Foodways in early farming societies: microwear and starch grain analysis on experimental and archaeological grinding tools from Central China
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Chapter 7 Conclusion

As discussed in Chapter 1, investigating foodways can offer information regarding different aspects of past human societies. From the perspective of foodways, this dissertation aims to reveal the daily life elements of people in the early farming societies in the upper catchment of Huai River (UCHR). This goal has been achieved in two steps.

In the first step, this dissertation focuses on the grinding tools that have been frequently unearthed at the Neolithic sites in the region of UCHR. Before delving into the detailed study of the archaeological grinding tools, experiments were designed and carried out to collect the fundamental data for more accurate interpretations of use-wear traces as well as residues that might have been left during the use of the tool surfaces (see Chapter 2, 3, and 4). Then, the archaeological grinding tools unearthed from the site of Jiahu and Tanghu were subjected to analysis. These two sites are attributed to the Jiahu and Peiligang Culture (see Chapter 2, 3, 4, and 5), which represent the earliest Neolithic cultures in the research region. The studies of experimental and archaeological grinding tools have addressed four specific research issues that have been proposed in Chapter 1, which enrich our understanding of a crucial aspect of foodways: food processing.

In the second step, the findings on the grinding tools were combined with other related data from previous studies to present how the past populations carried out different food-related activities, including food procurement, processing, storing, cooking, serving, consumption, and discarding (see Chapter 6). Chapter 6 also highlights the variations of foodways at the site of Jiahu, alongside population growth, settlement development, and different categories of tools. Different sets of results have been discussed in each chapter and the data were integrated in Chapter 6. The following sections highlight key findings and their implications, followed by an explanation of analysis limitations and suggested future directions.

7.1 Correlation between tool type and function

Neolithic grinding tools in China have often been employed to discuss past subsistence strategies, i.e., agricultural or a broad-spectrum subsistence economy (Chen 1990; Song 1997; Bellwood 2005; Higham 2005; Liu et al. 2010c; Zhang 2011; Dong et al. 2014). Notably, the grinding implements unearthed from the Neolithic sites in the region of UCHR are characterized by various shapes, suggesting that different technological choices were made by their manufacturers during tool production. Chapter 2 answers the question: why these grinding tools were made into various shapes? Different from previous studies that were primarily based on one method, i.e. starch grain analysis (Zhang 2015; Yang et al. 2015b), In Chapter

2, results from microwear and starch grain analysis were integrated to help interpret possible functions of Neolithic grinding tools from the site of Jiahu. Microwear analysis indicates that 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. Quantitative analysis of the starch data also indicates that grinding slabs without feet preserved more starch grains than the slabs with feet. The results from microwear and starch grain analysis are consistent, suggesting that specific types of grinding tools were used for processing specific kinds of plants. The correlation inferred from this study helps to understand the prehistoric technological choices in tool production. In other words, the past population probably designed different shapes of grinding tools for different use purposes. Thus, different types of grinding tools cannot be used as a whole assemblage to suggest past human practices. Instead, these objects should be classified according to their morphologies first, and then studied in a more detailed manner.

In Chapter 2, the finding of use-wear traces associated with wood-like material also suggests that the Jiahu grinding tools were not only involved in food processing. This proposition has been further attested in another case study at the site of Tanghu in the same region (Li et al. 2020, cf. Chapter 5), where there is limited evidence that grinding tools were involved in modifying bone. Nevertheless, these different uses of the grinding tools were absent in previous studies carried out in the same region (Liu et al., 2010; Yang et al., 2015; Zhang, 2011). Chapter 1 discussed how research solely relying on starch grain analysis could easily neglect used materials that do not produce starch grains. Meanwhile, microwear analysis has to overcome difficulties in determining a multi-functional object, as secondary use can remove or obscure microwear traces previously formed on a tool's surface (see also more discussions by Van Gijn 2014). Additionally, complete grinding tools allow analysts to take more microwear samples from different areas, which is important to provide a more thorough interpretation of a grinding tool's function. However, such complete objects are not always encountered in archaeological excavations. Furthermore, although PVS material can take good impressions of use-wear traces from a tool's surfaces, this method may still lose some information depending on how the sampling was done. For instance, issues such as the numbers of the casts taken in relation to the size of the tool and the number of the use faces should all be considered. Because of these reasons, the different uses of grinding tools are very likely underrepresented in the archaeological record, a suggestion that has also been put forward by Hamon (2009a). To overcome these obstacles, a combined approach of microwear and starch grain analysis have been proven to be more useful in Chapter 2 and 5.

7.2 Choices of food processing techniques in the past

Studies investigating different food processing techniques have shed light on the dietary habits and subsistence strategies adopted by ancient people (Wright 2004; Wollstonecroft 2011). Grinding is one of the basic forms of food processing, with different grinding methods, e.g. dry- or wet-grinding being applied to process different dietary plants. While many studies have focused on what type of material was processed on grinding tools, the grinding techniques employed during food processing have received less attention.

