Foodways in early farming societies: microwear and starch grain analysis on experimental and archaeological grinding tools from Central China
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Chapter 6 Foodways of the earliest farmers in the Huai River Basin, China

The inhabitants at the site of Jiahu have been considered as the earliest farmers in the Huai River Basin because of the findings of the domesticated rice there (Zhang and Hung 2013). Jiahu is also the most thoroughly studied site in the research region of this project (see Chapter 1.4). Over the past decades, scholars have applied multiple scientific methods to this site and produced large amounts of data relating to foodways. Furthermore, the previous chapters of this dissertation provide more information on culinary practices through the study of the Jiahu grinding tools. These conditions make Jiahu an ideal site to explore the early Neolithic foodways in the research region. The first objective of this chapter thus is to discuss Jiahu's foodways by combining the findings from the grinding tools with other related data from the site. Second, changes and continuities of foodways overtime at Jiahu are discussed.

6.1 Food procurement: plants, animals, and tools

According to Hastorf (2017), food procurement refers to hunting-gathering, while food production pertains to agriculture, horticulture, and animal husbandry. In this chapter, food procurement is considered as all kinds of ways to obtain food, which includes cultivating plants, rearing animals, as well as hunting, fishing, and gathering of wild food resources. People at Neolithic Jiahu had a diverse diet that relied on a variety of plants and animals including fish (Zhang 1999; Zhang 2015; Yang et al. 2017). The following section starts with introducing the plants and animals that were utilized at the site. Then the toolkits associated with agriculture, hunting, fishing, and gathering are discussed in order to consider how these food procurement activities were conducted.

6.1.1 Plants

Plant-based foods are a major part of human nutrition and health. Studies on past procurement of edible plants are largely based on macro- and micro-botanical remains, and on tools used in plant procurement activities. Systematic flotation work was carried out at Jiahu during the 2001 and 2013 excavation seasons (Zhao and Zhang 2009; Zhang et al. 2018). In total, 13, 800 L of soil samples were taken from the houses, graves, pits, as well as areas outside houses attributed to different phases. In addition, 43 soil samples (5 grams for each sample) were taken from the Jiahu residential area for phytolith analysis (Chen 2001; Zhang et al. 2018). Starch grain analysis has been applied to 15 grinding tools and 11 pottery sherds (Fig. 6.1) and initial results have been published in Chinese (Li 2015; Zhang 2015).

Figure 6.1 Recovered pottery sherds from Jiahu sampled and analysed for starch content (after Li 2015).

It should be noted that plant remains do not always preserve in optimal conditions due to complex post-depositional processes (Celant et al. 2015). At Jiahu, rice remains were discovered during the flotation work in 2001, the occurrence rate of rice macrofossils account for 15% of the total macrobotanical remains, while no rice remains were found in the flotation work carried out in 2013. This variation of recovered plant remains may be due to the nature of the excavated areas in 2013 were primarily human burial areas (Zhang et al. 2018). The discovered rice remains were dated back to 7000 BC, representing the earliest rice remains beyond the Yangtze River area in China (Zhao 2009; Zhang and Hung 2013). Studies have shown that the dimension of rice remains from Jiahu increased from phase I to III (Liu et al. 2007a; Liu et al. 2009), suggesting rice cultivation was initiated at the site. In the soil samples where rice remains occur, wild grasses were also abundantly recovered and identified from Panicoideae taxonomic subfamily, such as *Digitaria sanguinalis* (L.) Scop., *Digitaria ciliaris* (Retz.) Koeler, and *Echinochloa colona* (L.) Link. Nowadays, these wild grasses are common in rice paddies. Thus, it has been proposed that these wild grasses were very likely harvested together with rice and then brought back to the site (Zhao et al. 2001). Soil samples from outside of the residential areas for phytoliths to locate potential rice paddies (Yin 2015). Unfortunately, so far, no firm evidence of rice paddies has been found. Apart from rice, another 23 types of macrobotanical remains were recovered during flotation, which can be divided into five categories of fruits (e.g. grapes and sour jujube), underground storage organs (USOs, e.g. lotus roots), nuts (e.g. acorns), water plants (e.g. water caltrop), and wild soybeans (*Glycine max subsp. soja*) (Zhao et al. 2001). These species were considered as wild and could be obtained from nearby mountains or riverbeds in the southwest of the site.

Starch grain analysis confirmed the existence of rice extracted from the Jiahu grinding tools (Zhang 2015). Furthermore, starch grains from Job's tears (*Coix lacryma-jobi*) have been identified on the grinding tools and pottery sherds (Li, 2015). Job's tears are rich in nutrients and their grain sizes are bigger in comparison to rice and millet. Job's tears are widely cultivated in Asian countries and its starch remains have been recovered from many Chinese archaeological sites (e.g. Yang and Jiang 2010; Liu et al. 2015; Yao et al. 2016; Wang et al. 2016; Liu et al. 2018b; Wang et al. 2019), with the earliest evidence from at least 26,000 BC at the site of Shizitan (Liu et al. 2018a). However, the macrofossil remains of Job's tears have only been found sporadically from about seven sites from the Neolithic to the Han dynasty (Liu et al. 2019), which exclude Jiahu. Although starch grains from Job's tears have been identified on the Jiahu grinding tools, it remains unclear why macrofossil evidence of Job's tears is scarce in most of the archaeological sites. The other identified species through starch grain analysis include grass seeds from Triticeae tribe, lotus roots (*Nelumbo nucifera*), water caltrop (*Trapa* sp.), beans (*Vigna* spp.), and Chinese yam (*Dioscorea opposita*). The microbotanical (i.e. starch grains) and the macrobotanical remains at Jiahu both indicate that a wide range of edible plants were available and exploited.

6.1.2 Animals

The systematic study of faunal remains was carried out during the seventh archaeological season at Jiahu (Zhang 2015), in which 18,012 pieces of animal remains were subjected to classification and identification. Overall, identified species from the different phases were consistent, implying that wild animal food resources were relatively stable at the site and their use was patterned. These animals were divided into five categories: shellfish, fish, reptiles, birds, and mammals (Table 6.1). Because the number of identified skeletons (NISP) from birds, shellfish, and reptiles account for a small amount, the following sections focus on food resources from fish and mammals.

Table 6.1 Animal remains from fish, mammals, reptiles, birds, and shellfish during different phases at (after Zhang 2015)

	Phase I		Phase II		Phase III	
	Number (NISP)	Percentage	Number (NISP)	Percentage	Number (NISP)	Percentage
Fishes	4827	69.16%	3874	62.80%	3698	76.03%
mammals	1260	18.05%	1918	31.09%	737	15.15%
Reptiles	679	9.73%	323	5.24%	329	6.76%
Birds	206	2.95%	46	0.75%	99	2.04%
Shellfish	7	0.10%	8	0.13%	1	0.02%

Fish remains were abundantly recovered from Jiahu, their NISP accounting for over 60% among the total faunal remains (Zhang 2015). Based on the statistical analysis of age-mortality and species-selection profiles of the fish remains, Nakajima and colleagues (2019) have provided evidence that managed aquaculture of common carp (*Cyprinus carpio*) was present at Jiahu by around 6000 BC in Phase III. It is suggested that the Jiahu inhabitants probably started digging channels and controlling water levels and circulation, so fish could spawn and grow in the managed ecotones. Then, those juvenile fish were harvested in autumn. Nowadays, in the Hunan and Guizhou Province in southwest China, people release baby fish in rice paddies during the spawning season (Celant et al. 2015). These fish feed on rice flowers falling into the water and grow faster than those in the wild. This type of rice-fish farming is believed to have been practised in China for more than 1700 years and constituted a unique agro-landscape (MacKay 1995). Even though it remains unclear whether similar practices were used at Jiahu, fish remains were predominantly recovered throughout the occupation phases (Table 6.1), suggesting that these aquatic animals played a significant role in the diet of the Jiahu inhabitants.

