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Predynastic beer production, distribution, and consumption at Hierakonpolis, Egypt

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ABSTRACT

Beer was a staple food, but also served a variety of social functions in the political economy of Ancient Egypt. Recent excavations at Hierakonpolis, a major site of Egypt's Pre- and Early Dynastic period, have revealed large-scale brewery installations, suggesting that the beverage played a significant role in the development of complex society and the expression of power and status, with collateral impact on craft specialization. However, there is as yet no definite consensus on how beer was produced, distributed or consumed in Predynastic Egypt. To address this gap, this research applies microfossil residue analyses on pottery fragments recovered at two different areas at Hierakonpolis: from a midden near the Predynastic beer production site at Locality HK11C; and from the Second Dynasty ceremonial enclosure of King Khasekhemwy. The results provide the first scientific evidence for a long tradition of beer jars—pottery vessels specifically for and symbolic of beer—beginning in the early Naqada II phase of the Predynastic period. The results suggest that beer production contributed to the economic and ideological integration of society, the rise of the elite, and the cultural unification that took place leading up to the consolidation of the centralized political state.

1. Introduction

One of the main political problems facing nascent states and large-scale political organizations is how to simultaneously create solidarity and inequality among their members (Pollock 2003). A prime political means by which some political entities may attempt to achieve this balance is through practices involving alcoholic beverages. Alcohol and drinking constitute a basic medium of human social interaction, binding individuals together through a shared understanding of cultural conventions. Alcohol is also a socially valued good that helps create bonds of dependencies and provides an effective mechanism for labor mobilization and economic exchange (Dietler 1990; Goldstein 2003; Kennedy 1978; Barth 1967). On the other hand, alcoholic beverages can be used as a symbol of power and prestige to discriminate between social classes (Dietler 1996; Hayden 2014; Clark and Blake 1994; Arthur 2003). By restricting access to production or enhanced quality, certain social groups obtain a powerful means of resource control and thereby authority over others.

Previous anthropological and archaeological works have highlighted how alcohol was deployed to promote social unity and distinctions in ancient societies. For example, in early Mesopotamian states, drinking-related practices were integral to the creation of a stratified social order. Alcoholic drinks were served in the ritualized contexts of feasts for the upper classes and distributed as an institutionalized form of rations for workers. While the former promoted distinction and exclusivity, the latter underscored the commonalities among workers and even between classes (Pollock 2003). In the Inca Empire, the hierarchical relationship between rulers and subjects was partially mediated through the production and distribution of *chicha* (Morris 1979). By providing large amounts of *chicha* at state-sponsored feasts, the Inca ruler fulfilled their reciprocal duties and maintained political authority. The shared consumption of *chicha* also created a potent cultural symbol that connected the Inca ruler, the cosmos, and the people together (Cummins 2002; Jennings and Bowser 2009). In ancient China, alcohol was an essential element in funerary feasts from the Neolithic period to the Bronze Age (Keightley 1999; Underhill 2000). The Shang elite ingratiated themselves with their ancestors by offering alcohol in bronze vessels and in turn the ancestors would bring wealth and power to the living (Nelson 2003). These studies emphasize that alcohol has long been a prime political tool in state strategies of legitimation and control.

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The production of alcoholic beverages involves a series of biochemical transformations. Early alcoholic beverages include beer, wine, and mead. Wine and mead are made from fruits, honey, or other substances composed of simple sugars fermentable into alcohol with yeasts. Beer, on the other hand, is made from cereal grains or other starchy substances, such as barley, rice, millet, maize, and tubers. These raw materials contain nonfermentable starches that must be saccharified before fermentation (Jennings et al. 2005). Compared to wine, beer is relatively more time-consuming and labor-intensive to produce.

The invention of beer brewing technology had significant sociopolitical impact on human societies. Since the so-called "Braidwood Symposium" in 1953, researchers have hypothesized that beer was a "prestige food" for prehistoric communities, and its discovery was the impetus for the transition to agriculture (Braidwood et al. 1953, Katz and Voigt 1986, Hayden, 2009). This proposal has gained increasing support from recent research. Possible evidence of beer has been identified from ritual contexts at several pre-agricultural sites, suggesting that beer was a high-status drink for ritual feasting and ceremonial activities (Dietrich et al. 2012, Liu et al. 2018). In many agricultural societies, beer was a medium that allowed agricultural produce to be converted indirectly to labor, political power, and prestige (Dietler 1990: 360). The beverage also played a prominent role in the maintenance of political authority at multiple scales: from societies without formal political institutions like the Sebei of Uganda, to the chiefdoms of Chagga, to imperial states like the Inca (Dietler 1990, 2006; Hayden 2014). These studies demonstrate that a focus on beer offers an important point of entry into the study of human relations.

From the long-lived civilization of Ancient Egypt, there is a wide body of information on how the Egyptians living in the Dynastic age produced, used, and consumed beer. Its importance is widely attested in textual sources, such as offering lists, ritual notations, and administrative records, as well as by the artistic record on tomb walls and tomb models. The abundance of distinctive beer jars (as identified textually and artistically) in and around tombs and settlements further demonstrates its prevalence and position in life and death. Enjoyed by all members of the population, it is considered a staple food and an important commodity for economic exchange (Curtis 2001; Faltings 1998; Helck 1971; Hornsey 2003; Warden 2014).

In the preliterate Predynastic period of Egypt (3,800–3,100 BCE), the evidence is of a different type, coming hitherto almost exclusively from the installations that produced the beer. The importance of beer at this time is obvious from these breweries, which first appear in seemingly elite-controlled settings and exhibit the capacity to make this beverage in large, and in some cases industrial level, quantities. The earliest of these installations are known from the site of Hierakonpolis, where more than a dozen individual breweries have been identified so far. Analysis of the residue present within some of the brewing vats leaves no doubt that beer was being produced in them, although full details of the recipe are a matter of continuing research (Farag et al., 2019; Maksoud et al., 1994; Samuel, 2000; Attia et al., 2018; Geller, 1992; Heiss et al., 2020).

How this beer was distributed and consumed has remained more conjectural. As the "classic" beer jars of the Dynastic age only appear at the end of the First Dynasty (Naqada IIIC2-D), scholars have worked back based on presumed shape evolution to suggest types that might have served as beer containers (Hendrickx et al. 2002:291–294). Observations of "dregs" in some funerary vessels and the rare presence of a light mud coating inside some jars (to impede porosity while preserving some level of evaporative cooling) have also been considered to suggest function, but such remains are not frequent (Friedman 1994: Table 6.2; Buchez 1998). More recently, a study of the ceramic assemblages from in and around the breweries at Hierakonpolis has provided further indications of likely shape (Baba, 2011). However, scientific analysis of the residues within the potential beer jars and other forms had never been undertaken.

To investigate the sociopolitical significance of beer and its mass production in Predynastic Egypt, this research applies microfossil residue analyses on fragments from a variety of ceramic vessels from the site of Hierakonpolis. The results provide new insights into beer brewing ingredients and evidence for identifying vessels for beer storage and consumption. The data allow us to explore how beer production contributed to new specialized modes of ceramic production as well as the growing economic integration and social complexity that culminated in the Early Egyptian state.

2. The site

Hierakonpolis is a major site of Egypt's Pre- and Early Dynastic period. Archaeological evidence and ancient tradition attest to its role as the capital of an Upper Egyptian polity prior to unification and its intimate link with Dynastic kingship. Today, the desert portion of the site hosts the largest Predynastic settlement still extant and accessible, with occupational remains stretching for 3 km along the edge of the low desert, and outlying settlement and cemetery activity some 2 km into the desert (Fig. 1A). At its peak in the early Naqada II period (3,700–3,400BC), it is estimated to have covered 32–37 ha and supported a population of 5,000–10,000 inhabitants, making it the largest center known from this period of marked craft specialization and growing social complexity. Excavations and survey have revealed an array of localities of documented function, including domestic habitations, a ceremonial compound incorporating workshops for specialist manufacture of luxury beads, lithics and stone vessels, various cemeteries of differing status, middens, and industrial areas involved mainly in the production of pottery and beer (Friedman, 2011a,b; Moeller 2016:81–94).

Beer brewing in Predynastic Hierakonpolis was a highly organized and specialized production (Takamiya 2004, 2008). At least a dozen individual installations for beer preparation, capable of brewing from 390 to over 1,000 L at a time, have been detected. These were mainly clustered in two areas of the site: 1) at the edge of the cultivation, northwest of the main habitation area (Locality HK24), in and around a large mound of fire reddened material itself made up of defunct breweries and the debris from such activities (Geller, 1992; Geller, 1993); Takamiya 2016); and 2) in the southern part of the significant area of occupation situated nearly 2 km away, deep in the central wadi (HK11C) (Fig. 1A, C; Baba and Friedman 2016; Takamiya 2008). The remote location of the latter was apparently due to the nearby presence of the cemetery of the elite (HK6), and the needs of servicing the mortuary rites and other festivities taking place there. For the former, the notable grouping by the cultivation at HK24, proximity to the large ceremonial compound (HK29A), with its well-documented evidence for feasting and craft production (Friedman 2009), suggests a close relationship. In both cases, large-scale beer brewing appears to be associated with the elite and dedicated to fulfilling the needs of so-called "commensal politics" (Joffe 1998; Dietler 2010).