Drawing upon the results presented in Chapter 2 (e.g. the use of the Jiahu grinding slabs without feet primarily for processing cereals), Chapter 3 moves forward to investigate: What kind of grinding technique was adopted to process cereals? Systematic grinding experiments were first carried out to document microwear traces resulting from the dry- and wet-grinding cereals, which turns out to leave distinctive traces. Through this reference baseline it is feasible to infer ancient grinding techniques and it has been applied to the grinding tools from the site of Jiahu. The results reveal that dry-grinding was employed for cereal processing at Jiahu. The same grinding technique was also adopted at the site of Tanghu (Li et al. 2020. cf. Chapter 5). These results suggest that the people from these sites preferred the dry-grinding technique more than wet-grinding.

It is still inconclusive why grinding was adopted in human history for food processing. Hastorf (2017) has proposed several reasons of why grinding was preferred over other ways of food processing and cooking, which could be related to 'not enough fuel' and 'different local traditions'. In the research region of UCHR, the culinary practice of dry-grinding could have been inherited from their ancestors because grinding plants was used by earlier hunter-gatherers in this area (Yang et al. 2016). Another possible reason for choosing a dry-grinding technique could be related to the broad-spectrum subsistence strategy adopted at Jiahu and Tanghu. Compared to wet flour, which is a product that quickly spoils, dry flour is suitable for longer-term preservation. Dry flour is also suited to the preparation of a diverse array of portable foodstuffs, which would have allowed the population to have greater mobility and autonomy. Thus, the dry-grinding technique very likely was a practical choice of early farming societies, when agriculture was practised but hunting and gathering still played important roles (Liu and Chen, 2012, see also Chapter 6). Later, during the Yangshao Culture period (c. 5000-3000BC) in the same region, only a few grinding tools have been discovered (Zhang, 1999). Chapter 3 proposed one of the possible reasons to explain this phenomenon. In the Yangshao Culture period, one of the important social changes was that farming became the primary source of food supply (Liu and Chen 2012). For the Yangshao people, it can be imagined that dry flour probably was not as important because the more sedentary people were in less need of easily portable foods. Also, grinding is not essential for preparing and consuming cereals. Compared to boiling other food processing behaviours such as boiling, grinding is a time-consuming and labour-intensive work. Gradually, grinding and related culinary practices could have been replaced by boiling, which remains the most common method for cooking cereals in present-day China. In this sense, the choice of plant processing technique could be related to subsistence strategy, i.e., foraging or farming.

7.3 Rice processing in the early rice agricultural societies

China has three major regions that are currently considered as the earliest centres for rice domestication, which include the lower catchment of the Yangtze River (Jiang and Liu 2006; Liu et al. 2007a; Fuller and Qin 2009) , the middle catchment of the Yangtze River (Zhao 1998), and the region of UCHR (Zhang and Wang 1998). On the basis of macrobotanical and phytolith research, these regions all possess well-documented evidence for rice domestication during the early Neolithic period (Lu et al. 2002; Liu et al. 2007b; Zhao 2010; Wu et al. 2014). However, when applying starch grain analysis to the archaeological grinding tools from these regions, only a few starch grains from rice have been recovered and identified to date, leading to the suggestion that rice was not the primary ground cereal (Liu et al. 2010b; Yang et al. 2015a; Yao et al. 2016). Chapter 4 tested the following hypothesis: Were starch grains from rice underrepresented on grinding tools because of starch damage during grinding? First, four types of cereals were subjected to systematic dry- and wet-grinding experiments: rice (*Oryza sativa*), foxtail millet (*Setaria italica*), Job's tears (*Coix lacryma-jobi* L.), and barley (*Hordeum vulgare* L.). Then the ground starch samples were observed and their damage features were documented and compared. The results indicate that dry-grinding produces significant damage to starches to the point where they may be undetected in archaeological samples, while wet-grinding causes only slight morphological changes to the starch grains. Moreover, rice starch grains have more substantial alterations than the other plants from dry-grinding, possibly impeding their identification.

The sites of Jiahu and Tanghu are among the sites that possess evidence of rice agriculture but with few starch grains recovered from their grinding tools (Zhang 2015; Yang et al. 2015b). As has been argued in Chapter 3 and 5, the dry-grinding technique was adopted at both sites of Jiahu and Tanghu, and this could have consequently caused the relative scarcity of rice starch grains recovered from the grinding tools. Thus, previous interpretations of starch analyses need to be reconsidered because rice was possibly ground to a larger extent than we thought before. For example, in the Yangtze River basin in Eastern China, where rice cultivation and domestication also took place, starch grain analysis has also been carried out on the grinding tools from the sites of Xiaohuangshan (c. 7000-5000 BC) (Liu et al. 2010b; Yao et al. 2016) and Shanshan (Yang et al. 2015a). Similarly, few starch grains from rice were recovered from these grinding tools. If dry-grinding was employed at these sites, it might have adversely affected the preservation and potentially the recovery of ancient rice starch grains. These findings imply that starch grains from rice can be underrepresented in the archaeological record because of dry-grinding.