The second-largest group of faunal remains is from mammals, in which pigs (*Sus scrofa domesticus Brissonand*) and dogs (*Canis familiaris* L.) have been identified as domesticated animals (Zhang 2015). Most of the pig skeletons were distributed randomly in the residential areas and only pig mandibles were recovered from human burial caches (Zhang 1999). Further faunal analysis indicates that most pigs (92.1 %) were killed before they were two years old (Zhang and Luo 2008), suggesting they were raised for meat. Among the 130 identified mammals at the site (2418 faunal remains), 12 of which are identified as pig. The others were identified as remains of 3 dogs, 88 deer, 3 cattle, 1 unidentified large carnivore, 18 small carnivores, 1 animal from the Felidae family, 2 badgers, and 2 rabbits. According to these data and the estimated size of these animals, it has been proposed that pork accounted for around 27 % of meat resources used at Jiahu. In the Yangtze River region, pig skeletons were also found at the site of Kuahuqiao (c. 6200-5000 BC) (Jing 2017), showing different features from the Jiahu pigs. Accordingly, the Jiahu pigs resemble wild pigs from northern China, while the pigs from Kuahuqiao are similar to wild pigs from southern China. Thus, it has been suggested that the inhabitants from Jiahu and Kuahuqiao domesticated pigs independently in their own habitats.

China has a long history of eating dogs, whose meat was considered as delicacy for the upper class in the Shang (1558-1046 BC) and Zhou (1046-256 BC) dynasties (Li et al. 2017). Dog meat is still consumed in certain regions of present-day China, such as the Yulin city of the Guangxi Province in south China, bordering Vietnam (Rubin 2015). However, no firm evidence indicates these animals were killed for consumption at Jiahu. Unlike pigs, no fragments of dogs have been recovered from the residential area of Jiahu. The dog remains were only encountered in burial contexts (Zhang 1999). For example, a dog was found in the human grave (M341), in which the dog skeleton was placed by the left foot of the buried human. This burial suggests the dog had a close relationship with the person. In addition, another ten dog burials were found near the human burials or beside houses (Zhang 1999). According to ethnographic accounts, the Hani people in southwest China believe dogs are the protectors of their villages and thus often sacrifice dogs as offerings to ensure the protection of their village (Bouchery 1996). Zhang and Cui (2013) thus proposed that some of the Jiahu inhabitants probably treated their dogs in a similar way.

Other mammal remains found at Jiahu, include deer, cattle, unidentified small and large carnivores, and rabbit, were all classified as wild animals (Zhang 2015). The minimum number (MNI) of identified deer compose the largest proportion (around 60%) of the identified mammal assemblage, suggesting deer were the main hunting targets. From phase I to phase II, the NISP of deer that can be confirmed are stable and then decrease in phase III (Table 6.2). Differently, the NISP and MNI of pigs were relatively stable during phase I and II, and then increased slightly from Phase II to phase III. This changing trend suggests that the Jiahu inhabitants probably relied less on wild animals such as deer in phase III but more on domesticated pigs.

In summary, the Jiahu inhabitants made use of the local plant and animal resources. Through a broad-spectrum subsistence strategy, they could obtain both cultivated crops and wild plants, along with managed fish and pigs, as well as wild animals.

Table 6.2 Percentage of NISP and MNI of pigs and deer among the total identified mammal remains from Jiahu (after Zhang 1999)

	Pig		Deer	
	NISP	MNI	NISP	MNI
Phase I	9.79%	9.76 %	68.39 %	46.34 %
Phase II	9.82 %	11.11%	66.14 %	40.00%
Phase III	14.05 %	13. 79%	41.43 %	27.59 %

Note: NISP refers to the number of the identified animal remains; MNI refers to the minimum number of the animals that can be identified

6.1.3 Tools used in food procurement

In present-day southern China, denticulate sickles made of iron are still used for harvesting rice (Fig. 6.2e). Stone sickles with similar shapes were unearthed at Jiahu (Zhang 1999, 2015). These artefacts are made of schist and slate, and are characterized by denticulated edges (Fig. 6.2a). Fullagar and colleagues (2012) have carried out experiments by using replica sickles with and without denticulate edges to harvest grasses. The results indicate that denticulated sickles are useful for cutting grasses while sickles without denticulate edges are not. Further, microwear analysis conducted on the Jiahu sickles reveals that these tools were adopted to reap grasses (Fig. 6.2b, Cui et al. 2017), which probably include rice. Moreover, fan-shaped and dumbbell phytoliths probably belonging to rice were extracted from the Jiahu sickles (Fig. 6.2c and d, unpublished data from the author). These lines of evidence suggest that the Jiahu sickles were very likely employed in rice harvesting.

It is worth pointing out that the Jiahu stone sickles started to appear during Phase II, implying that a different harvesting method was adopted in the earlier period. Rice normally grows in water and has a deep subterranean root system, so it is arduous to harvest rice by uprooting. Ethnographic accounts and previous research on archaeological sickles from China suggest three methods of harvesting rice are used (Yang 1981; Ma 1986; Zhen and Jiang 2007; Vaughan et al. 2008): a) people can simply collect rice grains by hand or beat and detach rice spikelet into baskets; a similar method has also been documented for harvesting wheat (Anderson 1999); b) when using sickles, reapers can choose to cut rice plants from panicles, in which case rice leaves are not harvested; alternatively, c) reapers can cut from rice stems, which means rice leaves, panicles, and grains are all harvested. These different harvesting techniques result in bringing different parts of rice to end up in the residential area. Different parts of a rice plant produce three distinct types of phytoliths (Lü et al. 1997), including sheet element dumbbells (Fig. 6.3a) and cuneiform bulliform cells (fan-shaped, Fig. 6.3b) from the leaves, and double-peaked glume cells (Fig. 6.3c) from rice husks. Based on the percentage of the different types of rice phytoliths preserved in the residential area, it is possible to infer which method was used for rice harvesting. At Jiahu, Yin (2015) took 34 soil samples (at least 5 grams for each sample) from the residential area (e.g. houses and pits near houses) for phytolith analysis, with at least 9 samples attributed to each phase. Among the identified phytolith from rice, the percentage of double-peaked phytoliths from rice glumes were dominant in Phase I. When it came to the Phase II and III, although phytoliths from glumes were still abundant, the percentage of phytoliths from stems and leaves increased. These data suggest that the local people adopted different methods to harvest rice during different phases. In Phase I, it is likely that only rice grains were harvested using the first method (a) mentioned above, thus few phytoliths from rice leaves and stems were present in the residential area. When it came to Phase II and III, sickles were used and the inhabitants started to cut rice from the stems. As a result, more phytoliths from rice leaves and stems were brought back to the residential areas. Nevertheless, it is worth noting that the number of the phytolith samples from each phase was rather low and most of the samples are from pits near houses (20 out of 34) (Zhang et al. 2018). Thus, more samples from different types of contexts (e.g. interior of houses) are required to further testify the harvesting methods for rice at Jiahu.