These large-scale installations, however, do not preclude continued production within the household or by independent providers, as suggested by the evidence of low-level brewing within the household workshop of a potter at HK29 as well as indications elsewhere on the site (Fig. 1A) (Geller, 1992; Hoffman, 1982).

Two types of large-scale brewing installations have been revealed through excavations. The first involves a generally rectilinear structure of low mud-plastered segmented walls within which a series of large ceramic vats were set in rows. The walls were constructed with an adhoc mixture of stones, large potsherds and mud, with openings at intervals corresponding to the space between vats, allowing for the insertion of kindling and ventilation of the heating fire. To date, three installations of this type have been investigated, containing five or six (HK11C Operation B; Fig. 1D), at least eight (HK24A) and 16 (HK24B) vats respectively (Baba and Friedman, 2016; Geller, 1992; Takamiya, 2016). Based on surviving examples, each vat had a maximum capacity of roughly 65 L. The proximity of the vats to one another within the installations, and the ash layers around them, indicate they were all heated

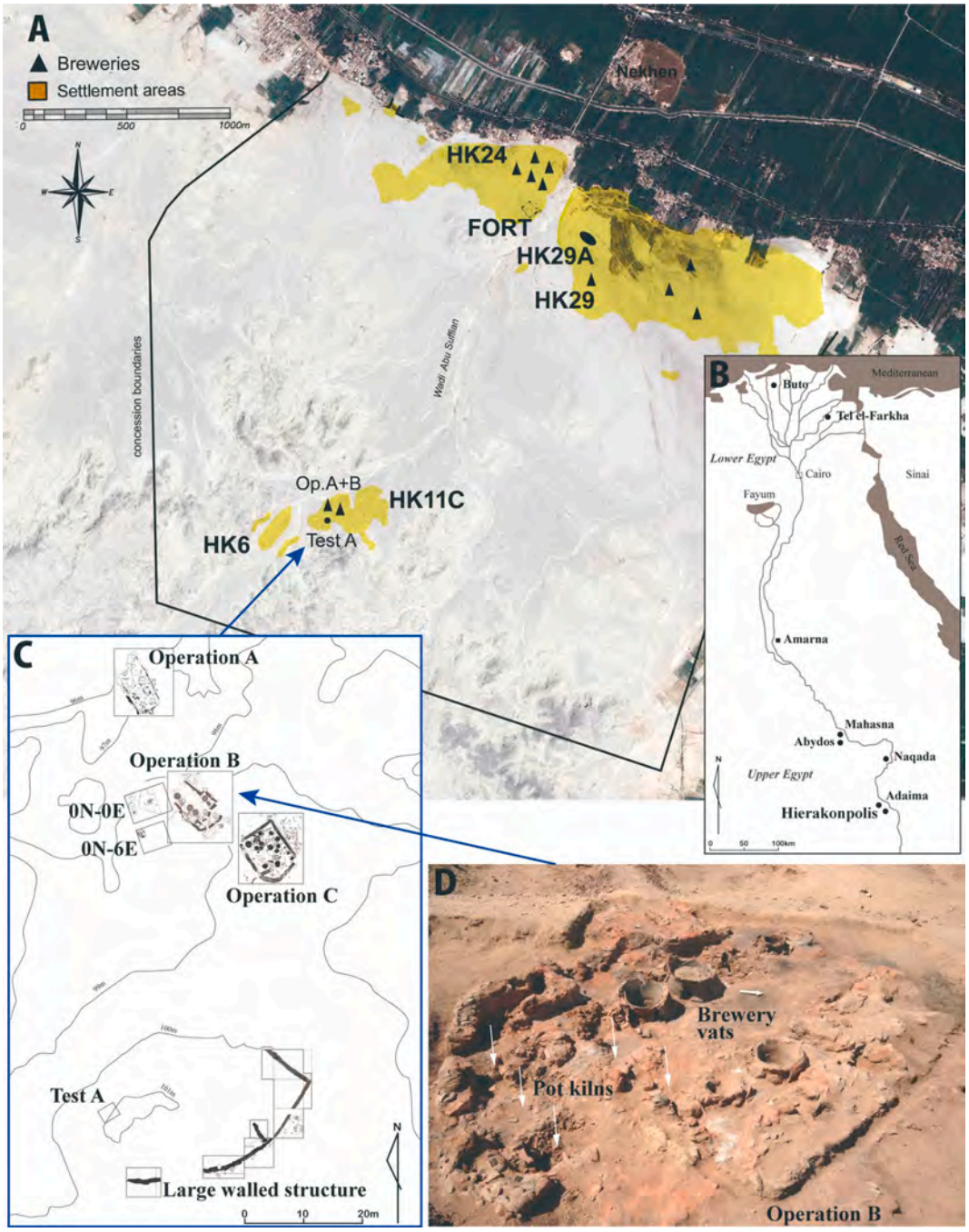

Fig. 1. A. Map of Hierakonpolis including the excavated localities mentioned in the text. B. General map of Egypt showing the location of Hierakonpolis and other archaeological sites mentioned in the text. C. Detailed map of the excavated areas at HK11C. D. Brewing installation at HK11C Operation B with vats and pottery kilns indicated.

simultaneously.

The second type, based on a single excavated example, takes the form of a semi-subterranean structure lined with large rectangular ceramic plates. Within it, the vats were arranged in two rows. These vats were supported by a concentric arrangement of specially made fire-bars of graduated sizes with wedge-shaped or fish-tail ends, 24 of which were needed for each vat. Of later date than the first brewery type, the greater investment made in this construction enhanced durability. In addition to providing better support and heat flow around the vats, the use of fire-bars may have also allowed failed vats to be replaced more easily. This installation at HK11C Operation A (Fig. 1C) contained eight, or possibly originally ten, vats (Takamiya 2008). Another example of this type has been detected by magnetometry near the cultivation edge (HK24) in conjunction with long brick benches, which may be malting platforms (Herbich 2010). This installation has not yet been investigated archaeologically.

The earliest and best-preserved of the breweries so far known is HK11C Operation B (Fig. 1C-D). The complex consisted of five, perhaps originally six, large ceramic vats set in rows within a low-walled structure that included several pit kilns for firing pottery jars, indicating a highly integrated, industrial mode of production (Baba, 2011). The vat exteriors had been covered with sherds and mud, an insulation technique for maintaining an interior temperature suitable for mashing and preventing thermal shock (Baba and Friedman 2016). Archaeobotanical

analysis of the thick residues adhering to the inner surfaces of these vats indicates a recipe involving emmer wheat (cf. *Triticum dicoccum*), with a smaller component of barley (*Hordeum vulgare* L.) and a possible weed plant such as *Lolium* sp. and *Digitaria* (Attia et al. 2018; Heiss et al. 2020). Chemical analyses have detected various organic acids and yeast fermentation products that are the signature of beer (Farag et al. 2019). It is calculated that this installation could have produced roughly 100 pottery jars and over 300 L of beer in one process, which is far beyond household level production (Baba In press).

Radiocarbon testing of the vat residue provides a date of 4,875+/-40BP, calibrating to 3,762–3,537BCE, making Operation B one of the oldest breweries of its size in the world. This date corresponds closely with the founding of the elite HK6 cemetery, and strongly suggests the brewery was established specifically to supply cemetery related activities, including tomb furnishing, funerary feasting and other rituals. When it later fell out of use, it was replaced by a pottery workshop and brewing was then shifted to the more sophisticated Operation A installation situated a short distance away (Fig. 1C). Other features in the immediate vicinity at HK11C include an area for grain preparation and possibly a malting bench (0N-6E), a mud brick facility for cooking large quantities of fish and meat (Operation C) (Baba et al. 2017), and a large walled structure, possibly originally serving as a holding pen for the animals but later filled with an impressive volume of dumped ash and charcoal, probably deriving from the food preparation industries (Fig. 1C). In strata underlying these industrial activities, light habitation has been detected, but its associations are unclear (Baba and Friedman 2016).

While these discoveries highlighted the investment and efforts put into making beer in Predynastic Hierakonpolis, there was no definite confirmation of how this beer was distributed or consumed. To address this gap, this research applies microfossil residue analyses on a variety of pottery vessels from a related deposit (Test A) in this productive locality.

3. Microfossil analysis of Hierakonpolis ceramics

3.1. Hierakonpolis potsherds and their archaeological contexts

For this study we analyzed 33 potsherds from two localities at Hierakonpolis: a stratified midden called Test A at Locality HK11C; and around the Second Dynasty mud-brick ceremonial enclosure of King Khasekhemwy, historically known as the "Fort" (Fig. 1A). The tested fragments are part of a study collection legally exported from Egypt by Michael A. Hoffman in 1980, mainly for the purpose of examining ceramic technology. The collection includes pieces from a wide range of shapes and fabrics from which a selection was made for this analysis, concentrating on those whose shape type could be deduced, and weighted toward bases or lower parts of closed forms. The vessel types examined include straw-tempered jars, slipped and polished black-topped untempered Nile silt beakers, and a selection of bowls in various fabrics (Fig. 2). Due to export restrictions, pottery recently excavated at the Hierakonpolis breweries and other relevant localities could not be analyzed for this study.

