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The contribution of starch grain and phytolith analyses in reconstructing ancient diets*

Abstract

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Starch grains and phytoliths are often found trapped in dental calculus or on the surface of lithic grinding tools. In the last decades, their analysis provided new information about the dietary habits of ancient populations, a topic that has recently become the object of numerous researches by archaeobotanists, archaeozoologists and anthropologists. The study of these micro-remains not only indicates which plants were used for feeding purposes but may also highlight our ancestors' ability to manipulate food.

Key words: starch grains, food plants, grinding tools, dental calculus.

Introduction

Numerous papers are currently devoted to the study of ancient diets, which can provide useful information for an understanding of the economic development of ancient cultures – specific technologies for the production and use of food crops, commerce, food manipulation etc. – and also the physiological adaptation processes of the human organism to the chemical components of food. Moreover, the study of the ancient human nutrition might shed new light on the essentials of the human diet and possibly contribute to the prevention of modern chronic degenerative diseases (Eaton 2006). Regarding the exploitation of food plants, direct information comes from the findings of seeds and fruits during archaeological excavations, especially in hearths and deposits; but these findings become more and more scarce as we regress in time. Therefore, archaeobotanists started to pay attention to micro-remains which could be found on the surface of ancient tools used for processing plant materials or were trapped in dental calculus: principally starch grains and phytoliths.

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These residues are not the most legible evidence to be interpreted among plant remains although they are, sometimes, the only available finds. Furthermore, when they are found on grinding tools or in dental calculus, they can offer accurate information. Indeed, through their analysis, it is possible not only establish which plants were used for feeding purposes but also deduce cultural information on food preparation, with very important implications when we think that we have very scarce knowledge of dietary habits in the Paleolithic period.

Plant remains on tool surfaces

In the Mediterranean area, the first important results in this type of research are those related to studies on the epi-Paleolithic site of Ohalo in Israel (Piperno & al. 2004; Nadel & al. 2012). These findings demonstrated that wild cereals, mainly *Hordeum* and *Avena*, were not only collected but also ground to make flour, a product which is easy to preserve but that requires a specific preparation before consumption. Thus, the discovery has highlighted the local population's ability to manipulate food.

Regarding Europe, the first study on grinding tools was performed on artefacts found in Mugello, Italy (Fig. 1), in an area now submerged by the waters of the Bilancino reservoir (Aranguren & al. 2007; Revedin & al. 2010). The site was a seasonal camp dating to the

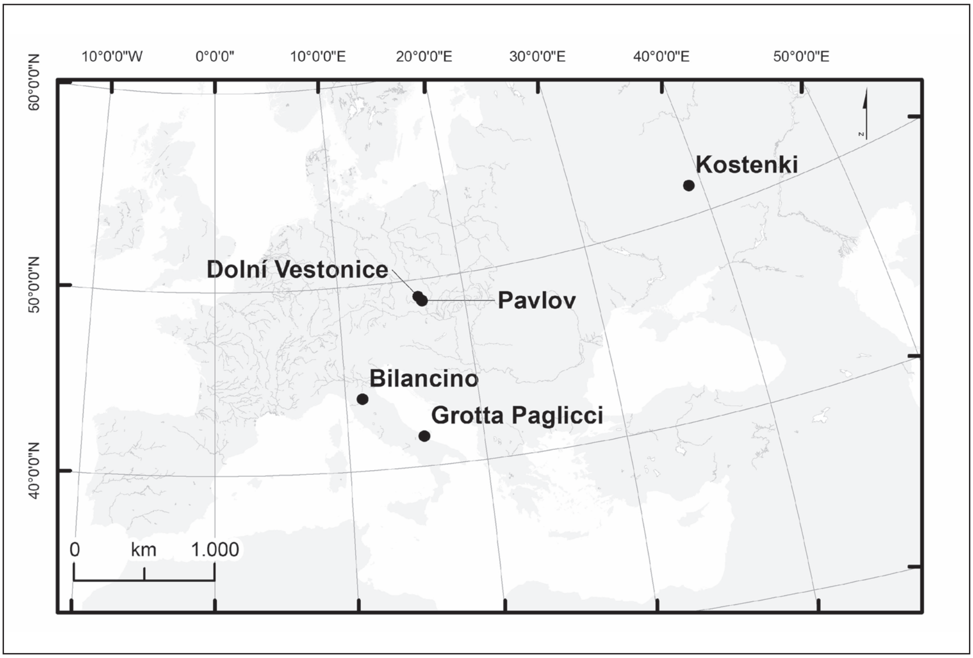

Fig. 1. Palaeolithic sites where starch analysis on grinding tools revealed plant processing, indicating that the production of flour has been a widespread practice across Europe for at least 30,000 years.

Gravettian, in the middle-upper Paleolithic, a period characterized by a colder climate than the present one. The site is located in an open area characterized by numerous wetland plants (Mariotti Lippi & Mori Secci 2002). The analysis of these tools revealed traces of use compatible with grinding. By washing their surfaces, it was possible to recover starch grains, which allowed us to establish that they were tools used for the grinding of plant materials. In particular, a portion of the starch grains had a morphology very similar to those of the caryopses of wild grasses and the rhizome of *Typha*, a part of the plant that can easily be ground once dry. Other grains have a morphology which did not allow their attribution to a specific plant.