Apart from sickles, modern shovels are also closely associated with agricultural activities. For instance, farmers can use shovels to dig, lift, or move bulk materials such as gravel and sand in their farmland. Based on tool typology, stone shovels

(Fig. 6.4a and b) were classified at Jiahu (Zhang 1999; Lai and Ying 2009; Zhou 2014). Further microwear analysis on the Jiahu shovels has proved these objects were indeed involved in earth-working (Cui et al. 2017). Apart from stone shovels, one scapular implement (*gusi* in Chinese) was found at Jiahu (Fig. 6.4d). According to the ancient Chinese book zhouli written during the Han dynasty (206 BC–220 CE), a *gusi* was a type of agricultural tool used for breaking ground and hoe up weeds in paddies. At the sites attributed to the Hemudu Culture (c. 5000-3000 BC) in the Yangtze River, similar types of *gusi* (Fig. 6.4c) have been subjected to microwear analysis (Xie et al. 2017, Fig. 6.4e-h). Although, other activities were carried out with these bone tools as well, such as fibre processing, many were demonstrated to have been employed in earth working. Unlike shovels that have been recovered from phase I contexts, *gusi*s were only found in phase III contexts (Zhang 1999). Meanwhile, compared to the *gusi* (n=1), far more shovels were unearthed (n=87). Thus, it can be implied that shovels were more common at Jiahu throughout the site's occupation and the *gusi* was a later invention or adoption.

In contrast to agricultural tools, direct lines of evidence of tools relating to gathering wild plant species are hard to be archaeologically detected. In terms of hunting and fishing, arrowheads and fishing darts were the primary tools that were used at Jiahu. The number of these tools account for 270 and 127 specimens respectively, much higher than the other types of fishing and hunting tools such as stone balls (n=12) and fishing net weights made of pottery (n=28) (Lai 2009). All these hunting-fishing tools were used throughout the site's occupation except for fishing net weights made of pottery that do not appear until phase II, suggesting a new fishing technique was adopted or invented during this period. The majority of these arrowheads were made from deer limb bones and a few were made from cattle and pig bones (Zhang 1999), which may be due to the fact that deer were the most consumed terrestrial animals at the site. These arrowheads and fishing darts were also made into different shapes (Lai 2009), yet whether these tools functioned differently in hunting and fishing activities (e.g. for big or small targets) has to be investigated further to draw concluding remarks.

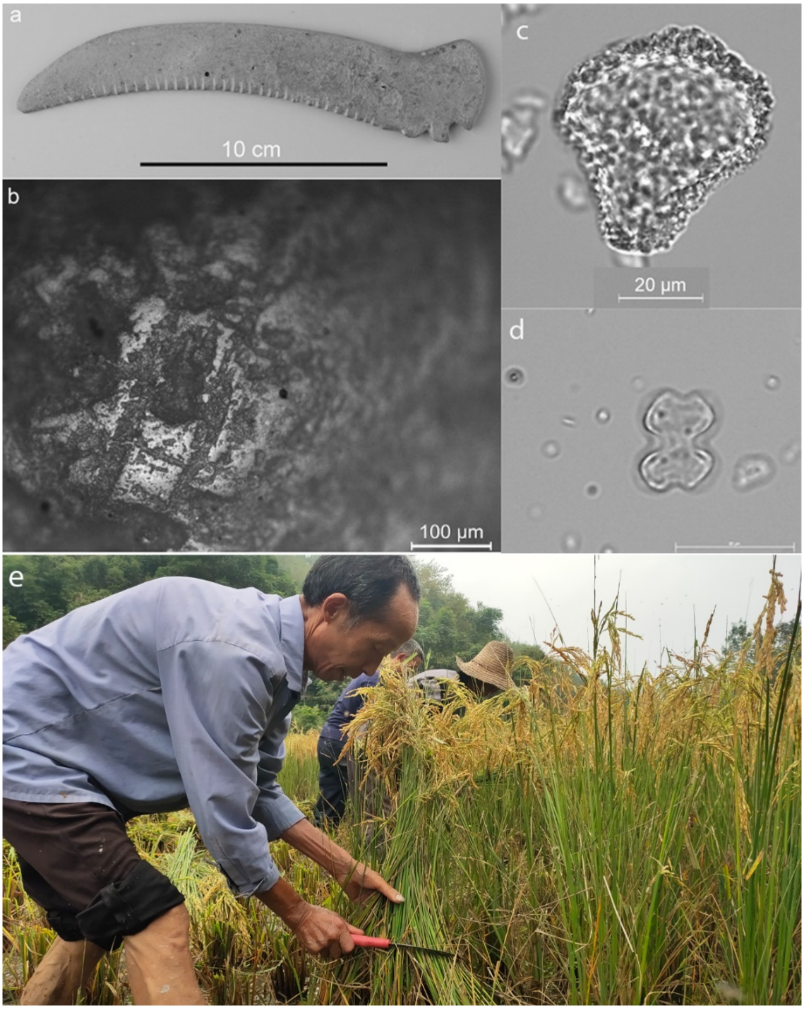

Figure 6.2 Phytoliths and microwear traces on the denticulate sickle from the site of Jiahu. a: An example of a stone sickle from Jiahu; b: the microwear traces associated with cutting grass observed on the cutting edge of this tool; c and d: dumbbell and fan-shaped phytoliths resembling those from rice, extracted from the surface of the Jiahu sickle; e: a local farmer from the Nvwashan village, Ankang city of China using an iron sickle to harvest rice (photo a, b, c, and d © Weiya Li, photo e © Jinzhoulinshi).

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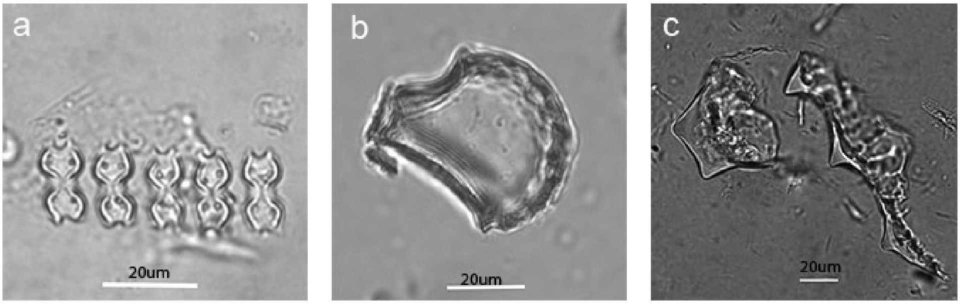

Figure 6.3 Three different types of phytoliths from rice. a: paralleled dumbbell phytoliths from rice leaves; b: fan-shaped phytoliths rice leaves; c: double-peak phytoliths from rice husks (all the pictures © Weiya Li).

