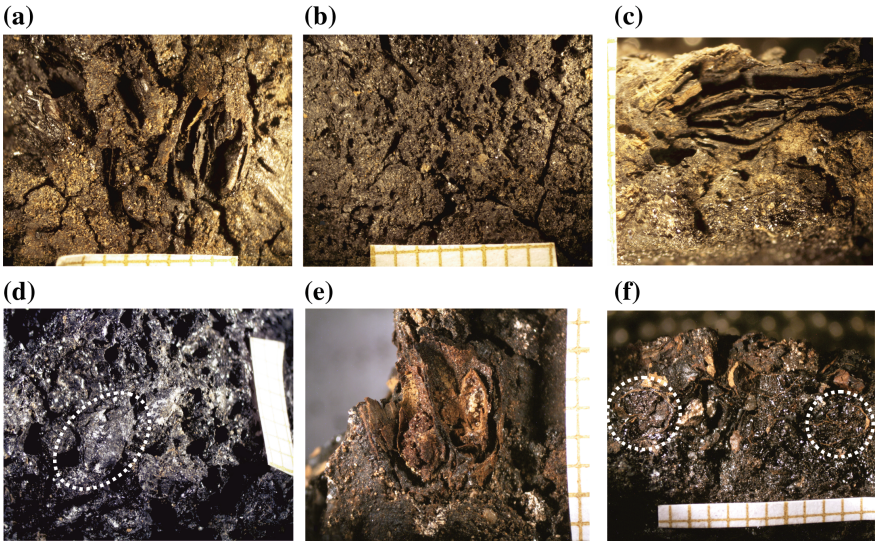


Fig. 4. Microphotographs of macro-botanical finds from the charred residues found in the vats of Operation B: **a** Surface of the charred residue, from inside Vat 2. Note the oval emmer spikelet; **b** Unexposed surface of the charred residue, attached to the wall of Vat 2; **c** View of the same residue in cross section; **d** Charred residue from Vat 4. Note an embedded grain of emmer within the dotted ellipse; **e** Partly charred emmer spikelet from Vat 4; **f** Partly charred plant remains in Vat 4, with doted ellipse are indicated broken in cross section cereal grains.

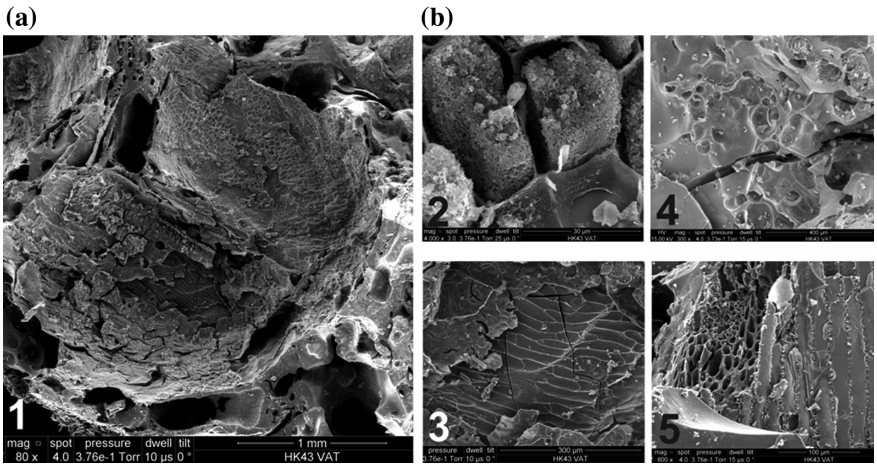


Fig. 5. **a** Charred emmer grain from the residue in Vat 4; **b** Rachis fragment, possibly free threshing wheat or artefact of the preservation of emmer chaff, from Vat 5 (scales 1 mm).

emmer), which are not charred completely. The lower part (originally adhering to the vat wall) is more homogenous and charred more strongly similar to those from Vat 4 (Fig. 4f). The sample from the surroundings of Vat 5 contains a mixture of chaff remains, but also clumps of clay that are rich in organic matter. There are also a few charred remains as well as very small fish bones and scales in the residue. This composition indicates the rather mixed character of the sample, and is probably the result of the disposal of refuse.

By close examination of the residues from all studied vats under reflected light microscope it was possible to observe epidermal tissues of chaff and pericarp fragments and layers of aleurone cells of cereal grains. Thus the porous matter within the residue consists also of cereals, but more strongly fragmented than those on the upper surface. The structures were documented with SEM (Fig. 6). Observed under higher magnification (100–400x), the burnt residues were found to contain various tissue remnants (Fig. 6a), mostly identifiable as originating from wheat (see Heiss et al. 2017). Considering the identified macro-botanical remains, this is a clear indication that emmer grains were crushed and ground together with its chaff. It is interesting to point out the presence of starch grains with perforations (Fig. 6b), suggesting, according to Samuel (2000), that they were subjected to fermentation. The presence of ground grains is also demonstrated by numerous cereal pericarp fragments and aleurone cell layers (Fig. 6c) visible under higher magnification. Closer examination of the fragmented grains and homogenous porous matter (Fig. 6d) revealed alternations (e.g. matrix of fragmented charred starchy endosperm, without any distinguishing features) similar to those observed in boiled grains by Valamoti et al. (2008). Among them also fragments of chaff epidermis and tissue (Fig. 6e) occur. This shows that the portions of the residue which appear under low magnification as porous structures are composed of crushed emmer grains and chaff.

