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Editorial: Ancient starch remains and prehistoric human subsistence

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Editorial on the Research Topic
Ancient starch remains and prehistoric human subsistence

1 Introduction

In recent years, micro-botanical fossil residue research in archaeology and paleoanthropology has grown in popularity (Guan et al., 2014). Invoking evidence from plant microfossils, such as phytoliths and starch granules, in association with various archaeological or paleontological remains (e.g., Barber, 2020; Liu et al., 2019b; Nava et al., 2021; Prebble et al., 2019; Scott et al., 2021; *etc.*), researchers have successfully reconstructed both local and regional plant resource utilization patterns and identified a variety of economic plants that have been processed in a number of Pleistocene and Holocene contexts.

One of the most prevalent plant compounds in the world is starch. The starch granule is therefore considered as essential plant microfossil that has been closely related to humans from prehistoric times (Teaford and Ungar, 2000; Summerhayes et al., 2010; Ungar, 2017). As a form of energy storage, starch is deposited in granules in nearly all green plants and numerous plant tissues and organs, such as leaves, roots, shoots, fruits, grains, and stems (Preiss, 2004). It is composed of discrete granules whose size, shape, morphology, chemical content, and supramolecular structure are dependent on the botanical source (Bertolini, 2010). The generation of a starch granule begins at a place known as the hilum, where successive layers of lamellae are deposited. In several species, the hilum is surrounded by fissures of varying forms (Gott et al., 2006). These visible characteristics, which differ between plant taxa, serve as the foundation for studying ancient starch granules.

Over the past 2 decades, many case studies have examined ancient starch remnants to better understand human behavior and the evolution of the human diet. Researchers extract starch granules from teeth and artifacts found at archaeological sites to investigate ancient carbohydrate diets (e.g., Hardy et al., 2016; Lu et al., 2005; Perry et al., 2007; Piperno et al., 2004; Scott et al., 2021; etc.). However, the process of starch granule analysis can be complicated due to issues like decomposition, preservation, and damage (e.g., García-

Granero, 2020; Haslam, 2004; Henry et al., 2016; Hutschenreuther et al., 2017; Li et al., 2020; Ma et al., 2019; etc.). Identifying the botanical origin of unidentified starch granules is a crucial step, and researchers have built a database of contemporary starch to aid in these identifications (Yang and Perry, 2013; Liu et al., 2014; Arráiz et al., 2016; Mercader et al., 2018a; Liu et al., 2019a; Wan et al., 2020). Starch analysis in archaeology has been challenging due to difficulties in botanical identification. Geometric morphometric analyses of starch granules may yield false positives when the reference Research Topic are small, decreasing the likelihood of identifying starch granules to the species level. (Arráiz et al., 2016; Mercader et al., 2018b). Contamination is also a concern, and it is critical to document contamination in ancient starch laboratories to develop more reliable methods for future research (Crowther et al., 2014).

The Research Topic *Ancient Starch Remains and Prehistoric Human Subsistence* includes 18 original research pieces on advanced techniques, regional studies, and alcoholic beverage consumption, as well as laboratory control and modern starch Research Topic. These works provide updated information and unique viewpoints, enhancing the field's knowledge and serving as a valuable resource for future studies.

2 Prehistoric starch remains, early agriculture, and foodway

After a long era of hunting and gathering, humans developed agriculture, which was a crucial turning point in the history of civilization. The study of the earliest agricultural practices and food production has been extensively researched by scholars as early as one hundred years ago (Candolle, 2011). Starch analysis, although only developed during the recent 20 years, is a key tool for understanding regional patterns of plant domestication and crop origins and spread worldwide. Case studies related to early agricultural practice have been presented in this issue.