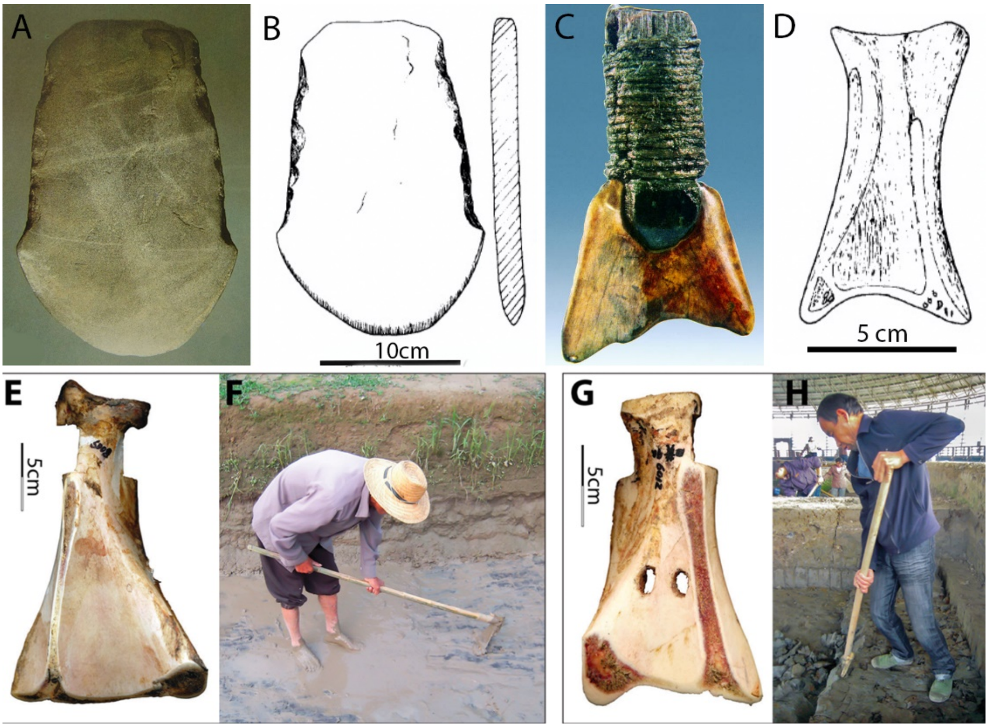

Figure 6.4 Tools associated with earth working. A and B: an example of a stone shovel unearthed from the site of Jiahu (© Juzhong, Zhang); C: a *gusi* implement unearthed at the site of Hemudu (ca. 7000-5000 BP) in the Yangtze River valley, China, note the *gusi* is still attached to a wooden handle with strings (© Encyclopaedia of China Publishing House); D: illustration of the *gusi* unearthed from the site of Jiahu (after Zhang, 1999); E and G: replicas of *gusi* made by Xie and colleagues (2017), F and H: demonstration of the use of replica *gusi* implements by the local farmers in China (© Xie et al. 2017).

A quantitative analysis has been carried out on different types of tools associated with agriculture, hunting, and fishing (Lai 2011, Fig. 6.5). The results show the number of agricultural tools, including shovels and sickles, increased from Phase I to Phase III (Fig. 6.5). In contrast, the number of tools associated with hunting and fishing, i.e., arrowheads and fishing darts, increased from Phase I to Phase II to the highest and then decreased in Phase III. These data reflect that farming was more widely adopted over time and in phase III, the Jiahu people relied less on hunting and fishing.

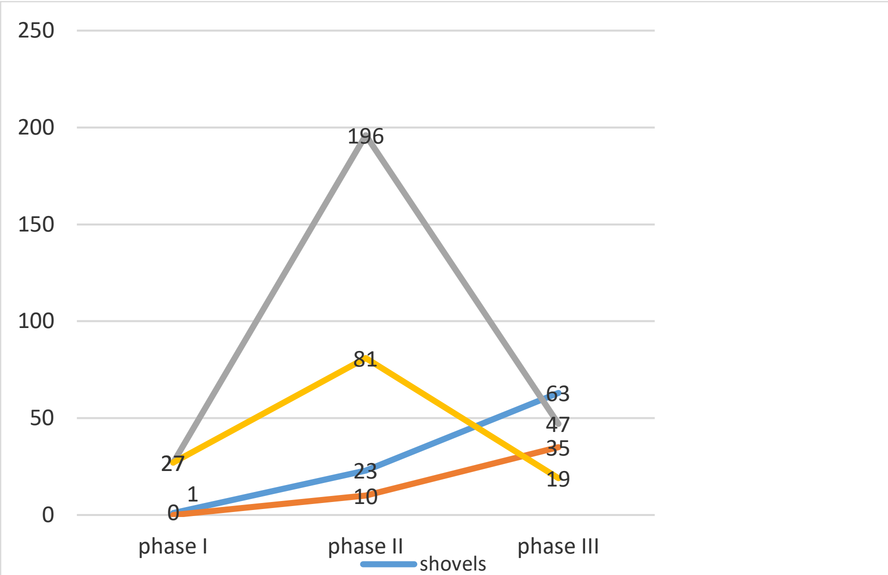

Figure 6.5 Number of shovels, sickles, arrowheads, and fishing darts from different phases at Jiahu (after Zhang, 1999)

6.2 Food processing

Raw foodstuffs often need to be processed for the sake of a longer period of storage, better taste, easier digestion, increased nutrition, or removal of undesirable substances (Stahl 1989; Caplice and Fitzgerald 1999). A wide range of culinary practices have been documented in ethnographic accounts, such as drying, smoking, salting, parching, grinding, pounding, leaching, butchering, brewing, fermenting, rotting, etc. (Katz and Weaver 2003; Li and Hsieh 2004; Speth 2017). People often choose different food processing techniques based on the properties of available ingredients and their own culinary preference (Atalay and Hastorf 2006). At Jiahu, microwear traces on the stone knives revealed that some of these objects were used to work animal bones (Cui et al. 2017), but whether these knives were used to cut bones or scrape meat from the bones was not clarified in this study. In addition, previous studies have not paid much attention to butchering marks on animal bones. Because the evidence for animal food processing is rare at Jiahu, the following sections concentrate on botanical culinary practices at Jiahu, which are inferred from the processed plant remains as well as implements involved in food processing.

6.2.1 Rice Processing

De-husking

During the flotation conducted in 2001 at Jiahu, 402 rice grains were recovered, of which 25 are complete. Most of these rice grains (24 out of 25) were already de-husked (Zhao and Zhang 2009). Ethnographic accounts reveal that wooden pestles were adopted for rice de-husking in China (Zhao and Li 2014). An archaeological example of a wooden pestle has also been unearthed at the early rice agriculture site of Hemudu in the Yangtze River region (Underhill 2013). Yet, wooden pestles have not been discovered at Jiahu, so scholars proposed that alternatively grinding tools were used for de-husking (Xu 2017). Although experimental research reveals that grinding slabs and rollers can be used for rice dehusking, these stone implements are less efficient comparing to wooden mortars and pestles for dehusking cereals (Wang 2008). So far, because the Jiahu grinding tools have not been subjected to phytolith analysis, it is uncertain whether grinding tools were employed for rice dehusking. Meanwhile, the possibility of adopting wooden mortars and pestles for de-husking cereals at Jiahu cannot be excluded due to the limited preservation of organic artifacts from aerobic conditions.

