**[SUPPLEMENTARY MATERIAL]**

**Early Holocene exploitation of taro and yam among southern East Asian hunter-gatherers**

Weiwei Wang1,\*[ORCID: 0000-0003-1158-7049], Zhen Li2,\*, Chunguang Zhao3 [ORCID: 0009-0003-4916-0486], Mike T. Carson4 [ORCID: 0000-0003-3755-9126], Hirofumi Matsumura5, [ORCID: 0000-0001-5453-7987], Chi Zhang6,7 & Hsiao-chun Hung1,\* [ORCID: 0000-0001-5794-3040]

1 Department of Archaeology and Natural History, Australian National University, Canberra, Australia

2 Guangxi Provincial Institute of Cultural Relics and Archaeology, Nanning, P.R. China

3 Department of History (Zhuhai), Sun Yat-sen University, Zhuhai, P.R. China

4 Micronesian Area Research Center, University of Guam, Mangilao, USA

5 School of Health Science, Sapporo Medical University, Japan

6 School of Archaeology and Museology, Peking University, Beijing, P.R. China

7 Center for the Study of Chinese Archaeology, Peking University, Beijing, P.R. China

\* Authors for correspondence ✉ hsiao-chun.hung@anu.edu.au & weiwei.wang@anu.edu.au &

nnlizhen@163.com

*Received: 3 April 2023; Revised: 4 October 2023; Accepted: 13 October 2023*

**1. Further details of extraction procedure**

The sediments and dust on each tool’s surface first were rinsed with distilled water and then cleaned in an ultrasonic bath with distilled water for five minutes to recover the residues. Next, the ultrasound mixtures were transferred into test tubes and processed to recover the micro plant remains, including starches and phytoliths, in the laboratory at the Department of Archaeology and Natural History, the Australian National University. The extraction process followed the methods used in previous studies (Yang *et al*. 2012; Ma *et al*. 2023). First, solutions of 6% H2O2 and 10% HCl were separately used to remove the organic matter and carbonate. Second, the starch grains were isolated with LST (lithium heteropolytungstate) heavy liquid with a density of 1.9 g/cm3. They were then mounted on a slide in a solution of 10% glycerin and 90% distilled water, and finally, the slide was sealed with clear nail varnish.

The extraction protocol of dental calculus is a modified version of previously published studies (Henry *et al*. 2008; Yang *et al*. 2022). First, calculus was extracted using a sterilised dental pick. Subsequently, the samples were treated with a 10% solution of HCl at room temperature for 24hrs to release the starch grains. After washing three times with distilled water, the starch grains were isolated with LST heavy liquid (density 1.9 g/cm3). The residue was then mounted on a slide in a solution of 10% glycerin and 90% distilled water, sealed with clear nail varnish, and examined under the microscope.

**2. Further details of identification**

Type Ia starch grains (n > 6) are occasionally captured under microscope when they show a compound morphology (Figure 6A’–B’) (Table S1). In addition, extensive small grains which highly resemble our modern reference of taro (*Colocasia esculenta*) were discovered on the muller tool of Liyupo (Figure 6A–B). A single starch grain of taro is commonly too tiny to identify under the microscope. However, the co-appearance of a large number of single as well as several compound grains were nearly identical with modern taro, thus improving the confidence to identify them as *C. esculenta*. Type Ib starch grains (n = 85) are spherical, bell-shaped, or polygonal in shape with most of them exhibiting multifaceted morphology (Figure 7A–A’). These types of starch grains are produced in many plants, especially commonly found in geophytes, although potentially they could be indistinguishable from one another if the total numbers are too small, whereas they could be distinguished when their sizes and morphological features are considered in combination. Through comparison with the modern references, they are most consistent with aroid plants, cf. konjac (*Amorphophallus konjac*)(Figure 7J–J’). Perhaps due to the preservation conditions, no raphides were found in our ancient samples.

Type II starch grains (n = 78) share the typical morphological features with those from tubers of *Dioscorea*. Sixty-five small polygonal granules (Type IIa) are comparable with lesser yam (*Dioscorea esculenta*) (Figure 7B–B’ & K–K’). The other thirteen starch grains (Type IIb) with triangular ovoid shapes and larger sizes (mean size 23.27±5.21μm) come from another species of genus *Dioscorea*, cf. purple yam (*Dioscorea alata*) (Figure 7C–C’ & L–L’).