Test A at HK11C is a 2 × 3 m sondage dug through a midden located to the south of the Operation B brewery and immediately adjacent to the large walled structure (Fig. 1C). The midden was likely built up through the dumping of small amounts of refuse over time, as evidenced by its thin, discontinuous lenses of soil mixed with cultural, botanical, and faunal materials. It was excavated by J.F. Harlan in 1978 to a depth of 2.15 m, where the underlying wadi sediments were encountered (Harlan 1980, 1982). The excavation was conducted in 20 arbitrary levels of 10 cm each, with the upper levels (1–14) contemporary and likely associated with the beer production installation at Operation B. The lower levels (15–20) are thought to predate the industrial activities at the site, although little differentiates the ceramic assemblages and mixing and disturbance cannot be ruled out. The ceramic material overall suggests a Naqada IC-IIB age (ca 3,800–3,600 BCE) for the majority of the accumulation, with some later material in the top levels (Fahmy et al. 2011; Baba and Friedman 2016). From Test A we analyzed 29 potsherds from levels 1 – 17.

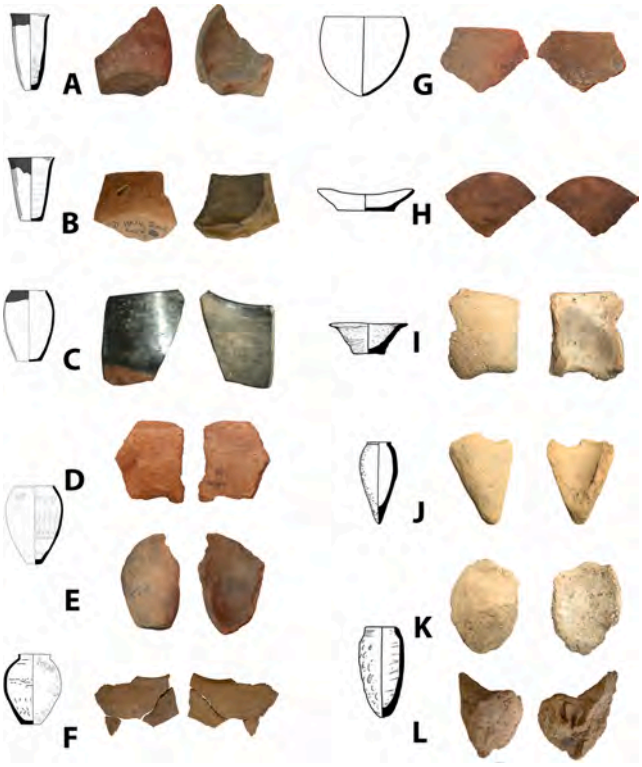

Fig. 2. Examples of sherds analyzed in this study and suggested shape (not to scale): A. Black-topped beaker (Pot 2, Test A level 4), base diameter 4.5 cm. B. Black-topped beaker (Pot 23, Test A level 15), base diameter 6.5 cm. C. Black-topped jar (Pot 26, Test A level 16), rim diameter 13 cm. D. Straw-tempered jar (Pot 16, Test A level 3), rim diameter 12 cm, with potmark. E. Straw-tempered jar (Pot 8, Test A level 5), base diameter 5 cm. F. Straw-tempered jar (Pot 19, Test A level 5), rim diameter 12 cm. G. Shale-tempered bowl (Pot 6, Test A level 16), rim diameter c. 25 cm. H. Straw-tempered bowl (Pot 4, Test A level 3), rim elliptical. I. Straw-tempered bowl (Pot 33, Fort, Naqada III), base diameter 8 cm. J. Straw-tempered jar (Pot 32, Fort, Naqada III), pointed base. K. Straw-tempered beer jar (Pot 30, Fort, Dynasty 2), rim diameter c.10 cm. L. Straw-tempered beer jar (Pot 31, Fort, Dynasty 2), rounded base.

The pottery samples from the so-called Fort, or ceremonial enclosure of King Khasekhemwy (Friedman 2007), come from a surface collection made in and around this monumental structure. The samples include two fragments (upper body and base) of roughly made, coarse organic-tempered conical jars identified as classic beer jars of Second Dynasty shape by archaeological, iconographic and textual sources (Faltings 1998:206–255; Raue 2007; Warden 2014). We also analyzed two other pieces: a straw-tempered bowl and a jar base of earlier Naqada IIIA-B (Dynasty 0–1) date. These likely originate from the large cemetery over which the Fort was later built. This sample collection allowed us to test for the diachronic changes in beer production, as well as to detect potential contamination from different archaeological contexts.

3.2. Microfossil analysis and identification

Ceramic residues were recovered and analyzed using well-established protocols for microfossil analysis (Wang et al. 2016). Starch and phytolith identification relied on a reference collection from over 1,800 economically important plant specimens and a database of fermented starch generated by our brewing experiments.

In recent years, we have developed a methodology to identify cereal-based fermentation through starch analysis (Wang et al. 2017). In

general, beer making follows the stages of malting, mashing, and fermentation, producing three types of starch modification: (1) starch granules showing pitting or hollowed interiors, which are features of enzymatic hydrolysis during the malting process (starch damage type 1, Fig. 3A-D); (2) starch granules showing "pizza-crust" shaped damage patterns caused by enzymatic hydrolysis and low-temperature heating (65–70 °C) due to mashing (starch damage type 2, Fig. 3E-H); and (3) gelatinized granules showing expansion and slight distortion, possibly caused by heating without adequate saccharification (starch damage type 3, Fig. 3I-L). According to our brewing experiments, both intact and modified starches are present in beer-making residues. Among the three types of starch damage, type 2 damage is a combined result of malting and mashing—a process that rarely occurs in other food processing techniques—and thus serves as a good indicator of beer brewing (Liu et al. 2019). The other two damage types could result from natural macrobiotic activities and general cooking.

Considering the complex taphonomic processes affecting starch damage patterns (Henry et al. 2016; Hutschenreuther et al. 2017), identification of beer residues relies on multiple lines of evidence. Two types of microscopically observable elements are expected to be present in beer-related vessels. The first is a population of starch granules showing all three damage types, which together indicate a multi-stage brewing process reflecting a deliberate human behavior (Wang et al. 2017). The second includes various brewing byproducts and fermentation agents or their sources, such as beer stone (calcium oxalate)(Michel et al. 1992), husk phytolith (likely from cereal malts), and yeasts. This combination of microfossil elements does not exist in artifacts unrelated to beer or natural soils, offering strong evidence of beer making. Among the Hierakonpolis potsherds we analyzed, some only contain starch granules showing type 2 damage or part of the microfossil elements mentioned above. The function of the source vessel is therefore considered only possibly as beer containers. Considering the potential effect of equifinality (García-Granero 2020), we do not make functional identification based on a single damaged granule. In addition, we consider vessel forms to strengthen our functional interpretation. To rule out the possibility of contamination from the enclosing soil matrix and post-excavation conditions, we analyzed six control samples from the surrounding soil from Test A and the external surfaces of selected potsherds.

3.3. Results

Our analyses suggest that beer production at Hierakonpolis was present from the earlier levels of the Test A deposit and continued throughout the accumulation of debris, co-eval with the development of the industrial food production activities. Modified starches consistent with those from beer brewing and their associated microfossil remains were identified from 14 vessels, including five from Test A lower levels, six from Test A upper levels, and three from the Fort (Table 1).

Residue samples yielded four types of identifiable starch granules:

1) Triticeae (Fig. 4A; n = 160, ubiquity = 78.8%[1], size range: 6.44 – 37.59 μm): Granules are discoidal or lenticular in shape, with flat surface, centric hila, and faint extinction cross. They most likely come from wheat and barley, which have been identified as the predominant cereal crops at the site (Fahmy et al. 2011).
2) Panicoideae (Fig. 4B; n > 100, ubiquity = 66.7%, size range: 4.84 – 24.02 μm): Granules are polyhedral, showing wrinkled surface, centric hila, and mostly straight extinction cross arms. They are likely from local weed plants such as *Digitaria* sp., which has been identified as a potential beer ingredient at the site (Attia et al. 2018), or local grasses like *Panicum turigidum*, *Setaria ntamperede,* species that are present in the macrobotanical remains from the midden (Fahmy et al. 2011).
3) Underground storage organs (USOs) (Fig. 4C; n = 18, ubiquity = 12.1%, size range: 6.29 – 69.17 μm): Granules are elongate oval in shape, showing extremely eccentric hilum, and bright extinction crosses with bent arms. However, they lack the features that would allow for identification at more specific taxonomic levels.
4) Fabaceae (Fig. 4D; n = 5, ubiquity = 6.1%, size range: 19.62 – 25.58 μm): Granules are characterized by their kidney shape, rough surface, radiated fissures and multi-armed extinction crosses.