Grinding

Grinding tools have been frequently recovered from archaeological sites, most of which were associated with food processing (e.g. Aranguren et al. 2007; Liu et al. 2010a; Portillo et al. 2013; Portillo Ramírez et al. 2014; Fullagar et al. 2015; Shoemaker et al. 2017; Dietrich et al. 2019). At Jiahu, the results from starch grains indicate that the grinding tools were used for processing various plants, mainly cereals, which include rice, Job's tears (*Coix lacryma-jobi*), and plants from the Triticeae tribe (Zhang 2015). The quantity of cereal starch grains accounted for nearly half of the total starch grains recovered (see Chapter 2). Meanwhile, the ubiquity of the starch grains from cereals is also the highest. Microwear analysis further correlates the results from starch grain analysis, revealing that the majority of the Jiahu grinding tools were primarily used for grinding cereals, probably into flour (Li et al. 2019b). In terms of grinding practices, although both dry- and wet-grinding are commonly practised nowadays (Yang and Seib 1996; Suksomboon and Naivikul 2006; Stock et al. 2016), the Jiahu inhabitants preferred a dry-grinding technique (see Chapter 3). The produced dry flour is quicker to cook, easier to carry and digest, which would have been beneficial to the Jiahu inhabitants, who still relied on mobile subsistence strategies such as hunting and gathering of wild food resources (Li et al. 2019a).

Compared to starch grains from Job's tears, the quantity and ubiquity of starch grains from rice are much lower on the Jiahu grinding tools (Zhang 2015, see also Chapter 2). The scarcity of starch grains from rice has led to the interpretation that rice was not the main processed cereals at the site. However, a further experimental study indicates that dry-grinding could cause heavy morphological changes to starch grains and consequently affects starch grain detection, especially in the case of rice (see Chapter 4) (Li et al. 2020a). This interpretation also suggests that rice starch remains could be underrepresented on the Jiahu grinding tools. In other words, rice could have played a more significant role in the local people's diet than previously suggested. In addition, it is worth noting that one of the most prominent cereals (the highest in both ubiquity and absolute number of recovered starch grains) in the assemblage is Triticeae, which appears to be a wild plant at this time, but the macrobotanical evidence of Triticeae is rare at Jiahu (Zhao and Zhang, 2009; Zhang et al. 2018). This issue has been noticed and pointed out by Yang (2017). Yet, it is still inconclusive why this is the case.

Fermenting

Together with fruits and honey, rice was also fermented to produce a beverage (McGovern et al. 2004). This proposition is inferred from a study carried out on the Jiahu pottery sherds using five analytical methods, which include gas chromatography-mass spectrometry (GC-MS), high-performance liquid chromatography-mass spectrometry (HPLC-MC), Fourier-transform infrared spectrometry (FT-IR), stable isotope analysis, and selective Feigl spot tests. The Jiahu samples yielded good FT-IR and HPLC, which correlates with different modern wines, including rice and grape wine. Meanwhile, samples in the Jiahu group show uniform presence of an inclusive series of n-alkanes, C^{23}–C^{36}, which may derive from wax and/or beeswax (McGovern et al. 2004). Furthermore, stable isotope analysis indicates the residues were from C_3 plants, such as rice or grape. Integrating these data in the light of the finding of macrobotanical remains at the site, it is interpreted that mixed ingredients, including rice, honey, and fruits (i.e. grapes and hawthorns) were probably fermented together. Nevertheless, no fingerprint compounds associated with fermentation have been found in this study. Thus, subsequent studies using different methods on these vessels should be useful to expand the range of data, and thus, lines of evidence for fermentation practices. For example, a recent study documented the resulting changes of starch grains from 17 species after fermentation (Wang et al. 2017b), which could be applied to indicate fermentation process as well as identify plants potentially used in beverage production. Ion chromatographic (IC) analysis could also be used to reveal the presence of oxalate, which develops during cereal mashing, steeping, and fermentation (Briggs et al. 2004).

The previous study on the Jiahu jars also found that most of the vessels (13 out of 16) possess similar chemical signatures (McGovern et al. 2004), implying a standardized recipe might have been used for beverage production at Jiahu. Unfortunately, the archaeological contexts of these analysed jars were not clarified. Therefore, issues such as recipe standardization in diachronic terms and the meaning of beverage production still need further considerations.

6.2.3 Acorn processing

Common acorns in China include Mongolian Oak (*Quercus mongolica*), sawtooth oak (*Quercus acutissima*), Chinese cork oak (*Quercus variabilis*), and ring-cupped oak (*Quercus glauca*) (Zhao and Zhang 2009). These species all contain tannic acid (also referred to as tannins) that negatively affects human digestion. Ethnographic accounts report different ways to remove the toxic acid from acorns. The procedures often include soaking acorns in cold or hot water, sun-drying, peeling, pounding, and sometimes mashing and boiling (Hosoya 2011). At Jiahu, some of the ethnographic practices can be detected from the discovered acorn remains. First, the macrobotanical remains of acorns found at Jiahu were all fruits without shells, indicating that shells of acorns were removed on purpose. Second, these acorn remains were also fragmented, suggesting that pounding probably was applied to reduce acorn fruits into smaller pieces. Last, from the grinding experiments of fresh acorns (Wang 2008), it is found that fresh acorns need to be dried before pounding or grinding. Thus, the Jiahu inhabitants at least adopted shelling, drying, and pounding before consumption of acorns.

6.2.4 Processing of underground storage organs (USOs)

Roots, rhizomes, and tubers are dietary staples in many parts of the world (Chandler-Ezell et al. 2006), their starch grains were often recovered from archaeological grinding tools (e.g. Piperno et al. 2000; Liu et al. 2014). Nevertheless, sometimes it is controversial whether these USOs were indeed ground by the past populations (Baysal and Wright 2005; Atalay and Hastorf 2006). The concerns mainly come from the fact that the size of some USOs such as lotus roots are not suitable for direct grinding and can be eaten as raw. At Jiahu, starch grains from lotus root and Chinese yam were found on the grinding tools (Zhang 2015), but use-wear traces associated with processing USOs were not identified (see Chapter 2) (Li et al. 2019b). It is thus inferred that USOs were probably occasionally processed on the grinding tools and the associated traces might have been obscured or removed by other grinding tasks, such as cereal processing. Meanwhile, considering airborne starch grains are possible from handling plant or food remains (Laurence et al. 2012; Crowther et al. 2014), it is also possible that starch remains of USOs were cross 'contaminated' on the ancient grinding tools through other culinary practices involving USOs carried out nearby, such as cutting, pounding, or cooking. Although the potential ancient 'contamination' may affect how we understand tool function, it does not change the fact that the starches identified from this context correspond to plants that were present and used (possibly gathered, cultivated, and consumed) by humans during this site's occupation. Moreover, recent experiments have been conducted to document damage patterns of starch grains from USOs associated with grinding, pounding, baking, boiling, and drying (Wang 2015). The results show that starch grains from USOs respond differently to each of the processing methods. These documented damage patterns of USOs create a reference baseline that could be applied to future research on grinding tools, which hold the potential to put further insights into the use of USOs in the past.

6.2.5 Tools used for food processing

The grinding tools from Jiahu have been subjected to use-wear and starch grain analysis (Zhang 2015; Li et al. 2019b). The distribution and character of the use-wear traces, as well as the quantitative analysis of starch grains recovered from the grinding tools from Jiahu indicate a correlation between tool type and function (see Chapter 2). Specifically, the grinding slabs without feet and cylindrical rollers were mainly associated with processing cereals, while grinding slabs with feet were mainly related to processing wood-like materials. Nevertheless, the sample size of the grinding tool assemblage for use-wear analysis is small, with only two grinding slabs with feet. The sample size was too limited to further testify the uses of different types of grinding tools at Jiahu. Future work at the site aims to supplement this study to further explore these themes, as well as examine spatial variation (activity areas) and diachronic continuities and/or changes in food processing practices.

