Archaeobotanical evidence reveals the origins of bread 14,400 years ago in northeastern Jordan

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The origins of bread have long been associated with the emergence of agriculture and cereal domestication during the Neolithic in southwest Asia. In this study we analyze a total of 24 charred food remains from Shubayqa 1, a Natufian hunter-gatherer site located in northeastern Jordan and dated to 14.6–11.6 ka cal BP. Our finds provide empirical data to demonstrate that the preparation and consumption of bread-like products predated the emergence of agriculture by at least 4,000 years. The interdisciplinary analyses indicate the use of some of the “founder crops” of southwest Asian agriculture (e.g., *Triticum boeoticum*, wild einkorn) and root foods (e.g., *Bolboschoenus glaucus*, club-rush tubers) to produce flat bread-like products. The available archaeobotanical evidence for the Natufian period indicates that cereal exploitation was not common during this time, and it is most likely that cereal-based meals like bread become staples only when agriculture was firmly established.

Bread is one of the most important foodstuffs consumed in the modern world. The simplest bread recipe contains a mixture of flour and water to produce dough or batter that maybe fermented before it is baked, fried or steamed. The outcome of this modest process is a rather versatile staple that is found today on many kitchen tables around the world. Despite its importance in modern cuisine, the origins of bread are still largely unknown. Early finds of bread in Neolithic sites in Europe and southwest Asia (1, 2) have inevitably related its invention to fully-fledged agricultural communities that exploited domesticated plant species [at least since circa (c.) 9.1 ka cal BP]. However, in southwest Asia (Near East), where the wild ancestors of domesticated crops such as wheat and barley occur naturally, hunter-gatherers of the Upper Paleolithic period (c. 23 ka cal BP) were already producing flour from wild grasses (3), and some authors claim that the invention of brewing, groats, porridge, and unleavened bread could have occurred as early as the late Epipaleolithic or Natufian period (14.6–11.7 ka cal BP) (3–6). However, direct evidence for cereal-based meals predating the emergence of agriculture has not been reported.

Shubayqa 1 is a hunter-gatherer site dated to the early and late Natufian from 14.6 to 11.6 ka cal BP located in northeast Jordan, in an area known as the Black Desert (7) (Fig. 1). The site was found and briefly dug by Allison Bets in the 1990s, and archaeologists from the University of Copenhagen, under the auspices of the Department of Antiquities of Jordan, have conducted four excavation seasons at the site from 2012 to 2015. Along with el-Wad Terrace, Shubayqa 1 represents one of the oldest Natufian sites so far discovered in southwest Asia (7). The site consists of two well-preserved superimposed buildings, the earlier one being Structure 1 (Fig. 2), which is a semisubterranean building with a carefully built flagstone pavement made of local basalt stones. This structure comprises exclusively Natufian deposits with a rich finds assemblage of chipped stones (7), ground stone tools (8), animal bones (9), and plant remains (10).

Archaeobotanical investigations at Shubayqa 1 have thus far focused on the contents of two fireplaces built in sequential phases at the center of Structure 1. The oldest fireplace is a large (approximately 1 m in diameter) circular structure made of flat basalt stones (Fig. 2). The contents of the fireplace were left intact after its last use and were subsequently buried beneath a thick deposit that covered the building (approximately 0.5 m). In the next occupation phase of the site, the inhabitants built a new fireplace above the previous one in almost the same location, very similar in size and shape, using angular basal boulders. The contents of this fireplace were also left in situ after abandonment. Seven radiocarbon dates of short-lived charred plant remains from within the fireplaces indicate their use around 14.4–14.2 ka cal BP, which corresponds with the early Natufian period (7).

Systematic sampling and analyses of the full content of the fireplaces revealed an extraordinary archaeobotanical assemblage, with more than 65,000 well-preserved nonwoody plant macroremains belonging to at least 95 taxa (10). From these, club-rush tubers (*Bolboschoenus glaucus*) were most common and comprised approximately 50,000 remains. Other plants preserved in the fireplaces included crucifers (* Cruciferae*), small-seeded legumes (*Trigonella/Astragalus*), and oat (*Avena sp*). In addition to these, the assemblage comprised at least 642 macroscopic (>2 mm) lumps of charred food remains. Charred food remains have rarely been recognized as a class of archaeobotanical material (i.e., artifact), and their analysis has not been systematic. However, food remains are

**Significance**

Despite being one of the most important foodstuffs consumed in the modern world, the origins of bread are still largely unknown. Here we report the earliest empirical evidence for the preparation of bread-like products by Natufian hunter-gatherers, 4,000 years before the emergence of the Neolithic agricultural way of life. The discovery of charred food remains has allowed for the reconstruction of the *chaîne opératoire* for the early production of bread-like products. Our results suggest the use of the wild ancestors of domesticated cereals (e.g., wild einkorn) and club-rush tubers to produce flat bread-like products. Cereal-based meals such as bread probably become staples when Neolithic farmers started to rely on the cultivation of domesticated cereal species for their subsistence.