Zhang et al.' s study of the Dingsishan Site in the Lingnan region of South China reveals that, during the earliest phase of the Holocene, ancient populations practiced a foraging-based subsistence, with wild plant foods comprising the majority. Huan et al. works also show the selection of plant food resources in South China during 7.3–6.8 ka B.P. In the study by Deng et al., the emergence of agriculture on a south China coast site was dated to 4,800–4,800 cal. BP, with the cultivation of rice and foxtail millet, sheds light on the study of agriculture's Southward dispersal and supports the universality of mixed farming in Southern coastal China.

In China, the lack of archaeobotanical investigations in the Yiluo River Basin hinders our knowledge of the interaction between agriculture and society in China. The study by Yang et al. indicates that millet was the most important crop in the late Yangshao Culture, followed by rice, which became more significant in the following Longshan Culture. During the Qijia period (4,400–3,100 B.P.), the introduction of dry agriculture and globalization of food affected the prehistoric human diet in Northwest China. The study by Ma et al. contributes to our understanding of the subsistence of the Qijia Culture and prehistoric food globalization, which is essential for appreciating East-West Asian connections during the Neolithic and Bronze periods.

Understanding when and how agriculture altered landscapes are essential for the study of human survival strategies and biodiversity. Zhang et al. discovered evidence that farmed rice existed on the Chengdu Plain 7,500 years ago, and that more advanced rice farming became the main survival strategy around 4,200 years ago, having a substantial impact on the local flora. Even in the more densely populated Yellow River watershed, deforestation and the consumption of cereal crops may have happened after 6,000 cal a BP, as suggested by He et al. and Li et al. in this issue.

The study by Wang et al. in the Cai Beo site in Ha Long Bay, northeastern Vietnam's coastal region, uncovered evidence that hunter-gatherers utilized a range of plants, including taros, yams, and acorns, as early as 7,000–6,000 years before present. The study proves the significance of roots and tubers in the ancient subsistence economy of Southeast Asia and confirms one of the earliest known findings of rice in Mainland Southeast Asia between 4,500 and 4,000 years before present.

García-Granero et al. investigation suggests that animal lipids, particularly non-ruminant fats, were predominantly processed in ceramic containers. The investigations also uncovered indications of plant processing, including grains, pulses, and underground storage organs. Despite challenges in conserving and interpreting archaeological material, the study offers a thorough account of past foodways in the region.

The study by Salazar Garca et al. on the diet of Iberian Cardial Neolithic people at the Cova Bonica site reveals a terrestrial C3-based diet with indications of cereal consumption and other plant items. The study sheds light on the Neolithization process in Iberia and transcends the limitations of conventional archaeobotanical and archaeozoological techniques.

3 Early brewing and alcoholic beverages

Recent studies have uncovered evidence of alcohol production and consumption during northern China's Neolithic period, particularly in the Yangshao Culture (ca. 7,000–5,000 cal. BP). Pottery samples from the Yangshao Culture site of Qingtai were analyzed by Liao et al. revealing a mixed filtered alcoholic beverage fermented with fruit and/or honey, and a shift from communal to individual drinking habits in the late Yangshao Culture. In China's Bronze Age, bronze ritual vessels like *gui*, *he* pitchers, and *jue* cups were symbols of high social status and were likely used in ritual feasts. He Y. et al., 2022 study found evidence of fermented beverages made with *qu* starter, emphasizing social status and coinciding with increased social differentiation during early state formation.

4 Functions of neolithic artifacts

Before 4,000 years ago, grooved clay vessels spread to central China from the Yangtze River, where they originated 6,000 years ago. The study by Wang et al. discovered evidence that these vessels were used to grind geophytes and dehull grain seeds, although the function of these vessels remains unknown. Similarly, Liu et al. on *li* tripods from Northeast China revealed that they were used for cooking and that the starch granules discovered on them belonged to millets, Triticeae, and tubers. The phytoliths found from the tripods suggested that these plants were utilized in the Chifeng region during the Bronze Age. These studies provide vital information about ancient Chinese people's diets and plant resource management.