Another interesting phenomenon about the Jiahu grinding tools is that the majority of the complete grinding tools were recovered from human burials, and only a few were encountered in pits that were related to ritual contexts (Zhang 1999; Zhang 2015; Yang et al. 2017). So far, it is inconclusive why all these complete objects ended up in graves or pits. What has been confirmed is that these tools were closely associated with botanical culinary practices (Zhang, 2015; Li et al. 2018). The middle part of the Jiahu grinding slabs and rollers also became relatively thinner, suggesting a prolonged use and maintenance of these implements before being buried in the ritual contexts. The appearance of these artefacts in all phases at Jiahu also suggest their indispensable role to the people in the settlement (Zhang 1999, 2015). Thus, these tools were likely used for quotidian activities rather than only for meals on special occasions.

The Jiahu pottery associated with beverage production were made of local clay without extra tempering materials (Zhang, 1999). These vessels were used in all occupation phases at the site and were well suited to prevent wine volatilization because of their narrow-necks and high, flaring mouths and rims (Fig. 6.6a). Their round base also allows upright storage of beverages by possibly embedding them in soft ground, such as sand. Deposits from beverages can also concentrate on the base. The vessel ears were produced with perforations, making them suitable to be hung from strings. Future research using microwear analysis to analyse ears and base of the Jiahu jars may provide new insights into the storage and fermentation practices at Jiahu.

Figure 6.6 Examples of the potteries from the site of Jiahu. a: an example of a jar associated with beverage production at the site of Jiahu; b: Jiaobaguan vessels used for cooking in phase I; c and d are Ding vessels used for cooking in phase II and III, note the black soot on the surface on the Ding vessel on c (© Juzhong Zhang).

6.3 Storage of food

The storage of food has been considered as an important strategy among early farming communities because it allows preservation and accumulation of food surplus over long periods of time, thus reducing dependency on food seasonality, while increasing food predictability and security (e.g. Kuijt and Finlayson 2009; Laland and O'Brien 2010; Urem-Kotsou 2017). Archaeological studies of food storage and storing technologies are largely based on research of storage facilities and vessels (Bogaard et al. 2009).

At Jiahu, around 400 storage pits were discovered, distributed around 50 houses (Zhang 1999; Zhang and Cui 2013; Zhang 2015; Yang et al. 2017). The Jiahu pits were divided into five main types according to their shape, dominated by pits with round openings. Most of the pits are between one to two metres in-depth, with visible digging traces on the walls in some cases (Zhang 1999). Soil samples taken from these pits provided the largest quantity of carbonized plant remains during botanical flotation recovery (Zhao and Zhang 2009). For instance, over 3000 grass seeds were yielded from 81 floated soil samples from pits, in contrast to only one unidentified charred seed from 18 soil samples from graves. In addition to plant remains, various animal remains were also found, including turtle shells, fish bones, and fragments from other mammals. These findings imply that different types of foods might have been stored in the pits. Pottery containers such as jars might have played a role in food storage at Jiahu as well. In present-day Chinese villages, pottery containers are often used for keeping cereals pickled vegetables (e.g. Fig. 6.7). Yet, residue analysis on pottery containers from Jiahu is still needed to investigate what was kept in these vessels.

Figure 6.7 Pottery vessels used for storing rice and seasoned vegetables at a village located in Jinmen city, Hubei Province of China (© Weiya Li).

During the eighth excavation season in 2013, a well was found outside a house (2013F5) attributed to Phase I (Yang et al. 2017). The use history of this house was divided into two periods. In the earlier period, the structure of the house was a semi-subterranean structure with seven post holes. The house is triangular and approximately 8m^2 in size. The door of the house faced east. During the second period, the house was expanded and transferred to a surface-level structure. The excavation of this house and of the well did not continue because of time restrictions. Nevertheless, the finding of the well provided important evidence about water management practices of the Jiahu population. Since the early occupation of the site, the local people could obtain water near their houses.

6.4 Cooking and serving

Humans benefit from cooking in the past and the present (Stahl 1989; Stahl et al. 2002; Speth 2015). After cooking, food is often served with different utensils with different forms and materials, which often reflects daily consumption practices (Sahlins 1976). The discussion of cooking practices at Jiahu are mainly based on the cooking facilities found during the excavations, fuel remains left in hearths, and vessels used for cooking (Zhang 1999; Zhang 2015), while serving at Jiahu is inferred from the description of serving utensils unearthed at the site.

Hearths were found both inside and outside of housing structures at Jiahu. Not all the houses were equipped with hearths and the outdoor hearths were in communal areas between individual houses, suggesting some of the households may have shared the hearths. Indoor hearths were normally located in the centre of the houses. For instance, in the house F16 assigned to Phase III, a square-shaped hearth was well preserved. This hearth is around 108 to 126 cm in length, 34 cm in width, and 13 to 15 cm in depth. Plant ashes were recovered from inside of the hearth, from 5 to 7 cm thickness, in which carbonized rice remains were identified, suggesting that rice straws (stems) were used as fuel for cooking in Phase III. Hearths were found in houses attributed to all phases, but the number of these facilities were limited, only 6 hearths were documented in the site report.

Four main types of cooking utensils have been identified on the basis of pottery typology as well as cooking traces (i.e. soot on pottery surfaces) (Fig. 6.6c): a) tripods (Ding in Chinese), which were designed with wide-flaring mouths and three standing feet; b) cooking jars (Jiaobaguan in Chinese, Fig. 6.6b), characterized by an oval-shaped body with two handles; c) a wok-shaped caldron (Fu in Chinese), which has a wide-open mouth but without feet; and d) vessels with holes on their bottoms (Zeng in Chinese), which might be used for steaming food (Zhang, 1999). All these vessels were made of clay, tempered with sand or rice husks. The diverse shape of cooking vessels implies that different methods such as boiling or steaming were employed to cook at the site. In addition, pottery lids have been identified, suggesting that the inhabitants knew how to retain the temperature during cooking. The majority of Jiaobaguan vessels used for cooking were found in the first phase, while Ding vessels were only used in the later phase II and phase III (Fig. 6.6b, c, and d). The development and use of different types of cooking vessels reflect changes in cooking practices at the site.

Based on morphology and analogies, pottery basins, bowls, cups, and ladles have been classified as utensils used for presenting and consuming food at Jiahu. Fragments from basins and bowls were abundantly unearthed (the exact number was not provided in the site report), in contrast to a small number of cups (n=10) and ladles (n=2) (Zhang 1999). The low percentage of ladles and cups suggests that these objects were probably used in specific circumstances or on special occasions (e.g., sharing soups or drinking alcohol).

6.5 Consumption and human diet

Multiple types of artefacts including pottery, grinding tools, and human bones were subjected to analysis at Jiahu, which have provided direct and indirect evidence about what the Jiahu people ate.