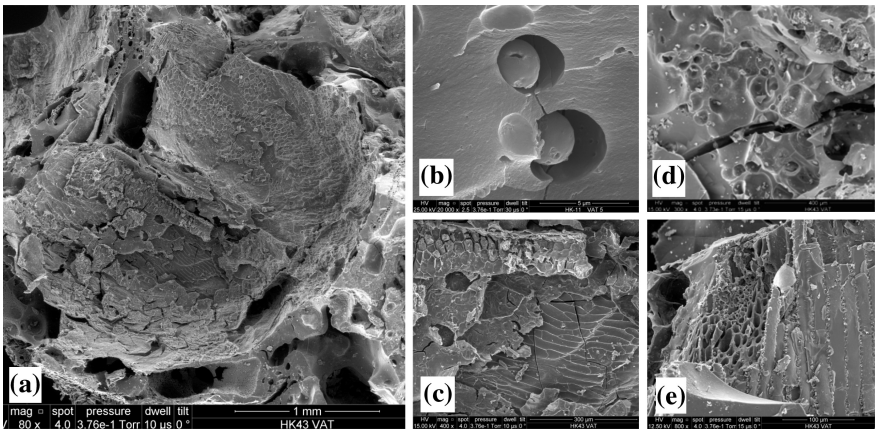


Fig. 6. SEM images of the microstructure of fragments of charred residues from the vats of Operation B: **a** overview of the residue fragment; **b** single starch grains showing predorations embeded in the charred residue; **c** transverse cell of grain pericarp; **d** matrix of fragmented charred starchy endosperm, without any distinguishing features; **e** chaff fragment with epidermal surface visible.

Discussion

The mud-brick structure of Square C3-4, within which food of animal origin was processed (Baba et al. 2017), yielded mainly by-products of cleaning emmer and barley, the principal cereal crops of the site (Fahmy et al. 2011), as well as weeds and some representatives of the wild growing vegetation. These remains probably reflect the use of crop cleaning by-products in the fuel (dung and wood) for heating during meat preparation. These findings are supplemented by the sample from the structure in Square C10-11, where burnt material, no doubt deriving from other industrial activities at the site, were dumped. The archaeobotanical analysis of those remains also provided information on weed and other wild growing flora. The field weed assemblages suggest a mono-seasonal crop regime restricted to winter. Other habitats reconstructed include marshes with saline soils surrounded by desert, probably used as pasture land for the domestic stock. Locally available *Acacia* sp. and *Tamarix* sp. were the major sources of charcoal and wood.

The archaeobotanical evidence from the partly charred residue adhering to the inside of large vats found in the food production installation at Operation B indicates that emmer grains were the main component of the residues and at least parts examined. The processing and subsequent heating must have resulted in a more or less homogenous matter (Fig. 6d) that was wet and finely ground (see Heiss 2014) when charred. It may represent either dough for bread making or, most probably, the mash for starting beer production (see Samuel 2000). Beer production is also suggested by several emmer grains showing features typical for malting (see Stika 1996, Valamoti 2017) found during the initial study of material from another installation (HK24B) at Hierakonpolis by A.G. Fahmy. The high frequencies of emmer wheat remains in archaeological sites from all over Egypt demonstrate that this crop played a very important role in the agricultural economy from Predynastic to Ptolemaic (304–30 BC) times (see Fahmy et al. 2011).

Conclusions

The botanical assemblages in the studied samples correspond well with previous findings on the Predynastic economy and environment at HK11C (Fahmy et al. 2011). The palaeoethnobotanical results from this study show that the economy of Predynastic Hierakonpolis was based on the cultivation of cereals: emmer wheat and barley. Both crops were cultivated in winter in local fields along the Nile, as shown by the weed assemblages. The fuel used in the studied cooking installation contained wood of *Acacia* and *Tamarix*, but also crop threshing residues and dung. Archaeobotanical analysis of the dung remains indicate that crop cleaning refuse and barley grains were one of the main components of the animal fodder. The archaeobotanical assemblages reflect not only cultivated plants, but also those coming from the wetlands and the desert.

Archaeobotanical finds from vat contents provide the oldest direct evidence of the cereal ingredients and procedures for beer production in ancient Egypt, since radiocarbon testing of a sample of the residue from inside Vat 4 resulted in a calibrated date

of 3762–3537 BC (uncal. C^{14} 4875 ± 40 BP) (Baba and Friedman 2016). The residues are composed in part of entire unthreshed emmer grains, some preserved as such and others strongly fragmented and only recognisable through the fragments of cereal bran and chaff fragments. Observations on the microstructure of the emmer grains from the residue indicate changes in the structure of the starch grains pointing to traces of fermentation and provide strong evidence together with the archaeological context for interpreting the charred residues as the remains of beer brewing.

Acknowledgements. This archaeobotanical study was possible due to the kind scientific and financial support provided by unit "Quaternary Environments and Humans" of the Royal Belgian Institute for Natural Sciences (Brussels). The excavations at HK11C were undertaken under the auspices of the Hierakonpolis Expedition with funds provided by the Japan Society for Promotion of Science (Grant-in-Aid for Scientific Research (C) 16K03167). The authors would like also to thank Andreas Heiss for valuable comments and discussion on earlier versions of the manuscript. We are also grateful to the editor, Catherine D´Andrea, the reviewers Michelle Wollstonecroft, Lara Carretero Gonzalez and an anonymous reviewer who provided useful comments and suggestions to improve the manuscript. The research on the material presented here represents a continuation of the research begun by Ahmed G. Fahmy focussing on the investigation of the food ingredients and processing procedures (including beer production) at the site of Hierakonpolis, aiming to define the parameters involved in food production through systematic archaeobotanical analyses of the industrial facilities, ceramic vats, and burials (comparing e.g. human dental calculus, stomach contents, intestinal contents, and coprolites).

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