Triticeae and Panicoideae starch granules were present in samples from both archaeological localities, but Fabaceae and USO granules were only observed in the Fort samples.

Phytolith data correspond with the starch assemblage, indicating the presence of Triticeae and Panicoideae grasses (Table 2). A total of 25 grass inflorescence long cells were encountered, including elongate dendritic (n = 15), elongate echinate (n = 5), and elongate crenate (n = 5). The dendritic long cells are consistent in pattern and shape with those from *Triticum/Hordeum* husk (Rosen 1992; Ball et al. 2015), but they could not be morphometrically analyzed due to the small number of wave-lobe patterns (Fig. 3M). Crenate long cells are produced by several taxa of the Panicoideae family (Weisskopf and Lee 2014; Kealhofer et al. 2015; Madella et al. 2016) (Fig. 3N). Other short cells from Panicoideae grasses, such as bilobate and cross, are also present. Some of the phytolith remains were likely derived from beer brewing, which would have involved using whole grain cereal malts to produce active enzymes. Overall, the amount of phytoliths (n = 78) recovered from the residue samples is small, suggesting that the vessels examined in this study were used to store or consume filtered beer.

In addition, we observed two other types of microremains related to beer brewing. Yeast cells (Fig. 3P), which are characterized by the presence of small protuberances indicative of budding processes, were found in seven vessels. One jar (Pot 16) yielded an octahedral crystal consistent with calcium oxalate (Fig. 3O).

The profile of microfossil remains from the control samples is clearly different from that of the residue samples (Fig. 5, Tables 1-2). Analysis of seven control samples revealed only one Triticeae starch (0.17/sample). Control samples from soils contained large quantities of phytoliths predominated by articulated dendritic phytolith skeletons (13/sample). The dendritic phytolith skeletons are consistent with *Triticum/Hordeum* husks, which likely derive from the refuse materials from food preparation activities at the site. In contrast, the residue samples yielded high quantities of the starch granules (>12.6/sample) but small quantities of phytoliths (2.48/sample). These observations suggest that the microfossil residues from pot interiors were not derived from the enclosing soil matrix at Test A or post-excavation conditions.

At Hierakonpolis, the manufacture of straw-tempered pottery involved the use of "chopped straw" and more likely chaff as additives to the paste and the vessels were fired at an estimated temperature range of 600 °C to 800 °C (Friedman 1994: 143-44; Baba, 2011). Phytoliths from plant temper can survive if a pot is fired at a low temperature (<1,100 °C) or for a short duration (Lippi 2011; Yao et al. 2012). Therefore, some of the phytoliths recovered from straw-tempered potsherds might derive from the plant temper. However, phytoliths are also present in the interior surfaces of untempered pottery, such as the black-topped vessels, and these should represent the residues from pot contents, be it from beer making or other food processing activities. Because the firing temperature is significantly higher than the maximum temperature for starch preservation (200–220 °C) (Lelivre 1974), the recovered starch residues reflect vessel uses rather than relics of pottery manufacture.

[1] Ubiquity value is the percentage of all samples in which a specific taxon is present. For example, triticeae starch is present in 26 out of 33 samples, so its ubiquity value is 78.8%.

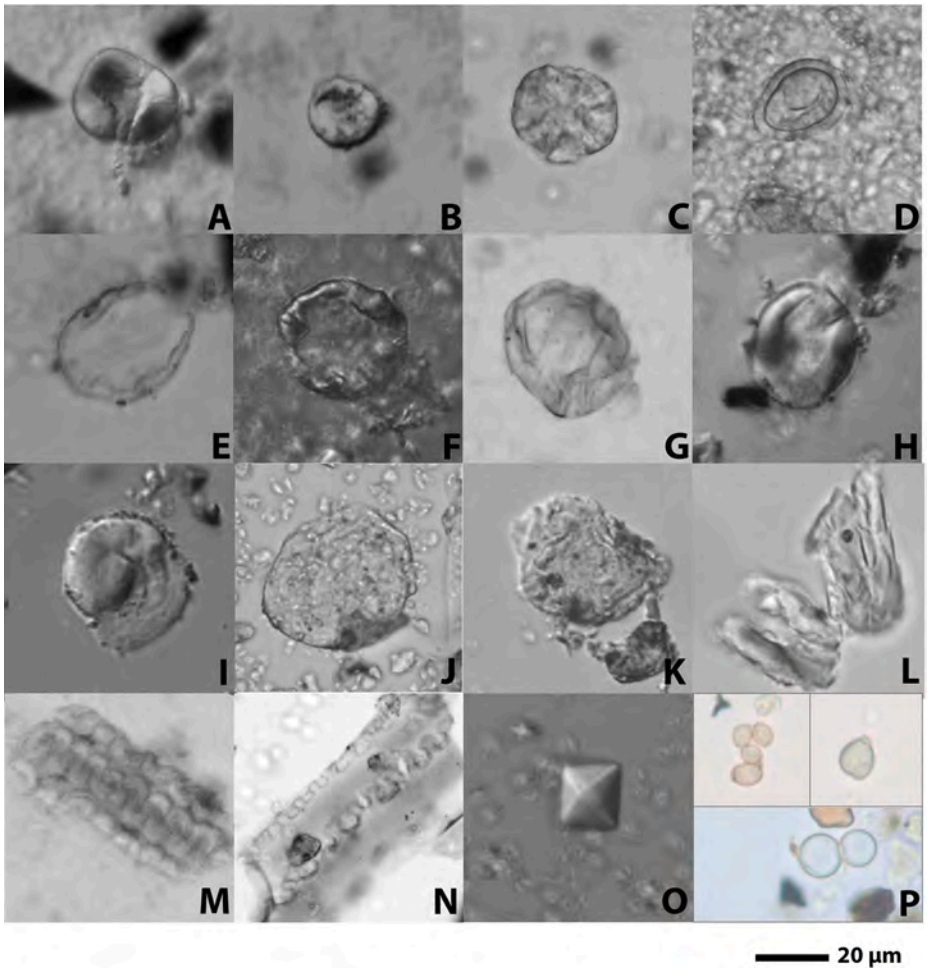

Fig. 3. Microfossils from Hierakonpolis potsherds. A-D: starch damage type 1, characterized by central pitting (A-C) and partial erosion (D), a pattern consistent with starch damage from enzymic hydrolysis (comparable to barley/wheat malt in Wang et al. 2017); E-H: starch damage type 2, characterized by "pizza-crust" shaped starch granules showing depressed center and distortion, resembling combined effects of low-temperature gelatinization and enzymatic hydrolysis (comparable to fermented barley in Wang et al. 2017); I-L: starch damage type 3, general gelatinization damage without evidence of enzymatic hydrolysis, possibly caused by heating without adequate saccharification (comparable to cooked barley in Wang et al. 2017); M: Dendritic silica skeleton, possibly from wheat/barley husk; N: grass silica skeleton with crenate long cells, possibly from a panicoid husk; O: Beer stone crystal; P: Yeast cells.

4. Discussion

4.1. Reconstructing beer production, distribution, and consumption at Hierakonpolis

Combining the residue data and pottery forms, we identified ten jars (one untempered black-topped and the remainder straw-tempered) and four beakers (all black-topped) as beer-related vessels (Table 1, Fig. 2 A-F, J-L). In addition, five bowls (straw, shale or mixed temper; Fig. 2G-I) revealed starch granules showing general gelatinization damage without evidence of enzymatic hydrolysis, suggesting their use as food cooking or serving vessels, which corroborates earlier assumptions about their function based on their forms and manufacture. The functions of fourteen other pots remain unconfirmed by the residue data, either due to the small amount of residues present or the lack of food processing evidenced from starch modification.

Previous research suggests that ancient Egyptian beer brewing was based on a two-part method, which involved mixing two batches of ingredients: one of coarsely ground grain or malt and the other of well-cooked grain (Samuel 1996, 2000; Kubiak-Martens and Langer 2008). This method may have been used at Hierakonpolis, as both gelatinized and unmodified starch granules were found in beer-related vessels. However, the variation of starch damage was also likely caused by granules' differential responses to the brewing process, as evidenced by an experimental study that utilized a single batch of cereal malts (Wang et al. 2017). Therefore, we do not rule out the possibility of other brewing techniques being used at Hierakonpolis. Nevertheless, concurring with Samuel's (1996, 2000) analysis, our data do not support the use of bread for beer making. Baking would have involved high cooking temperatures, transforming starch granules to heavily gelatinized forms beyond visual recognition (Bowler et al. 1980; Williams and Bowler 1982). The ubiquitous presence of moderately gelatinized starch granules (Fig. 3E-H) in the Hierakonpolis samples indicates that the cooking temperature was not very high, best resembling that of mashing (<70 °C). The small quantities of phytolith residues recovered from the beer jars indicate that filtration was applied to rid the mash of cereal husks. The resulting brew would have been most likely a cloudy, sweet beverage with low alcoholic content.