Three types of starch grains were identified from the pottery sherds, including those from Job's tears, Triticeae, and lotus roots (Fig. 6.8). It should be mentioned that these pottery sherds were too small for further classification of their types, e.g., a cooking vessel or a container (Li, 2015). Four types of identified starch grains were recovered from the Jiahu grinding tools, including those from rice (*Oryza sativa*), water caltrop (*Trapa* sp.), beans (*Vigna* spp.), Chinese yam (*Dioscorea opposita*) (Zhang, 2015). These data show different assemblages of starch grains on pottery and grinding tools. For instance, starch grains from rice were found on the grinding tools but not on pottery sherds. Thus, these objects were likely in contact with different types of plants. Another possibility to consider is that cooking and grinding could have created damages to starch grains and consequently lead to biased preservations of the plant remains. Cooking experiments have been carried out to explore how starch grains from different species are affected by cooking (e.g. Henry et al. 2009; Ge et al. 2011). A recent cooking experiment was also carried out using a replica of Ding vessels from Jiahu to cook rice (Fig. 6.9a and b), in which the morphological changes of starch grains after cooking were documented (Fig. 6.9c, d, e, and f, unpublished research by the author). Meanwhile, grinding experiments were also carried out to document damage patters of starch grains from different cereals (see Chapter 4) (Li et al. 2020a). These data applied to more research of Jiahu pottery and grinding tools would contribute to a better understanding of the exploitation of plants at the site. Apart from starch grain analysis, other methods including High-temperature gas chromatography (HT-GC) and combined HT-GC/mass spectrometry (HT-GC/MS) on pottery vessels are also needed to reveal more information regarding the consumption of animal foods at the site.

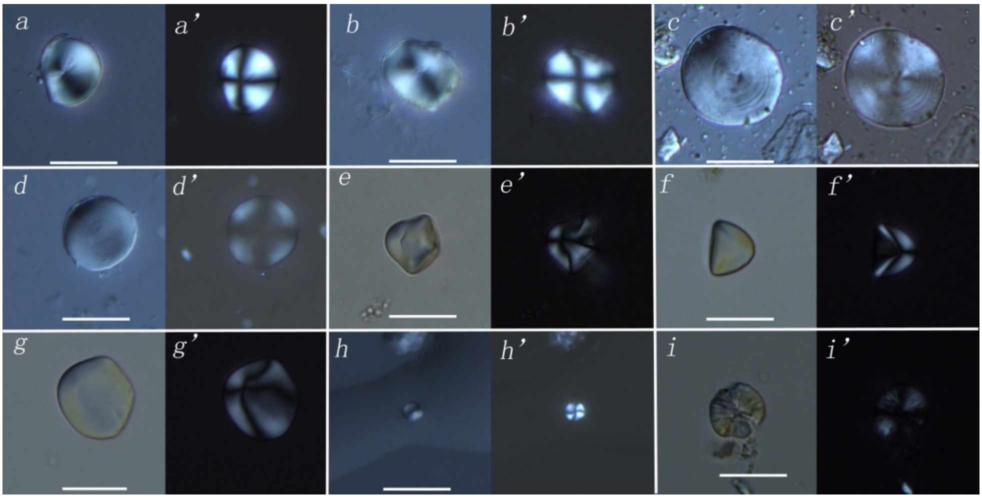

Figure 6.8 Starch grains found on the pottery sherds from the site of Jiahu. a, a', b, and b' from Job's tears; c, c', d', d' from plants belong to Triticeae tribe; e, e', f, f', g, and g' from USOs, probably from the lotus roots; h and h' are small undetermined starch grains; i and i' are damaged starch grains (after Li, 2015).

To reconstruct the human diet at Jiahu, Hu e. al (2006, 2007) carried out stable carbon and nitrogen isotope analysis on 28 human remains attributed to different Phases. The authors suggested that "carbon isotope ratios ($^{13}C/^{12}C$) of bones can be used to estimate the dietary proportions of C_3-based foods such as rice that have low $^{13}C/^{12}C$ ratios, and C^4-based food such as millet that has high $^{13}C/^{12}C$ ratios. Nitrogen isotope ratios ($^{15}N/^{14}N$) increase from plants to herbivores to carnivores, and can be used to reconstruct animal versus plant protein consumption" (Hu, 2006, pp. 1319-1320). Their results indicate that Collagen $\delta^{13}C$ values of the Jiahu samples were low for all the individuals, suggesting the primary dietary sources of these people were predominantly C_3 plants (e.g. rice, Triticeae, USOs, and acorns) as well as C_3-feeding animals. In addition, the correlation coefficient values between Collagen $\delta^{13}C$ and $\delta^{15}N$ are low (r=0.063), suggesting that plant foods account for the main proportion of their diet while animal food was the supplement. This proposition is consistent with another study on Jiahu human teeth, in which 71 individuals from Jiahu were studied. The results indicate that 14 people (19.72 %) assigned to different phases had dental caries, a disease that may result from the consumption of carbohydrates. The proportion of people having dental problems is even higher than that of modern agricultural societies (4.3% to 14.8 %) in northern China (He 2004). It is worth noting that the sample size of 28 is a small proportion of the recovered human remains at Jiahu (n=349 during the first six excavations). Meanwhile, 13 of the samples had completely non-collagenous compositions, so the interpretation of the human diet was based on the remaining15 samples. With limited samples per phase, more studies are still needed to evaluate diachronic trends in the diet at the site. Nevertheless, based on the current data, human remains assigned to Phase II had the highest $\delta^{15}N$ and lowest apatite $\delta^{13}C$ values, implying that people in this period had the highest proportions of animal protein and a larger amount of C_3 plants, which likely include rice.