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preserved in archaeological sites and provide empirical data on prehistoric plant-food selection, preparation, and consumption activities that would otherwise be very difficult to characterize. In this study we present the results of a total of 24 remains categorized as bread-like. The analyses carried out involved general description of the remains (i.e., size, texture, particles, and inclusions) using low-magnification microscopy, and their examination under scanning electronic microscopy (SEM) for the identification of plant particles (i.e., ingredients) and characterization of the matrix (number and types of voids) (2, 11–14). In addition to these, six specimens were subject to starch analyses (Materials and Methods and SI Appendix, Supplementary Information Text).

**The Identification of Prehistoric Bread**

The identification of “bread” or other cereal-based products in archaeology is not straightforward. There has been a tendency to use modern culinary terms to refer to ancient cereal-based products such as bread, often without the application of tested identification criteria and relying on the presence of cereal tissue and the overall shape of the remains to catalog them (11). The detailed tissue analysis of experimental cereal-based preparations has recently allowed for the establishment of new criteria to identify flat bread, dough, and porridge-like products in the archaeological record (2). After mixing flour and water, occluded gas cells of 0.01–0.1 mm develop in the dough. The molding of dough modifies the gas cell structures by making the small air bubbles burst, collide, and combine into big ones. If this dough is directly charred, it shows a hollow matrix with large closed voids (0.5–0.8 mm) covering more than 30% of the surface (2). The most dramatic change to the dough microstructure takes place during baking, when gas cells expand into an open network of pores or voids (15). If the dough has been cooked into flat bread and later charred, the matrix shows a low proportion of small (0.05–0.25 mm in size) micropores that cover 5–10% of the surface (ref. 2 and SI Appendix, Fig. S8).

At Shubayqa 1, a total of 24 food remains were categorized as bread-like products based on the estimation, quantification, measurement, and typological classification of plant particles and voids visible in the food matrix (Materials and Methods). From these, 22 were found in the oldest fireplace and 2 in the youngest. Macroscopically, all fragments showed a starchy, often vitrified, microstructure and irregular porous matrix, indicative of well-processed food components (Fig. 3 and SI Appendix, Figs. S1 and S8). The average size of the remains was between 4.4 mm width, 2.5 mm height, and 5.7 mm length (SI Appendix, Table S1). The basic classification system based on height measurements suggests that they probably represent unleavened flat bread-like products, as their height was <25 mm (13). This idea is supported by the size of the voids. In modern leavened breads, voids are >1 mm in size and commonly cover 40–70% of the matrix (14). The size of the voids of the bread-like remains from Shubayqa 1 was 0.15 mm on average and they were present in 16% of the matrix (SI Appendix, Table S2). These results are in agreement with finds identified as “flat breads” from several Neolithic and Roman age sites in Europe and Turkey (2, 11, 12).
The Plant Ingredients

In terms of the ingredients used in the food preparations from Shubayqa 1, the results indicate the presence of remains made of cereals and some others made of a mixture of cereals and non-cereal components. From the 24 fragments, 15 showed cereal tissue, primarily pericarp tissue (longitudinal and transverse cells or bran layers), endosperm cell structures (aleurone layers) (Fig. 3B and C and SI Appendix, Figs. S2–S4), and starch-containing cells (SI Appendix, Fig. S5). Fragments of longitudinal and transverse cells were the most common type of particles among the food remains (present in 11 of 24 remains) and measured from 50 to 2,000 μm in size, with an average size of 600 μm. In five of the remains, cereal grain cross-sections were identified. At least two specimens showed single-celled aleurone layers, typical of wheat species (Triticum), rye (Secale), millets (Panicum and Setaria), and oat (Avena), but the presence of double- or triple-layered aleurone found in grasses such as barley (Hordeum) cannot be completely excluded. In one of the remains analyzed for starch Avena-type was identified within the ingredients (SI Appendix, Table S3). The processing and consumption of large-seeded grasses in Shubayqa 1 is supported by the assemblage of plant macroremains found in association with the food remains. Approximately 46% of the grains of wild wheat and barley found in the fireplaces showed a bulging pattern on broken edges (10). This pattern is caused when the grains are ground before char-ring (16), and it is commonly linked to food production activities such as dehusking or bulgur/flour making (17). The evidence therefore suggests that several large-seeded grasses were most probably used in the food preparations from Shubayqa 1.