The starch assemblage from beer-related vessels shows two different sets of beer brewing ingredients. The Predynastic beer was mainly made from wheat, barley, and a possible panicoid grass. These results are generally consistent with the macro-botanical analyses of the residual material recovered from the brewing vats at Operation B and a similar installation at the Lower Egyptian Predynastic settlement of Tell el-Farkha (Kubiak-Martens and Langer 2008; Attia et al. 2018). Interestingly, analysis of the two fragments of beer jars (Pots 30–31, Fig. 2K, L) from the Fort shows that legumes and tubers were added to the brew during the Second Dynasty.

The diversification of the brewing ingredients was likely associated with the changing modes of food production during the Early Dynastic period. The introduction of new pottery forms, most notably the classic Old Kingdom beer jar and the wide-spread use of bread molds (Hendrickx et al. 2002), is a major indication of changes that may also have transformed brewing technologies and recipes. This time period also witnessed the appearance of new agricultural practices, such as intercropping legumes with cereal crops, basin irrigation, and specific

Table 1
Summary of microfossil residue analysis from Hierakonpolis.

Lab ID	Artifact ID	Artifact Type	Triticeae	Panicoideae	USO	Fabaceae	Unidentified	**Total**	Starch damage type 1*	Starch damage type 2*	Starch damage type 3*	Yeast	Functional interpretation	Context
POT1	Level 9 no. 4	red polished bowl, large, base	1	1				2		1			undetermined	HK11C Test A Upper Level, Predynastic
POT2 Fig. 2A	Level 4 no. 21	black-topped beaker, narrow, base	4	1			3	8		4			**possible beer serving**	HK11C Test A Upper Level, Predynastic
POT3	Level 3 no. 3a	black topped beaker/jar, medium, base	2	1			4	7					undetermined	HK11C Test A Upper Level, Predynastic
POT4 Fig. 2H	Level 3 no. 29	straw tempered bowl, elliptical, rim					2	2			2		possible food serving	HK11C Test A Upper Level, Predynastic
POT5	Level 8 no. 3	red polished saucer, rim		1			1	2					undetermined	HK11C Test A Upper Level, Predynastic
POT6 Fig, 2G	Level 16 no. 42	shale-tempered bowl/jar, rim	1				2	3			2		possible food serving/cooking	HK11C Test A Lower Level, Predynastic
POT7	Level 5 no. 31	bowl, mix temper, large, body	3				1	4			1	P	possible food serving/cooking	HK11C Test A Upper Level, Predynastic
POT8 Fig. 2E	Level 5 no. 35	straw-tempered jar, base	3	2			5	10	1	4			**possible beer storage**	HK11C Test A Upper Level, Predynastic
POT9	Level 3 no. 11	black-topped beaker/jar, medium, base		1			1	2					undetermined	HK11C Test A Upper Level, Predynastic
POT10	Level 16 no.25	black-topped beaker medium, base	6	1			7	14	2	8	4		**possible beer serving/storage**	HK11C Test A Lower Level, Predynastic
POT11	Level 2 No. 1	black-top beaker, large rim	1	1				2					undetermined	HK11C Test A Upper Level, Predynastic
POT12	Level 9 No. 11	straw-tempered bowl, large base						0					undetermined	HK11C Test A Upper Level, Predynastic
POT13	Level 5 no. 45	straw tempered vat, large, base	1				1	2					undetermined	HK11C Test A Upper Level, Predynastic
POT14	Level 1 no. 9	straw-tempered jar, base		2				2			1		undetermined	HK11C Test A Upper Level, Predynastic
POT15	Level 1 no.10	straw-tempered jar, base	7	1			1	9	1	1	1		**possible beer storage**	HK11C Test A Upper Level, Predynastic
POT16** Fig. 2D	Level 3 no. 21	straw-temper jar, rim	7	6			3	16	2	2	5	P	**beer storage**	HK11C Test A Upper Level, Predynastic
POT17	Level 3 no 19	black-topped beaker, medium, base	4				1	5			1		undetermined	HK11C Test A Upper Level, Predynastic
POT18	Level 4 no. 33	black-topped beaker, small, base	3	2			5	10					undetermined	HK11C Test A Upper Level, Predynastic
POT19 Fig. 2F	Level 5 no.44	straw tempered jar, body, sherd	2					2		2			**possible beer storage**	HK11C Test A Upper Level, Predynastic
POT20	Level 8 no. 9	Black-topped beaker, medium, base	5	2			1	8		6	1	P	**possible beer serving/storage**	HK11C Test A Upper Level, Predynastic
POT21	Level 10 no. 1	straw tempered bowl, medium, base	2	3			1	6	1		1		possible food serving	HK11C Test A Upper Level, Predynastic
POT22	Level 11 no. 23	black-topped beaker, black top, narrow, base	4	3			2	9	2		1		undetermined	HK11C Test A Upper Level, Predynastic
			3				6	>100				P	**beer storage**	

(*continued on next page*)

Table 1 (*continued*)

Lab ID	Artifact ID	Artifact Type	Triticeae	Panicoideae	USO	Fabaceae	Unidentified	**Total**	Starch damage type 1*	Starch damage type 2*	Starch damage type 3*	Yeast	Functional interpretation	Context
POT23 Fig. 2B	Level 15 no. 1	black-topped beaker, medium, base		>100 (2 granule + 1 cluster)					>100 (1 cluster)	>100 (8 granules + 1 cluster)	>100 (1 cluster)			HK11C Test A Lower Level, Predynastic
POT24	Level 15 no.5	straw-tempered bowl, large, rim						0					undetermined	HK11C Test A Lower Level, Predynastic
POT25	Level 15 no. 8	straw-tempered jar, base	3	2			1	6	1	2	1		**possible beer storage**	HK11C Test A Lower Level, Predynastic
POT26 Fig. 2C	Level 16 no. 11	black-topped Jar, medium to large, rim	2	2				4	2	1	1	P	**beer storage**	HK11C Test A Lower Level, Predynastic
POT27	Level 16 no. 39	straw-tempered bowl/jar	19	4			11	34	2	2	4	P	**beer storage**	HK11C Test A Lower Level, Predynastic
POT28	Level 16 no. 98	black-topped beaker/jar, small, base			1			1					undetermined	HK11C Test A Lower Level, Predynastic
POT29	Level 17 no. 34	straw-tempered jar, base	3				1	4		1			undetermined	HK11C Test A Lower Level, Predynastic
POT30 Fig. 2K	Fort 1	straw-tempered jar, Dynasty II beer jar, rim	28	6	10	1	7	52	2	7	2		**possible beer storage**	Fort, King Khasekhemwy
POT31 Fig. 2L	Fort 4	straw-tempered jar, Dynasty II beer jar, base	24	6	3	4	6	43	3	8	9	P	**beer storage**	Fort, King Khasekhemwy
POT32 Fig. 2J	Fort 2	straw-tempered jar, Naqada III, pointed base	1				2	3		2			**possible beer storage**	Fort, King Khasekhemwy
POT33 Fig. 2I	Fort 3	straw-tempered bowl, Naqada III	20	18	4		2	44	1		6		food serving	Fort, King Khasekhemwy
POT8-EX	POT8 Exterior	control sample						0						
POT9-EX	POT9 Exterior	control sample						0						
POT31-EX	POT31 Exterior	control sample						0						
L3-DUNG	Level 3-DUNG	control sample						0						
L3-F1	Level 3-F1 soil	control sample	1					1			1			
L13	Level 13 soil	control sample						0						

P = present.

* Starch damage type 1 = damage from enzymatic hydrolysis only (Fig. 3A-D), possibly from malting; Starch damage type 2 = damage from low-temperature heating and enzymatic hydrolysis, a diagnostic damage pattern from mashing and fermentation (Fig. 3E-H); Starch damage type 3 = general gelatinization damage without evidence of enzymatic hydrolysis, possibly caused by heating without adequate saccharification (Fig. 3I-L).