Type III starch grains (n = 187) are characterised by polygonal shapes, centric hilum and straight cross arms, exhibiting the typical features with Paniceae. Forty-eight starch grains (Type IIIa) with small sizes and open concave hilum are with high probability from wild grasses, such as green foxtail (*Setaria viridis*) (Figure 7D–D’ & M–M’) (Table S2). One hundred and thirty-nine starch grains (Type IIIb) usually have near round shapes, larger sizes, flat surfaces and some exhibit lined or stellate fissures, resembling those from Job’s tears (*Coix lacryma-jobi*) (Figure 7E–F’ & N–O’) (Table S2). Unfortunately, the identification is not 100% confident.

Type IV starch grains (n = 52) are identified as belonging to the family Fagaceae. Type IVa (n = 29)starch grains are near-round with a centric hilum (Figure 7G–G’), displaying similar features with the *Castanopsis* sp. (Figure 7P–P’). Type IVb starch grains (n = 23) are generally droplet-shaped, exhibiting typical features of the *Quercus* sp. (Figure 7H–H’ & Q–Q’).

Type V starch grains(n = 6) are elongated ovoid with extremely eccentric hilum (Figure 7I–I’). They closely resemble starches found in the piths of Arenga palm (*Arenga* sp.) (Figure 7R–R’).

**References**

Henry, Amanda G. & Dolores R. Piperno. 2008. Using plant microfossils from dental calculus to recover human diet: a case study from Tell al-Raqā'i, Syria. *Journal of Archaeological Science* 35: 1943–50.http://doi.org/10.1016/j.jas.2007.12.005

Ma, Zhikun, Chi Zhang, Shu Liu, Perry Linda, Xiujia Huan, Yongchao Ma, Zhiwei Wan, Guangming Zhou & Xiaoyan Yang. 2023. Use-wear traces and plant micro-remain analysis reveal the function of perforated shell tools from the Xianrendong and Diaotonghuan sites in the middle reaches of the Yangtze River, China. *Journal of Archaeological Science: Reports* 48. http://doi.org/10.1016/j.jasrep.2023.103852

Yang, Jishuai*, et al.* 2022. Sustainable intensification of millet–pig agriculture in Neolithic North China. *Nat Sustain* 5: 780–86.http://doi.org/10.1038/s41893-022-00905-9

Yang, Xiaoyan, Jianping Zhang, Linda Perry, Zhikun Ma, Zhiwei Wan, Mingqi Li, Xianmin Diao & Houyuan Lu. 2012. From the modern to the archaeological: starch grains from millets and their wild relatives in China. *Journal of Archaeological Science* 39: 247–54. http://doi.org/10.1016/j.jas.2011.09.001