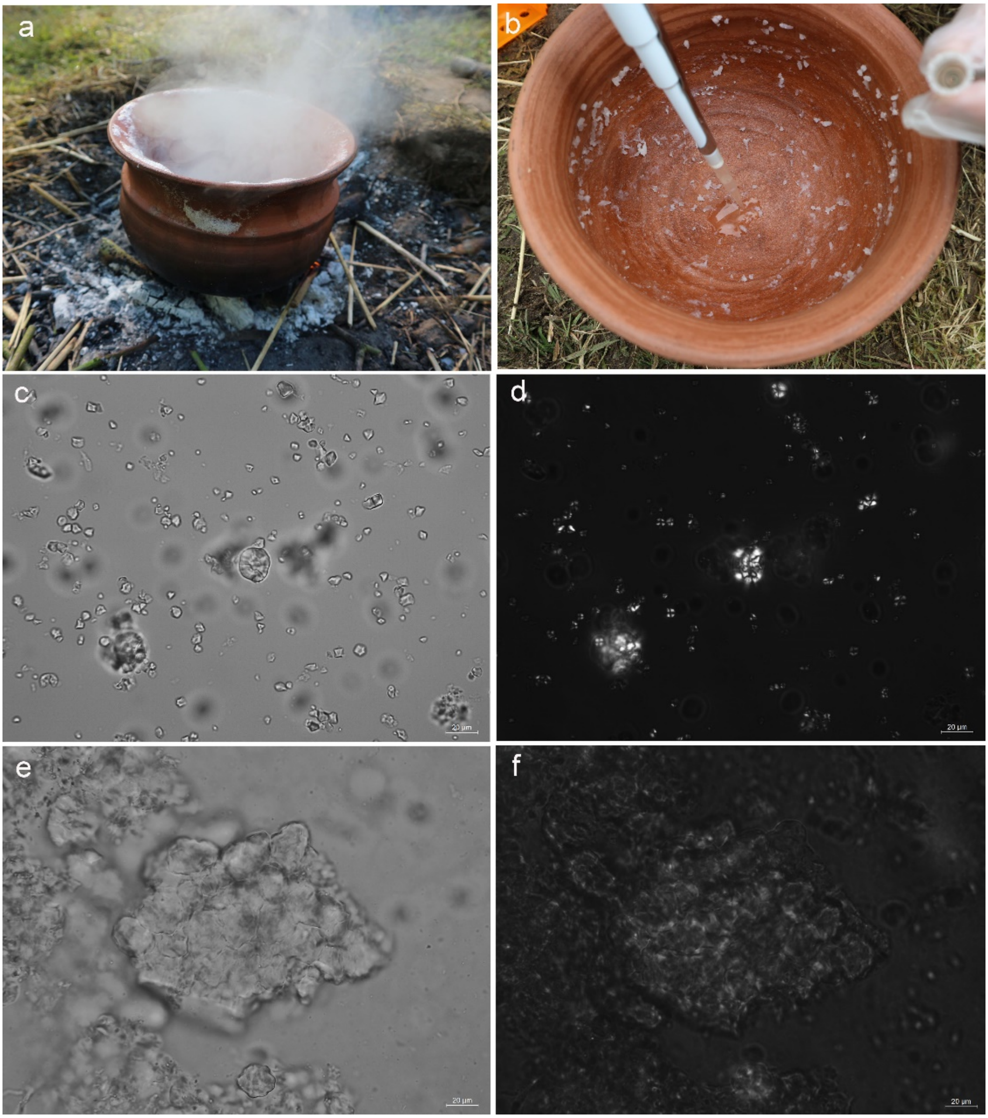

Figure 6.9 Cooking experiment using a replica of Ding vessel from the site of Jiahu. a: cooking experiment using a replica of Ding vessel from the site of Jiahu; b: extracting residue samples inside the Ding vessel after cooking rice, c and d: starch grains from rice before cooking; e and f: the resulting changes of starch grains from rice after cooking (© Weiya Li, unpublished data from the author).

6.6 Discard and recycling of food remains

Activities involved in dealing with food waste provide insights into a society's use of space and their concepts of cleanliness (Hill 1995). At Jiahu, food remains such as fish bones were often recovered from inside of the houses, suggesting food waste was discarded indoors. In addition to discard, recycling of food remains was also detected at the site. For instance, animal bones were made into different types of hunting tools, allowing the inhabitants to hunt for more wild animal resources; Ulnae bones from the red-crowned cranes (Grus japonensis) were made into musical instruments, e.g., flutes (Zhang et al. 1999); turtle shells and pebbles were used in ritual activities (e.g. divination, Zhang 1991). Regarding plant remains, rice husks were used as temper in pottery production as well as in house construction mixed with mud and then used to coat the floors or the walls. It was proposed that the prepared coating after burning is efficient to protect the houses against moisture (Zhang 1999).

The inhabitants from Jiahu might also have fed pigs with their leftover food remains. According to the isotopic analysis of 11 Jiahu pig remains, the $\delta^{13}C$ of the pig samples is 20.17±1.17‰ on average (Zhang 2015), which is similar to the isotopic signatures from the human remains. This result suggests these pigs were mainly fed with C_3 based foods similar to the human diets. In some of the present-day Chinese villages, leftovers from human food, such as rice husks are often crushed and mixed into pig feed. Further research applying starch grain and/or phytolith analysis on human and animal dental calculus may provide more insights on this issue.

6.7 Foodways at Jiahu: chronological trends

The previous sections of this chapter have discussed various culinary practices at Jiahu, from food procurement to processing and storing, from cooking to consuming and discarding. Since Phase I, the inhabitants of Jiahu started using arrowheads and fishing darts for hunting and fishing, grinding tools for cereal processing, specific types of jars were used for beverage production, pits for storage, and hearths for cooking. These tools, vessels, and facilities were used from Phase I throughout Phase II until Phase III, reflecting continuities of the Jiahu foodways throughout the site's occupation. It implies that foodways were not always changing, but sometimes passed down from one generation to the next.

Apart from same traditions in the Jiahu foodways, changes were also notable over different time periods. Studies have refined the climactic sequence from around 8500 to 3000 BP in China (Shi et al. 1992). In Phase I, the climate at Jiahu was transforming from dry cold to warm and wet. It has been calculated that the population in Phase I was around 50-70 people based on the formula P= A× $\mathbf{Sum/T}$ (Zhang, 2015). Sum refers to the total number of the interred in the cemetery in each Phase, A is the average life span of the decedents, T stands for the duration of the cemetery in each phase which is around 500 years. The formula assumes that the population was relatively stable in each phase overall, which might not be the real scenario. Nevertheless, the result can still be used to imply the increase and decline of population size in different phases. In Phase I, the settlement layout was also simple with a few houses and burials distributed in the same area (Zhang, 2015). In this period, the Jiahu inhabitants started agriculture practices on a small scale as suggested by the scarcity of recovered agricultural tools, with the ratio of agricultural tools to tools associated with hunting and fishing being 1.85% (Fig. 6.5).

Phase II was the warmest and most humid period, with the average temperature estimated as 1.4 to 1.7 °C higher than today. More arrowheads and fishing darts were used for hunting and fishing in this period than the previous (Fig. 6.5). The number of agricultural tools also dramatically increased. In addition, several new types of tools were adopted during Phase II, indicating new developments in culinary practices. For example, denticulate sickles were used for harvesting and fishnet weights were a new tool. Food obtained from domesticated and wild resources was probably enough to meet the requirement of the Jiahu population, which increased to around 160-190 people in Phase II (Zhang, 2015). The settlement in this period also demonstrates more planning, with the living and burial areas separated (Zhang and Cui, 2013).

In Phase III, the climate was warm as well and the population stayed approximately the same (Zhang, 2015). Compared to Phase II, the quantity of shovels and sickles both increased (Fig. 6.5). In addition, a new type of agricultural tool, i.e., *gusi*, appeared in Phase III, even though the number of *gusi* was low (n=1). Differently, the quantity of arrowheads and fishing darts declined. The ratio of agricultural tools to tools associated with hunting and fishing to was 133.3% (Fig. 6.5). These changes are also reflected in the decreasing number of wild deer and the increasing number of domesticated pigs (Table 6.2). It is possible that rice agriculture and animal husbandry played more important roles in the subsistence strategies in Phase III, so the Jiahu inhabitants relied less on wild food resources. This proposition correlates with the aquaculture demonstrated at Jiahu, which was first practised in phase III. According to radiocarbon dating and stratigraphic data, it has been proposed that the inhabitants had to abandon the site because of a flood around 5400 BC (Zhang and Cui, 2013). Clearly, during different Phases of site occupation, an interaction was occurring among climatic fluctuations, population growth, and settlement developments, as well as the foodways of the Jiahu people, especially in terms of food procurement.

6.8 Conclusion

With the data related to different food activities, we can picture more clearly the daily lives of the past populations at Jiahu and the region they inhabited. These people started cultivating pigs and rice, with wild plants and animals remaining significant parts of their food resources. After obtaining these foods, various methods and tools were adopted for processing, in which grinding tools played a major role in cereal processing. Foodstuffs were kept in storage pits and/or pottery vessels. Cooking at Jiahu was carried out both inside and outside of houses, and different types of cooking vessels were used in every occupation phase. Evidence of food consumption was found inside the households, where the leftovers such as fish bones were discarded nearby hearths inside of a house during Phase I. This chapter also highlights the variations of foodways at Jiahu, alongside developments of the population, settlement, and tools. However, some aspects of the Jiahu foodways remain unclear, such as methods used to process animals for food. Overall, by combining the research on grinding tools and the information related to other parts of foodways, this chapter provides an effective way to reveal elements of the past society's lifeways.

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