** A beer stone crystal is present in this sample.

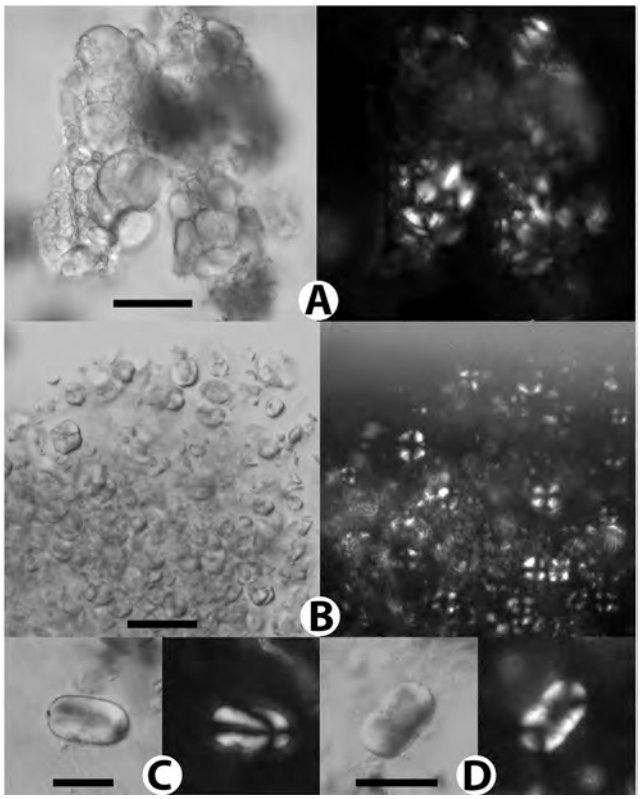

Fig. 4. Starch granules from Hierakonpolis potsherds. A: Aggregation of Triticeae type A and B starch granules; B: Aggregation of Panicoideae starch granules, some showing gelatinization; C: Unknown underground storage organ (USO); D: Fabaceae. All images were taken under DIC and cross-polarized light (Scale bars = 20 μm).

harvesting techniques, which provided the Nile river region with a more diversified supply of plant foods (Murray, 2000; Malleson, 2016; Moustafa et al., 2018). Brewers may have added legumes and tubers as starchy additives to increase fermentable sugars and aroma, making the beer a multi-ingredient concoction. The residue assemblage of the beer jar fragments from the Fort indicates that the recipe and the production methods may be more variable at this time than previously thought.

More importantly, our findings provide the first scientific evidence for a long tradition of beer jars going back to the Naqada II period. Based on the pottery forms, the beer-related vessels from Test A can be categorized into two functional groups: beer consumption and beer storage (Table 1). Possibly the earliest indication of beer storage jars comes from Pot 26 (Fig. 2C), the rim of a black-topped jar from level 16 (Corpus B74 in Petrie 1921). Whether this shape already carried connotations with regard to its preferred content (e.g. beer) remains to be investigated. When the pottery tradition began to change in the Naqada II period with the introduction of straw tempered wares, it is this shape that was adapted to make the first dedicated beer jars. These straw-tempered jars, characterized by their flat bases and modeled rims, were apparently made especially for beer and are the most common shape at the Operation B brewery. Among the six fragments of straw-tempered jars of this type from Test A, five revealed evidence of beer. Over time, the beer jar evolved into more conical and then narrower shapes (R81-84 to L30-31 and pl. xli-xliii, xlvi in Petrie 1921), until attaining its classic Old Kingdom form, a trend confirmed by our detection of beer-related residues from a pointed-base jar of Naqada III date from the Fort (Pot 32, Fig. 2 J). Future microfossil analysis involving a larger sample from this period may elucidate the shape developments more clearly.

The scientific identification of beer jars provides critical data for reconstructing beer distribution and elite activities at Hierakonpolis. Our findings lend significant support to the idea that the beer produced at the brewery at HK11C supplied the ritual activities in the nearby elite HK6 cemetery. An especially compelling connection between the two areas is provided by Pot 16 (level 3, Fig. 2D), a rim and upper body fragment preserving on the shoulder a crescent-shaped potmark, which was applied while the clay was wet. Such potmarks have also been observed on jar fragments at the brewery as well as on complete examples from graves in the elite cemetery (Fig. 6A; Hendrickx 2008; Baba and Friedman 2016: Fig. 11; Friedman 2020). Analysis of Pot 16 reveals both starch residues, indicative of beer fermentation, as well as yeast. Its function is further confirmed by the presence of a calcium oxalate crystal (beer stone), one of the key markers for cereal beer (Michel et al. 1992; Xie et al. 2011). Thus, combining evidence from ceramic shape, potmarks and residue data, we can suggest that the beer jars, fired in the Operation B brewery (Baba, 2011, In press), were filled with the beer brewed there, and then transported to service funerary feasts and other rituals in the elite cemetery at HK6.

Complete vessels from the elite cemetery show that most of these straw-tempered beer jars had a volume of 5–6 L and would have been too heavy to manipulate easily for direct drinking. Thus, as the analysis of four black-topped sherds from Test A suggests, the contents may have been decanted into the smaller and finer beakers for consumption (cf. Fig. 6A). At Hierakonpolis, these highly attractive, black-topped beakers were likely specialized vessels for beer drinking. They are common components of grave assemblages of this period and they occur in large numbers in areas associated with rituals and feasting both in the HK6 cemetery and the HK29A ceremonial center. Some of the beakers (e.g., Pot 10 and Pot 23) were relatively large and thus may have been shared within a drinking party, traveling from hand to hand. However, modes of beer consumption changed over the course of the Naqada II period. The beaker forms (and black-topped red ware) fell out of fashion, while the beer jar remained relatively stable in size (Hartmann 2016:266). Small bottles or bowls, which became more frequent in the latter part of the period, may have filled the role and such transformations suggest that the use, perception and presentation of beer continued to be negotiated and redefined during this formative time.

4.2. *Beer production, craft specialization, and state formation*

From the onset of large-scale brewing in the Naqada 1C/IIA period, the massive output of beer had a strong impact on pottery production at Hierakonpolis. This connection is clear from the Operation B installation at HK11C, with its integrated pottery kilns for firing the jars, which we can now demonstrate held the beer. For these jars, the potters utilized a "straw" or chaff tempered paste, perhaps initially making use of the waste product from the grain processed for the beer. This paste type differs significantly from that used for the home-made utilitarian wares common across Upper Egypt up to this time. These came in a limited range of simple shapes (cf Fig. 2G) and employed fluid regionally distinct recipes involving coarser tempers (e.g., grog, shale) to create vessels for cooking and food preparation, while finer specialist-made polished red and black-topped wares were used for serving and consumption (Friedman 1994, 2000).

The addition of “straw” to the Nile silt made the clay easier to work, dry and fire. This new straw-tempered technology soon expanded beyond the manufacture of beer jars, developing into a specialized production for utilitarian pottery that quickly overwhelmed the home-made wares. A new range of shapes were introduced, only a few of which, like the beer jar, appear to have been borrowed from the repertoire of the table wares. These fine slipped and polished table wares had long been made by specialists, perhaps on a seasonal basis, and were the only pottery that was considered suitable as grave goods during the time of homemade utilitarian pottery production in the Naqada I period (Hendrickx 2006), This, however, began to change in early Naqada II, when straw-tempered beer jars first appear in the tombs of the elite.

For the early elite, beer production provided another avenue for the display of status and patronage. The straw-tempered beer jars, despite

Table 2
Results of phytolith analysis from Hierakonpolis.

Lab ID	Taxa Artifact ID	Triticeae inflorescence Elongate dendriform	Panicoideae bilobate	Panicoideae cross	Poaceae inflorescence Elongate Echinate/ columellate/crenate	Poaceae leaf/culm El. Psilate/ sinuate	Poaceae Saddle	Poaceae stomata	Poaceae bulliform	Poaceae rondel	Other phytoliths Elongate undetermined	 Tracheary element
POT1	Level 9 no. 4											
POT2	Level 4 no. 21					1				1		
POT3	Level 3 no. 3a											
POT4	Level 8 no. 29											
POT5	Level 8 no. 3			1								
POT6	Level 16 no. 42											
POT7	Level 5 no. 31		1			1	3					
POT8	Level 5 no. 35											
POT9	Level 3 no. 11											
POT10	Level 16 no. 25						1					
POT11	Level 2 No. 1											
POT12	Level 9 No. 11											
POT13	Level 5 no. 45											
POT14	Level 1 no. 9											
POT15	Level 1 no.10											
POT16	Level 3 no. 21											
POT17	Level 3 no 19											
POT18	Level 4 no. 33											
POT19	Level 5 no.44	2			1	5						
POT20	Level 8 no. 9	1	1			2		1			1	
POT21	Level 10 no. 1	1					1					
POT22	Level 11 no. 23		1									
POT23	Level 15 no. 1				1		1		1			
POT24	Level 15 no.5	4			10	2						
POT25	Level 15 no. 8											
POT26	Level 16 no. 11	2				4	3					
POT27	Level 16 no. 39	1			2	19	2					
POT28	Level 16 no. 98											
POT29	Level 17 no. 34											
POT30	Fort 1					1					1	
POT31	Fort 4					2						
POT32	Fort 2					1	1					
POT33	Fort 3											
RESIDUE PHYTOLITH TOTAL		**11**	**3**	**1**	**14**	**38**	**12**	**1**	**1**	**1**	**2**	
POT8 Exterior	EPOT8-EX											
POT9 Exterior	POT9-EX											
POT31 Exterior	POT 31-EX											6

(*continued on next page*)

Table 2 (*continued*)

Lab ID	Taxa Artifact ID	Triticeae inflorescence Elongate dendriform	Panicoideae bilobate	Panicoideae cross	Poaceae inflorescence Elongate Echinate/ columellate/crenate	Poaceae leaf/culm El. Psilate/ sinuate	Poaceae Saddle	Poaceae stomata	Poaceae bulliform	Poaceae rondel	Other phytoliths Elongate undetermined	 Tracheary element
Level 3-Dung	L3-Dung	52			1	2						
Level 3-F1 soil	L3-F1				2	8		1				
Level 13 soil	L13	15			2	1					1	
CONTROL SAMPLE TOTAL		**89**	**0**	**0**	**10**	**13**	**0**	**1**	**0**	**0**	**2**	**6**

their "rough" appearance, were considered appropriate as offerings in elite graves, possibly as a reflection of restricted access to their contents. In the HK6 elite cemetery at Hierakonpolis, these jars are present in the earliest of the main elite graves, Tomb 16, which is dated to Naqada IC/IIA. This large tomb was marked with a wooden superstructure and surrounded by subsidiary burials of humans and a variety of animals, including an elephant (Friedman et al. 2011). It also contained >115 pottery vessels, amongst which were 58 straw-tempered beer jars, the majority bearing pre-firing potmarks identical or similar to those at the Operation B brewery and the analyzed fragment (Pot 16) from Test A (Hendrickx 2008; Friedman 2020).