At least five of the bread-like remains showed the presence of noncereal components, including parenchyma cells, vascular tissue, and root-type starch (Fig. 3C and SI Appendix, Figs. S5–S7 and S10 and Tables S2 and S3). The vascular tissue preserved represents most likely club-rush tuber (B. glaucus), since more than 50,000 underground storage organs of this species were recovered in the two fireplaces (10). Ethnobotanical and experimental evidence indicates club-rush tubers are best consumed as gruel or flour to make bread, instead of boiling or steaming (18, 19). Pure club-rush tuber bread is brittle, crumbly, and flaky, but the addition of bread wheat (Triticum aestivum) flour (i.e.,...
gluten) allows for the production of elastic dough that can be pressed onto the walls of a tandir-type oven structure and be baked (18). Evidence for cereal and club-rush tuber preparations have been identified at late Neolithic sites in Turkey (2) and The Netherlands (20). The finds from Shubayqa 1 suggest a considerably earlier date for their dietary use.

The *Chaîne Opératoire* for the Production of Bread-Like Products in Shubayqa 1

The measured sizes of the cereal and noncereal components suggest that the texture of the foodstuffs was controlled by repeated milling, sieving, and/or careful winnowing of the remains. Experimental studies indicate that without sieving, large bran fragments of 5-mm length and above occur in cereal food products (21). The metrical analyses of the particles from Shubayqa 1 show sizes between 0.05 and 2 mm (*SI Appendix*, Table S2). A total of 41.18% of the particles range within the modern dust and flour category (i.e., <0.5 mm), 29.41% of the particles were classified as semolina (i.e., 0.3–1 mm in size), and the other 29.41% were particles >1 mm, or grit type. The overall number of measurable particles found in Shubayqa 1 is low, but the results indicate larger proportions of flour-type particles than bread-like remains at later Neolithic sites (e.g., ref. 11). Another difference is the absence of cereal chaff, whole grains, and other gritty matter, inclusions that tend to characterize later “stapel” breads (11, 12, 22). It is possible that the flour used to make the bread-like remains at Shubayqa 1 was meticulously ground and carefully sieved to obtain a consistency similar to modern flours. Indeed, one of the main landmarks of Natufian culture is the intensive use of grinding and pounding tools (23), and Shubayqa 1 has yielded the largest assemblage of ground stone tools from secure late Epipaleolithic contents in the southern Levant (8).

The prevalence of hand-stones and lower grinding implements at the site shows that grinding was a regularly practiced activity and suggests that the inhabitants were skilled in processing raw materials such as plants.

Starch analyses of the remains shows that five of the six remains analyzed had little or no starch, whereas one showed good preservation (*SI Appendix*, Figs. S9–S13 and Table S3). The absence of starch may be the combined result of grinding and pounding tools (23), and Shubayqa 1 has yielded the largest assemblage of ground stone tools from secure late Epipaleolithic contents in the southern Levant (8). The prevalence of hand-stones and lower grinding implements makes it possible to obtain a consistency similar to modern flours. Indeed, one of the main landmarks of Natufian culture is the intensive use of grinding and pounding tools (23), and Shubayqa 1 has yielded the largest assemblage of ground stone tools from secure late Epipaleolithic contents in the southern Levant (8).

The whole contents of the two fireplaces were retrieved and sampled for plant macroremains. The charred bread-like products were recovered by dry sieving the soil samples with a 2 × 2 mm metal mesh. The dry sieving of the samples was carried out previous to flotation to pick out plant remains such...
as tubers and charred food remains that could have been subject to disintegration when entering in contact with water (10).

During the general preparation of the microphotography and photography of the food fragments, were carried out using a stereobinocular microscope (Nikon binocular SMZ 1000) at magnification from 7× to 45× at the Universidad del Pais Vasco-Euskal Herririkro Unibertsitatea (UPV-EHU). A fraction of the food remains (a total of 49 remains) was chosen for further analysis and observation under SEM for the identification of their botanical composition and characterization of the matrix. SEM observations of the food remains were taken with a S-3400N scanning electron microscope housed at the Institute of Archaeology at University College London. For SEM observation, samples were cleaned from soil sediments with a brush to remove adhering soil or sediment, sputter coated with approximately 1 μm of gold. During the microscopic analyses, two main aspects were investigated: the identification of specific types of plant tissue contained in the remains and the examination of their microstructure, which are the outcome of the processing and cooking methods used for their preparation. From the 49 remains, a total of 24 showed clear characteristics of bread in terms of plant composition and type of matrix.

For the identification of the botanical composition of the food remains, this study is based on the tissue identification criteria developed by several authors (2, 11, 12, 43–46). The main edible plant tissues were considered and tested such as: layers present in the cereal kernels (pericarp and seed coat); chaff (epidermis of pales and lemmas); other parenchyma tissues (pulses and tubers); vascular tissues (underground storage organs); and starch granules, which although not easily preserved in charred material, can provide vital information about food processing and preparation techniques (17, 22, 24).

Due to the low overall number of plant particles identified in the food preparations, a total of six bread-like remains were subject to starch analyses. For the preparation of a small sample, a small subsample taken from the microphotograph and preparation of the food remains document early formative maize (Z. mays L.) in tropical Ecuador. 2713.

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