5 Research method exploitation

In this Research Topic, Li et al. examined data to determine the possible significance of starch-rich woody plants as food sources in ancient South subtropical China. This work offers information on the role of non-tuberous woody plants as sources of carbohydrates for prehistoric societies in this region. Louderback et al. established diagnostic characteristics for recognizing the starch granules of major North American plant families and developed a dichotomous identification key. This has worldwide significance, as these families have had nutritional significance since prehistory. To investigate starch retention in dental calculus, the experimental model of Bartholdy and Henry introduced biofilms to known amounts of dietary starches. The study indicated that dental calculus provides a limited and skewed view of the original dietary consumption of starches, but the model is effective for verifying methodologies and biases in dental calculus studies pertaining to nutrition.

6 Further perspectives

In recent years, the study of ancient starch has made great progress due to the introduction of new technology and analytical techniques. As the field continues to evolve, several opportunities exist for further research and development. It has been determined that simple picture comparison cannot meet the requirements for accuracy and precision. Therefore, the geometric morphology approach has become a well-recognized, subjectivity-free method of discrimination (Coster and Field, 2015; Chen, 2017; Wan et al., 2020). Using machine learning algorithms such as *Artificial Neural Networks*, *Random Forests*, *Support Vector Machines*, and other prevalent techniques, the enormous geometric morphological data matrix can be evaluated and modeled with greater ease, resulting in more accurate identification of ancient starch granules. Zhang et al.'s work in this Research Topic applies the approach to archaeological case studies and demonstrates its validity for identifying ancient starch. Several experimental articles have been published, however they will not be covered here (e.g., Zhang et al., 2021b, etc.).

Future research on ancient starch analysis should broaden its focus to encompass various time periods and regions, with greater intercultural communication to investigate potential trading and exchange across early civilizations. Discoveries in this field could potentially uncover global patterns and trends in human subsistence and social development. Furthermore, ancient starch analysis has the potential to contribute to contemporary food security and sustainability issues, using old methodologies and expertise. In conclusion, expanding and developing ancient starch analysis may offer valuable insights into the lifestyles, cultural activities, and meals of past civilizations.

Author contributions

The three authors jointly organized and edited this Research Topic, making the publication of this Research Topic possible. The main author of the editorial is the first author YG, and the other two authors have put forward constructive comments and suggestions on it.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Arráiz, H., Barbarin, N., Pasturel, M., Beaufort, L., Domínguez-Rodrigo, M., and Barboni, D. (2016). Starch granules identification and automatic classification based on an extended set of morphometric and optical measurements. *J. Archaeol. Sci. Rep.* 7, 169–179. doi:10.1016/j.jasrep.2016.03.039

Barber, I. G. (2020). Further wet-taro evidence from Polynesia's southernmost Neolithic production margins. *Proc. Natl. Acad. Sci.* 117 (3), 1257–1258. doi:10.1073/pnas.1918374117

Bertolini, A. C. (2010). Trends in starch applications. In *Starches: Characterization, properties, and applications*. A. C. Bertolini, 1–20. Boca Raton, London, New York: CRA Press.

Candolle, A. D. (2011). *The origin of cultivated plants*. Cambridge: Cambridge University Press.

Chen, X. (2017). *Application of geometric morphometry to aquatic organisms*. Beijing: Science Press.

Coster, A. C. F., and Field, J. H. (2015). What starch grain is that? – a geometric morphometric approach to determining plant species origin. *J. Archaeol. Sci.* 58, 9–25. doi:10.1016/j.jas.2015.03.014

Crowther, A., Haslam, M., Oakden, N., Walde, D., and Mercader, J. (2014). Documenting contamination in ancient starch laboratories. *J. Archaeol. Sci.* 49, 90–104. doi:10.1016/j.jas.2014.04.023

García-Granero, J. J. (2020). Starch taphonomy, equifinality and the importance of context: Some notes on the identification of food processing through starch grain analysis. *J. Archaeol. Sci.* 124, 105267. doi:10.1016/j.jas.2020.105267

García-Granero, J. J., Suryanarayan, A., Cubas, M., Craig, O. E., Cárdenas, M., Ajithprasad, P., et al. (2022). Integrating lipid and starch grain analyses from pottery vessels to explore prehistoric foodways in northern Gujarat, India. *Front. Ecol. Evol.* 10. doi:10.3389/fevo.2022.840199

Gott, B., Barton, H., Samuel, D., and Torrence, R. (2006). "Biology of starch," in *Ancient starch research*. Editors R. Torrence and H. Barton (California: Left Coast Press Inc).