Whether the large number of straw-tempered jar in Tomb 16 had actually been filled or served a symbolic purpose remains to be determined (Hendrickx 2008); however, beer jars of the same type, present in more modest numbers (2–4 per person) in the subsidiary graves bear stains and residuals of contents. This change in mortuary practice was not limited to Hierakonpolis; jars of identical type (but in lesser numbers) were also found in some of the well-endowed tombs at Abydos at this same early time, such as Tomb U279 (Hartmann 2016:167, abb. 151).

At Hierakonpolis, the beer jars are similar in fabric, shape and method of formation (Hendrickx 2008; Baba In press). Based on the

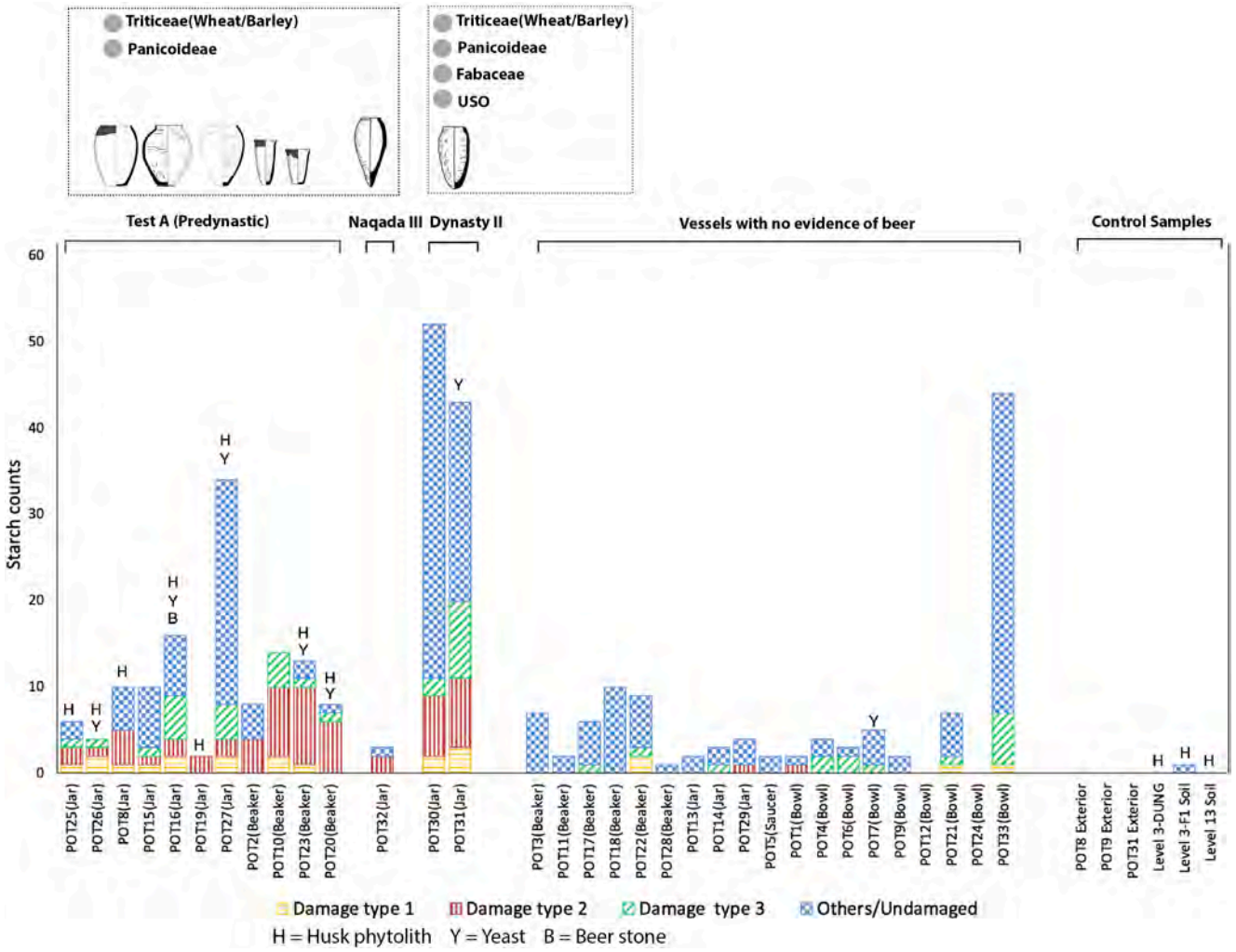

Fig. 5. Summary of microfossil residues from Hierakonpolis potsherds. For simplification, the starch cluster in POT23, which contains > 100 granules, is counted as one in this graph.

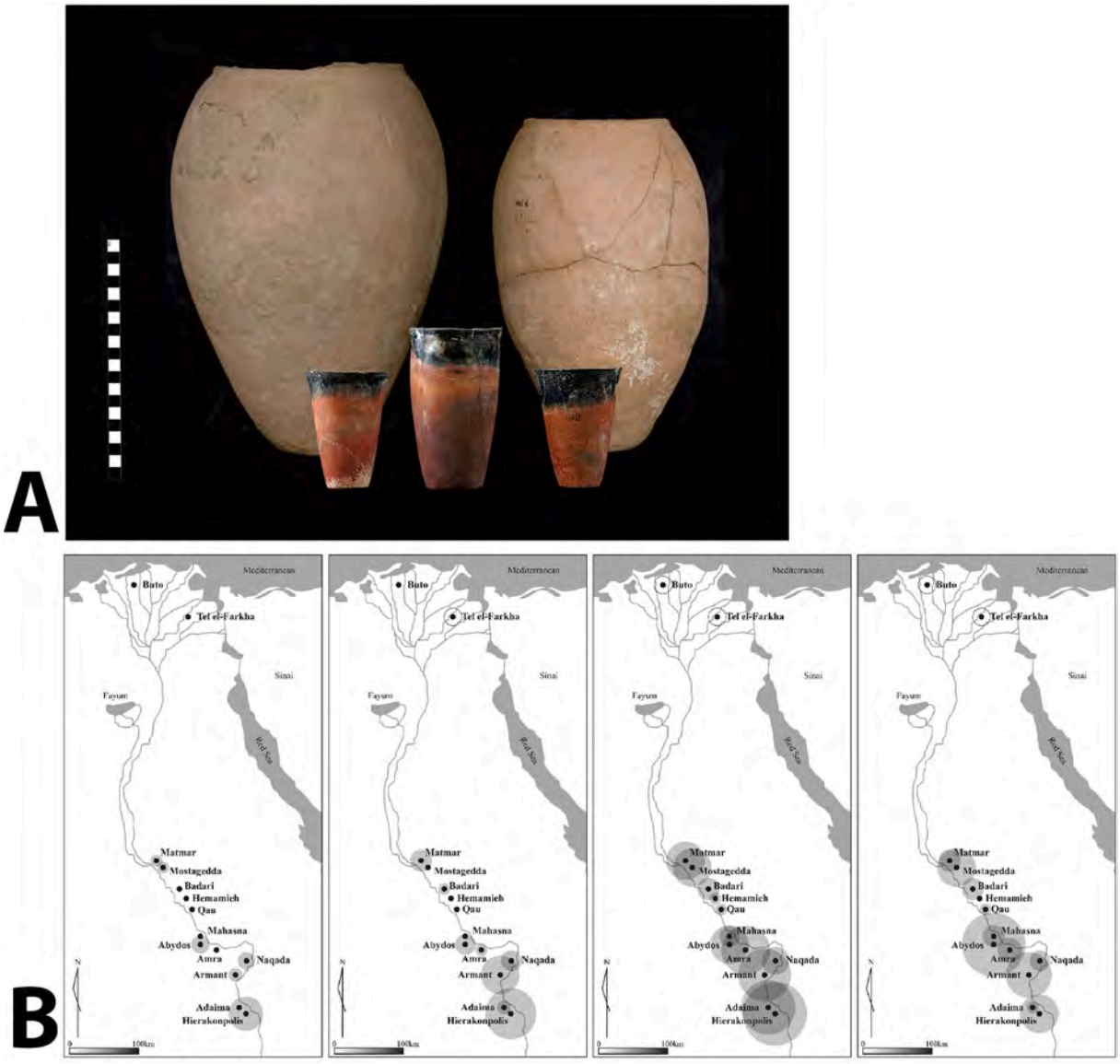

Fig. 6. A. Straw-tempered beer jars and black-topped beakers from the elite cemetery at Hierakonpolis; B. The distribution and spread of straw- tempered beer jar forms (R81-R84) in Upper Egypt during the Naqada II period based on reported frequencies in tomb assemblages (compiled after Baba in press).