In future studies of Neolithic grinding tools, it is imperative to investigate different grinding techniques and consider the damage patterns of starch grains after processing, because these practices will lead us towards a more nuanced interpretation of how rice and other cereals were processed in the past.

7.4 Foodways in different Neolithic communities

As mentioned in Chapter 1, the sites attributed to the Jiahu Culture and the Peiligang Culture are in the same region, the UCHR. These two cultures share many similarities in their material remains (see Chapter 1). For instance, both cultures possess unpainted pottery assemblages that are characterized by various cooking, serving, and storage vessels. Their ground stone tools, including axes, adzes, sickles and grinding tools, also show similar morphological features. Unlike some of the Peiligang Culture sites that are in hilly areas, Jiahu is situated on a larger alluvial plain with thicker cultural deposits. Jiahu also possesses some unique material remains such as the domesticated rice and flutes. Considering these differences and similarities, Liu and Chen (2012, p144) classified the site of Jiahu to the Peiligang Culture but stands for a different type because it “may have had higher levels of sedentism and more complex social organization”. In contrast, other scholars argue that Jiahu represents a different culture altogether (Zhang 1989; Chen 2014, see also Chapter 1). The Chinese archaeologists who focus on the differences tend to think that the site Jiahu stands for different Culture, while those who focus on the similarities, attribute Jiahu to the Peiligang Culture albeit as a sub-type. The study of foodways provides valuable insights into a community and often reflect elements of group identities (Wing 1981; Lyons 2007; Ishak et al. 2013). The following sections explore the relationship between the Jiahu and other Peiligang Culture sites from the perspective of their foodways.

Most of the Peiligang Culture sites were excavated in the 1980s and the unearthed material remains have not been intensively studied. At present, it is therefore not possible to present a comprehensive study of Neolithic foodways in the entire region. Nevertheless, some differences and similarities among these Neolithic archaeological cultures can be briefly discussed here. In terms of tools used for food procurement, it is noticed that most of the artefacts unearthed from the Peiligang culture sites are associated with agriculture, while tools used for hunting and fishing are rare (Zhang 1989). Differently, tools used for agricultural and foraging practices were equally abundant at the site of Jiahu. In addition, millet agriculture was practised at most of the Peiligang Culture sites (Lee et al. 2007; Zhang 2011; Wang et al. 2017a), except for the site of Tanghu that is located on an alluvial plain, where both rice and millet were cultivated (Zhang et al. 2012). It has been argued that different local landscapes might have contributed to different agricultural practices (Wang et al. 2017a): sites located in hilly areas are more suitable for cultivating short-season crops such as millet, while some of the sites (e.g. Tanghu) on an alluvial plain are ideal to grow both rice and millet. The exception is the site of Jiahu, which is located to the South of the main Peiligang Culture settlements, with two rivers and a lake nearby. It is believed that the wetland environment of Jiahu was not suitable to cultivate millet, instead only rice was cultivated (Wang et al. 2017a). Even though different crops were cultivated at Jiahu compared to the majority of the Peiligang Culture sites, similar types of tools, including denticulate sickles and shovels, were adopted in both cultures for food procurement practices (Li 1979; Ren et al. 1984, cf. Chapter 6).

In regards to food processing at Peiligang Culture sites of Egou in a hilly area and Shigu on an alluvial plain, starch grain analysis indicates their grinding tools were primarily used to process acorns (Liu et al. 2010c). Whereas at the Peiligang culture site of Tanghu as well as the site of Jiahu, the sampled grinding tools were mainly employed for cereal processing with a dry-grinding technique (Li et al. 2019; Li et al. 2020b, cf. Chapter 3 and 5). Apart from dietary plant processing, some of the grinding tools from Jiahu and Tanghu were used for processing a wood-like material or bone. These different uses of grinding tools have not been documented in any other Peiligang Culture sites. Although the sites of Jiahu and Tanghu seem to share many similarities, distinctions between the sites of Jiahu and Tanghu have also been reported. For example, a few starch grains from acorns (n=6) were recovered from Tanghu grinding tools (Li, 2015), but none of them have been recovered from Jiahu grinding tools (Zhang, 2015). Additionally, starch grains from aquatic plants and legumes were only recovered from Jiahu grinding tools and not from Tanghu grinding tools (Li et. al. 2020b, cf. Chapter 5).