Guan, Y., Pearsall, D. M., Gao, X., Chen, F., Pei, S., and Zhou, Z. (2014). Plant use activities during the upper paleolithic in east eurasia: Evidence from the shuidonggou site, northwest China. *Quat. Int.* 347, 74–83. doi:10.1016/j.quaint.2014.04.007

Hardy, K., Radini, A., Buckley, S., Sarig, R., Copeland, L., Gopher, A., et al. (2016). Dental calculus reveals potential respiratory irritants and ingestion of essential plant-based nutrients at Lower Palaeolithic Qesem Cave Israel. *Quat. Int.* 398, 129–135. doi:10.1016/j.quaint.2015.04.033

Haslam, M. (2004). The decomposition of starch grains in soils: Implications for archaeological residue analyses. *J. Archaeol. Sci.* 31 (12), 1715–1734. doi:10.1016/j.jas.2004.05.006

He, Y., Zhao, H., Liu, L., and Xu, H. (2022b). Brewing and serving alcoholic beverages to erlitou elites of prehistoric China: Residue analysis of ceramic vessels. *Front. Ecol. Evol.* 10. doi:10.3389/fevo.2022.845065

Henry, A. G., Debono Spiteri, C., Büdel, T., Hutschenreuther, A., Schmidt, S., and Watzke, J. (2016). Methods to isolate and quantify damaged and gelatinized starch grains. *J. Archaeol. Sci. Rep.* 10, 142–146. doi:10.1016/j.jasrep.2016.09.003

Hutschenreuther, A., Watzke, J., Schmidt, S., Büdel, T., and Henry, A. G. (2017). Archaeological implications of the digestion of starches by soil bacteria: Interaction among starches leads to differential preservation. *J. Archaeol. Sci. Rep.* 15, 95–108. doi:10.1016/j.jasrep.2017.07.006

Li, W., Pagán-Jiménez, J. R., Tsoraki, C., Yao, L., and Van Gijn, A. (2020). Influence of grinding on the preservation of starch grains from rice. *Archaeometry* 62 (1), 157–171. doi:10.1111/arcm.12510

Liu, L., Duncan, N. A., Chen, X., and Cui, J. (2019a). Exploitation of job's tears in Paleolithic and Neolithic China: Methodological problems and solutions. *Quat. Int.* 529, 25–37. doi:10.1016/j.quaint.2018.11.019

Liu, L., Ma, S., and Cui, J. (2014). Identification of starch granules using a two-step identification method. *J. Archaeol. Sci.* 52, 421–427. doi:10.1016/j.jas.2014.09.008

Liu, L., Wang, J., Levin, M. J., Sinnott-Armstrong, N., Zhao, H., Zhao, Y., et al. (2019b). The origins of specialized pottery and diverse alcohol fermentation techniques in Early Neolithic China. *Proc. Natl. Acad. Sci.* 116 (26), 12767–12774. doi:10.1073/pnas.1902668116

Lu, H., Yang, X., Ye, M., Liu, K.-B., Xia, Z., Ren, X., et al. (2005). Millet noodles in late neolithic China. *Nature* 437 (7061), 967–968. doi:10.1038/437967a

Ma, Z., Perry, L., Li, Q., and Yang, X. (2019). Morphological changes in starch grains after dehusking and grinding with stone tools. *Sci. Rep.* 9 (1), 2355. doi:10.1038/s41598-019-38758-6