**Table S1. Identification of starch grains recovered from the studied sites.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Number** | **Field number** | **Tool type** | **I** | | **II** | | **III** | | **IV** | | **V** | **Unidentified** | | **Total** |
| **Ia** | **Ib** | **IIa** | **IIb** | **IIIa** | **IIIb** | **IVa** | **IVb** |
| **Huiyaotian** | | |  |  |  |  |  |  |  |  |  |  |  | | |
| 1 | 2006NSHT1009M20 | Grinding stone |  | 14 | 5 | 2 | 1 | 2 | 2 | 4 |  | 6 | | 36 |
| 2 | 2006NSHT1105③:03 | Grinding stone |  | 1 |  | 1 |  |  | 5 | 3 |  | 1 | | 11 |
| 3 | 2006NSHT1009④:03 | Grinding stone |  | 3 |  |  | 2 | 4 | 2 | 1 |  | 2 | | 14 |
| 4 | 2006NSHTM14 | Muller |  | 1 | 1 |  | 1 |  |  |  | 1 | 2 | | 6 |
| 5 | 2006NSHT1105③:10 | Shell knife |  | 1 |  |  | 1 | 7 |  | 1 |  | 6 | | 16 |
| 6 | 2006NSHT1105③:12 | Adze |  | 1 |  |  | 3 |  |  | 2 |  | 1 | | 7 |
| 7 | 2006NSHM20 | Dental calculus | 1 |  | 1 |  | 1 | 4 | 3 |  |  |  | | 10 |
| 8 | 2006NSHM29 | Dental calculus |  | 12 | 25 |  | 7 | 5 | 5 | 1 |  | 7 | | 62 |
| 9 | 2006NSHM35 | Dental calculus |  | 4 | 1 | 2 | 7 | 3 |  | 3 |  | 5 | | 25 |
| 10 | 2006NSHM45 | Dental calculus |  | 15 | 4 |  | 3 | 2 |  | 1 | 2 | 3 | | 30 |
| 11 | 2006NSHM54 | Dental calculus |  | 13 | 5 |  | 3 | 20 | 6 | 3 |  | 4 | | 54 |
| 12 | 2006NSHM56 | Dental calculus | 1 | 5 | 13 |  | 5 | 9 |  |  |  | 7 | | 40 |
| **Total** | | | 2 | 70 | 55 | 5 | 34 | 56 | 23 | 19 | 3 | 44 | 311 | | |
| **Liyupo** | | |  |  |  |  |  |  |  |  |  |  |  | | |
| 1 | 2008LDGLT11⑧:1 | Grinding stone |  |  |  |  | 2 | 8 | 4 | 1 |  | 2 | | 17 |
| 2 | 2008LDGLT8⑤:4 | Grinding stone |  |  |  | 1 | 3 | 20 | 5 |  | 1 |  | | 30 |
| 3 | 2008LDGLT11③:5 | Grinding stone | 3 |  |  |  | 1 | 24 | 3 | 1 |  | 3 | | 35 |
| 4 | 2008LDGLT11③:3 | Muller | numerous |  |  |  |  | 7 |  |  |  | 1 | | >8 |
| 5 | 2008LDGLT8⑥:2 | Axe | 1 |  |  | 3 | 1 | 4 | 2 |  |  | 5 | | 16 |
| 6 | 2008LDGLT8⑥:1 | Adze |  |  |  | 1 | 3 |  | 1 |  |  | 2 | | 7 |
| 7 | 2008LDGLM6 | Dental calculus |  |  | 3 | 1 | 1 | 7 |  |  |  | 2 | | 14 |
| 8 | 2008LDGLM12 | Dental calculus |  | 8 |  |  | 1 |  | 8 |  |  | 3 | | 20 |
| 9 | 2008LDGLM19 | Dental calculus |  | 1 | 1 |  |  | 4 | 1 |  |  | 2 | | 9 |
| 10 | 2008LDGLM22 | Dental calculus | 2 | 3 | 2 |  | 2 | 6 | 1 | 2 |  | 3 | | 21 |
| 11 | 2008LDGLM34 | Dental calculus |  | 3 | 4 | 1 |  | 3 |  |  | 2 | 2 | | 15 |
| **Total** | | | >6 | 15 | 10 | 7 | 14 | 83 | 25 | 4 | 3 | 25 | 192 | | |

**Table S2. Morphology of starch grains from the studied sites.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Subtype** | **Granule shape** | **Size range (μm)** | **Mean size (μm)** | **Granule form** | **Hilum** | **Fissures** | **Lamellae** | **Extinction cross** | **Identification** |
| Ia | Polygonal/round | <5 | <5 | Single, compound | Centric | Absent | Absent | Straight | *Colocasia esculenta* |
| Ib | Spherical/sub-round/ rounded polygonal | 5.89–21.39 | 11.49±2.65 | Single, semi-compound | Centric | Absent | Absent | Straight | cf. *Amorphophallus konjac* |
| IIa | Polygonal | 4.55–10.07 | 6.7±1.4 | Single, clustered | Highly eccentric | Absent | Absent | Bent arms | *Dioscorea esculenta* |
| IIb | Triangular/elliptical ovoid | 12.05–33.06 | 23.27±5.21 | Single | Highly eccentric | Absent | Absent | Bent arms | cf. *Dioscorea alata* |
| IIIa | Polygonal | 6.29–13.62 | 9.29±1.48 | Single, clustered | Centric | Open slot | Absent | Straight | cf. *Setaria viridis* |
| IIIb | Polygonal | 7.83–21 | 13.52±2.68 | Single, semi-compound | Centric | Lined, stellate | Absent | Straight | *Coix lacryma-jobi* |
| IVa | Spherical | 11.13–19.36 | 14.19-2.03 | Single, clustered | Centric | Absent | Absent | Straight | *Castanopsis* sp. |
| IVb | Irregular ovoid | 7.38–21.85 | 11.97±3.14 | Single | Slightly eccentric | Absent | Absent | Bent arms | *Quercus* sp. |
| V | Elongated ovoid | 11.27–26.27 | 16.18±4.85 | Single, semi-compound | Extremely eccentric | Absent | Absent | Bent arms | *Arenga* sp. |