From a foodways perspective, it can be concluded that the site of Jiahu was like Peiligang Culture sites in several ways, which is especially noticeable in a comparison to the site of Tanghu that is also located on an alluvial plain. The distinctions among the site of Jiahu and most of the Peiligang Culture sites are mainly reflected in their different subsistence strategies in terms of cultivated crops (rice versus millet) and the materials grinding tools processed (cereals versus acorns). However, Tanghu was one of the few Peiligang Culture sites that cultivated both rice and millet (Zhang et al. 2012; Bestel et al. 2018). These variations could be related to different ecological landscapes and food resources at these sites. In addition, Jiahu was occupied a few hundred years earlier than the site of Tanghu and some of the other Peiligang Culture sites (cf. Chapter 1), which could be a contributing factor for different foodways. Overall, a comparison of foodways from

Jiahu and the Peiligang Culture sites suggests both similarities and differences between these two cultures, reflecting the intangible cultural boundaries and interactions among these Neolithic communities.

7.5 Limitations and future directions

Clearly, some issues need to be considered for future studies on grinding tools using use-wear and/or starch grain analysis. First, the use-wear analysis on grinding tools in this dissertation is primarily based on the experiments designed to study grinding tools made from sandstone. It has been acknowledged that the raw stone material of tools is a key factor that could affect the development of use-wear traces (e.g. Lerner et al. 2007; Delgado-Raack et al. 2009). Thus, the reference baseline may not be applicable to grinding tools made from different types of stone (e.g. granite). Moreover, each experimental tool in this study was used for processing one specific type of plant or material, and use-wear traces developed during the processing of multiple contact materials were not investigated. The latter aspect should also be explored as ethnographic accounts indicate that grinding tools can be used for processing multiple types of plants or materials. A series of further experiments focusing on processing different types of materials (e.g. wood-like material and dried lotus root) and their associated traces would improve our understanding of the types of materials processed and the nature of practices involved with grinding tools.

Second, in terms of starch grain analysis, this dissertation compared the starch damage patterns of cereals after dry- and wet-grinding in relation to Chinese archaeological sites. This research can be expanded to include the effect different processing techniques have on the modification and preservation of starch grains from other plants such as other seeds than rice as well as acorns or underground storage organs.

Third, by comparing the dimensions of complete grinding tools, it is possible to make inferences about the scale of flour production in the past (e.g. Tsoraki, in press). Yet, no complete grinding tools have been recovered from the site of Tanghu. The number of complete grinding tools from the site of Jiahu considered in this research, unfortunately, is too small to draw similar inferences. Further research on the complete grinding tools from Jiahu or other sites will provide further insights into the scale of flour production.

Fourth, it has been clarified in the introduction chapter that the current dissertation focuses on one crucial aspect of foodways: food processing. Thus, the research of the cooking experiments is only summarily explored and presented in Chapter 6. Nevertheless, these cooking experiments are closely associated with the issue regarding starch taphonomy, which also contributes to a better understanding of ancient ways of cooking. Due to time restriction, the analysis of cooked starch grains still needs to be further explored and the results will be presented in detail in the future.

Last but not least, archaeologists have combined the results from microwear and starch grain analysis on grinding tools with contextual analysis to address more research issues; such as, the location of grinding activities (Tsoraki 2007), feasting models (Wright 2014), and ritual practices (Tsoraki 2018), which all contribute to a better understanding of past foodways. Nevertheless, addressing these issues relies heavily on information regarding spatial distribution, completeness, and raw materials of grinding tools as well as other types of ground stone tools (Tsoraki 2007; Tsoraki 2008). However, in the case studies of Jiahu and Tanghu, the contexts of the grinding tools were not always documented in a detailed manner. For example, in the site report of the latest excavation at Jiahu, only one pair of the grinding tools was described in terms of their morphology (Yang et al. 2017). In addition, the completeness and raw material of each grinding tool was not specified or studied in most of the archaeological site reports in China, which include the sites of Tanghu and Jiahu (Kaifeng Cultural Relics Management Committee of Xinzhen 1978; Zhang 1999; Zhang et al. 2008; Xin et al. 2010; Zhang 2015). Because of these obstacles, contextualizing the results of the current study for discussing the aforementioned issues will be more feasible for future research.

In summary, this study adopts an integrated approach of use-wear and starch grain analysis to study the experimental and archaeological grinding tools. The results provide new insights into several archaeological issues, including the correlation between tool type and function, choices of food processing techniques, rice processing of early farming societies, and other culinary practices of different Neolithic communities. These strands of information all contribute to an enhanced understanding of one crucial aspect of ancient foodways: food processing. By integrating these new data with previous foodways' research, this dissertation revealed a more detailed view of early farmers' lifeways in the central plane of China.

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