assemblage in Tomb 16, they came in two sizes: large ones with a height of 29–32 cm and a maximum diameter of 20–23 cm; and smaller versions with a height of 25.5–27 cm and a maximum diameter of 17.5–19 cm (Fig. 6A). Filled to the rim, the capacity of the larger jars ranges generally from 5000 to 6000 ml, while the smaller jars held 2500 to 3200 ml (Friedman 2020). The appearance of these standardized beer jars is a strong indicator of ceramic specialization, but whether it also indicates centralized control over the production and distribution of resources and labor remains a matter of discussion (Wengrow 2006; Warden 2014). In such discussions bread and beer are often linked. However, it must be noted that how or where bread was made during the Predynastic period remains unknown and its association with beer production is so far unsupported, as demonstrated by this study and previous research (Samuel 2000). The archaeological evidence to date indicates that primarily beer was the focus of elite investment and interest, both as symbol and likely as payment and reward, spurring on the intensification of pottery production within a milieu of increasing specialization in the manufacture of elite goods (Takamiya 2004; Köhler 2010).

From these early beginnings at Hierakonpolis, straw-tempered vessels begin to gain acceptance as suitable equipment in the graves at other sites and gradually grow to dominate the funerary assemblage. Beer jars and associated shapes in tomb inventories reflect the spread of this new technology across Upper Egyptian by Naqada IIC (Fig. 6B), which likely moved as part of a package leading to the greater economic and ideological integration of Upper Egyptian culture (Baba in press). The conditions under which this diffusion occurred are not well understood. It may represent general interaction and mutual exchange practices amongst various communities or chiefdoms (Köhler 2008) or the imposition of a new order by a larger expansionist entity (Wilkinson 2000). Nevertheless, beer related technologies provide another avenue of approach for charting state formation processes in Upper as well as Lower Egypt .

To date, beer production facilities in Upper Egypt have been identified only at first-tier sites, such as Naqada, Mahasna, and Abydos, but details are lacking (Garstang, 1902; Geller, 1992; Peet, 1914). Those at Abydos are currently being reinvestigated and have been associated with the provisioning of royal rites and funerals (Doyon 2021). Dated to the early First Dynasty, the Abydos facilities are the latest of the fixed vat brewery installations so far known.

Evidence for the uptake of beer technology in the Predynastic period is more prevalent in Lower Egypt. During this time, the northern region of Egypt was inhabited by communities with material cultures and mortuary practices distinctly different from Upper Egypt, but beginning in the Naqada IIC period, interactions between the two areas increasingly eroded the distinctions. This resulted in a unity of the material culture or "acculturation" by Naqada IIIA (Bard 2017; Midant-Reynes and Buchez 2019). Some of the earliest detectible influences from Upper Egypt affecting this transformation are related to beer.

At Tell el-Farkha, in the east Delta, beer production first appears under the control of local elites (Ciałowicz 2017). A brewery composed of multiple vats supported by firebars was installed in the western part of the site. Capable of producing 200 L at a time, the brewing facility is associated with a special residence of the local elite, and together they represent the earliest indication of social complexity in this region (Cichowski 2008; Chłodnicki and Gemming 2012; Ciałowicz 2012; Adamski and Rosińska-Balik 2014). Analysis of the residue within the vats indicates the same method of grain preparation and ingredients as detected at Hierakonpolis (Kubiak-Martens and Lager 2008). The influence of this beer production on the ceramic assemblage is evident from the beginning (Naqada IIB-C), with beer jars of the Upper Egyptian form making up over 10% of all diagnostic ceramics from the Central Kom, the residence area of the site. Certain technical aspects indicate that pottery-making was still in hands of local potters, suggesting a transfer of Upper Egyptian technology rather than a significant influx of people (Mączyńska 2011, 2016). Around the same time, a similar process took place in the west Delta. At Buto, the establishment of a brewery involving 11 vats encircled by fire-bars had significant influence on the local pottery both in form, with the introduction of beer jars, and the intensity of production (Hartmann in press). Exposure is still too limited to determine the type of settlement here at this time, but in successive levels above, beer production continues to be significant. Ultimately, in the late First Dynasty the area became a palace, a symbol of central authority and seat of local administration and likely had a similar role earlier (Hartung In press).

In both cases, beer production can be seen as an elite project that facilitated the homogenization of the material culture shortly before the inception of the Egyptian state. For the early elite, beer production was a mechanism for transforming agricultural produce into a value-added medium for payment and rewards, thus legitimizing the institutionalized relations of asymmetrical social power that were emerging in this period (Dietler 2010; Joffe 1998). At the same time, the exchange and movement of beer-related technologies and materials generated new social memories among both the elite and common Egyptians (Stevenson 2016). The increasingly homogenized material culture and shared social experience transformed the relationships between Egyptian polities prior to and during the processes of unification.

Yet, the special position this beverage held during the Predynastic shifted with the development of the unified state. By the end of the First Dynasty, elite investment in brewery construction had ceased. This change corresponds with a widespread transformation in food processing technologies. New forms of food preparation pottery appeared, including the bread pot, classic beer jar, and spouted beer vat (Hendrickx et al. 2002). The way food production was organized also changed (Małecka-Drozd and Kazimierczak In press). The preparation of beer and bread was now grouped together in facilities requiring no great outlay to construct, with production units present in sites of all sizes (Buchez 2004). The reasons for this shift are still being discussed. Coming at a time of consolidation of the administrative apparatus of the Early Dynastic state, it could be related to increased central control of agricultural goods and their distribution as is often stated, but more recently alternative explanations have also been proposed, including a network of local/community oversight, or a system of market exchange based on recognized media (i.e. beer jars) and concepts of value (Warden 2014, 2017).

5. Conclusions

Ethnographic and archaeological studies have shown that once societies have incorporated alcohol into their social reproduction and economic systems, they rarely reverse the trend (Dietler 1990). This research offers the first scientific evidence for a long tradition of beer jars—pottery vessels specifically for and symbolic of beer—going back to the early Naqada II period. Beer residues were detected in five Predynastic straw-tempered jars with flat bases and modeled rims at Hierakonpolis, scientifically confirming their use as beer jars, a function previously assumed on the basis of their prevalence in and around the numerous large-scale breweries on the site. Four beaker-shaped vessels of fine clay coated with black-topped slip also revealed beer residues, suggesting their use for drinking and serving at this time.

While not precluding other uses for these vessels, our findings allow us to assess the changing modes of beer production and distribution and their relation to the emergence of social distinctions at Hierakonpolis. Before the appearance of large-scale breweries, beer was already a commodity made domestically for subsistence. The domestic production of beer likely continued throughout the Predynastic period, but in Naqada IC-IIA, in conjunction with the founding of the elite burial grounds (HK6), investment was made in a specialized production area (HK11C Operation B), which included brewery vats and pottery kilns, to service the funerals and mortuary needs. This change in production intensity indicates that beer production and consumption were incorporated into the political and economic strategies of the emergent elites. Data from other Predynastic sites also suggest that beer production was introduced as an elite-controlled industry.

The large quantities of beer jars at the elite cemetery indicate that the beverage was not simply a staple food for the living, but a symbol of status and authority, and an important element in elite feasting and burial rituals in this life and the next. On the other hand, the mass production of beer necessitated new modes of pottery manufacture and promoted the growth of a utilitarian straw-tempered ware industry. These materials generated shared social memories and bonds of dependencies among the elite and common Egyptians. These ways of political manipulation of beer contributed to the creation and maintenance of elite social status while at the same time helping to forge allegiances and the ideological integration of society.

Our findings also lead to new research questions. It remains unclear how and why expenditure on brewery installations ceased by the end of the First Dynasty. This cessation corresponds with widespread transformations in the mode of staple food preparation and the development of new recipes for beer brewing. Residue analysis of Second Dynasty beer jars from the Hierakonpolis Fort indicates a more variable set of ingredients and suggests the recipe and the production methods may not be as monolithic as previously thought. Perhaps with the consolidation of the political state by the end of the First Dynasty, the elite found new ways to express their status.

As the focus of the elite gaze shifted with the introduction of viniculture to royal estates of the First Dynasty kings, wine became the beverage of political feasting and reward. Beer changed in significance and perhaps character, but nevertheless remained a central plank of Dynastic civilization, as a staple food and medium of exchange. Future research from excavations and material culture analysis may elucidate the changing roles of beer and other alcoholic beverages in the political economy of early Egypt.

CRediT authorship contribution statement

Jiajing Wang: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing– original draft, Writing – review & editing, Visualization, Funding acquisition. **Renee Friedman:** Conceptualization, Investigation, Resources, Writing– original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Masahiro Baba:** Investigation, Visualization,

Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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