Mercader, J., Abtosway, M., Bird, R., Bundala, M., Clarke, S., Favreau, J., et al. (2018a). Morphometrics of starch granules from sub-saharan plants and the taxonomic identification of ancient starch. *Front. Earth Sci.* 6 (146). doi:10.3389/feart.2018.00146

Mercader, J., Akeju, T., Brown, M., Bundala, M., Collins, M. J., Copeland, L., et al. (2018b). Exaggerated expectations in ancient starch research and the need for new taphonomic and authenticity criteria. *FACETS* 3 (1), 777–798. doi:10.1139/facets-2017-0126

Nava, A., Fiorin, E., Zupancich, A., Carra, M., Ottoni, C., Di Carlo, G., et al. (2021). Multipronged dental analyses reveal dietary differences in last foragers and first farmers at Grotta Continenza, central Italy (15,500–7000 BP). *Sci. Rep.* 11, 4261. doi:10.1038/s41598-021-82401-2

Perry, L., Dickau, R., Zarrillo, S., Holst, I., Pearsall, D. M., Piperno, D. R., et al. (2007). Starch fossils and the domestication and dispersal of chili peppers (Capsicum spp. L.) in the Americas. *Science* 315 (5814), 986–988. doi:10.1126/science.1136914

Piperno, D. R., Weiss, E., Holst, I., and Nadel, D. (2004). Processing of wild cereal grains in the Upper Palaeolithic revealed by starch grain analysis. *Nature* 430, 670–673. doi:10.1038/nature02734

Prebble, M., Anderson, A. J., Augustinus, P., Emmitt, J., Fallon, S. J., Furey, L. L., et al. (2019). Early tropical crop production in marginal subtropical and temperate Polynesia. *Proc. Natl. Acad. Sci.* 116 (18), 8824–8833. doi:10.1073/pnas.1821732116

Preiss, J. (2004). "Plant starch synthesis," in *Starch in food: Structure, function and applications*. Editor A.-C. Eliasson (Boca, Raton, Boston, New York, washington DC: CRC Press).

Scott, A., Power, R. C., Altmann-Wendling, V., Artzy, M., Martin, M. A. S., Eisenmann, S., et al. (2021). Exotic foods reveal contact between South Asia and the Near East during the second millennium BCE. *Proc. Natl. Acad. Sci.* 118 (2), e2014956117. doi:10.1073/pnas.2014956117

Summerhayes, G. R., Leavesley, M., Fairbairn, A., Mandui, H., Field, J., Ford, A., et al. (2010). Human adaptation and plant use in highland new Guinea 49,000 to 44,000 Years ago. *Science* 330, 78–81. doi:10.1126/science.1193130

Teaford, M. F., and Ungar, P. S. (2000). Diet and the evolution of the earliest human ancestors. *Proc. Natl. Acad. Sci.* 97 (25), 13506–13511. doi:10.1073/pnas.260368897

Ungar, P. S. (2017). *Evolution's bite: A story of teeth, diet, and human origins*. New Jersey: Princeton University Press.

Wan, Z. W., Lin, S. P., Ju, M., Ling, C. H., Jia, Y. L., Jiang, M. X., et al. (2020). Morphotypological analysis of starch granules through discriminant method and application in plant Archaeological samples. *Appl. Ecol. Environ. Res.* 18, 4595–4608. doi:10.15666/aeer/1803_45954608

Yang, X., and Perry, L. (2013). Identification of ancient starch grains from the tribe Triticeae in the North China Plain. *J. Archaeol. Sci.* 40 (8), 3170–3177. doi:10.1016/j.jas.2013.04.004

Zhang, X., Zhu, X., Hu, Y., Zhou, Z., Olsen, J. W., and Guan, Y. (2021b). Ancient starch remains reveal the vegetal diet of the neolithic late dawenkou culture in jiangsu, east China. *Front. Ecol. Evol.* 9 (554). doi:10.3389/fevo.2021.722103