Similar analyses were also carried out on grinding tools coming from other famous Paleolithic sites, such as Kostenki in Russia and Pavlov and Dolni Vestonice in the Czech Republic (Fig. 1). Plant micro-remains - and especially starch grains – were found on these artefacts as well (Revedin & al. 2010).

The mere finding of starch grains is important evidence in itself, as it places these tools in a different context from that of the tools used to grind minerals for dyes. But the identification of the plant remains is also of great interest.

The attribution of the starch grains to a specific plant is fairly difficult for two main reasons. First, the number of detectable features on the grains is quite limited: we can analyse size, presence and shape of the hilum, shape and position of the cross formed under polarized light, and very little else. Second, there is scarce reference material, as the existing atlases are mainly dedicated to the flours in use nowadays. Moreover, the same plant may produce starch grains which differ in shape and/or dimension (see for example Fig. 2), and only some of those are identifiable.

The identification requires the examination of the morphology of the starch grains of many plants. For this purpose, the knowledge of the flora present around the archaeological site at the time of its occupation is very useful to reduce the number of plants to be considered. A great indication of the past environment comes from other archaeobotanical analyses, mainly pollen analysis.

Another important information which may be deduced from the analysis of the starch grains on tool surfaces involves the treatment of the food plant material before processing. The study carried out on a pestle-grinder from Paglicci in Apulia, Italy (Mariotti Lippi & al. 2015, Fig.1), revealed that the starch grains had been treated thermally in the absence of water (perhaps toasted) before grinding, as attested by their swelling in water/glycerin solution (Fig. 3).

Grinding is generally done for material that has been previously dried, but here the behavior of the grains attests to a proper thermal treatment, probably used to accelerate the drying in a time of colder climate than the present. The Grotta Paglicci has a very long history of human occupation from about 39,000 years ago to the middle of the nineteenth century. The pestle-grinder comes from the Gravettian levels, dated to 32,000 years BP. The grains found on the tool were attributed to caryopses and acorns. In particular, the grinding of the caryopses is attested both by the scarce phytoliths and the numerous starch grains. Many of them have been attributed to *Avena*, very likely *Avena barbata*. The starch grains on the tool of the Grotta Paglicci are currently the oldest documentation of the grinding of cereals in the world and of the use of cereals in Europe.

Concerning phytoliths, they are more rarely recorded in noticeable amount than the starch grains on the surface of the grinding tools. Liu & al. (2013) suggested that the

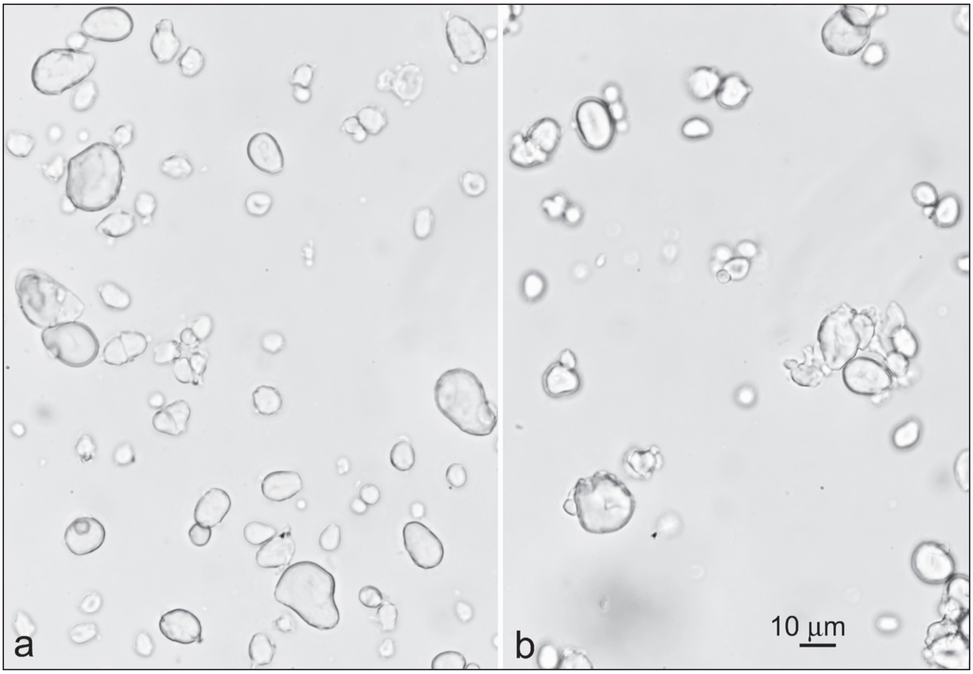

Fig. 2. Starch grains obtained by grinding the acorns of *Quercus ilex* (a) and *Q. pubescens* (b). Note the remarkable variety of morphotypes.

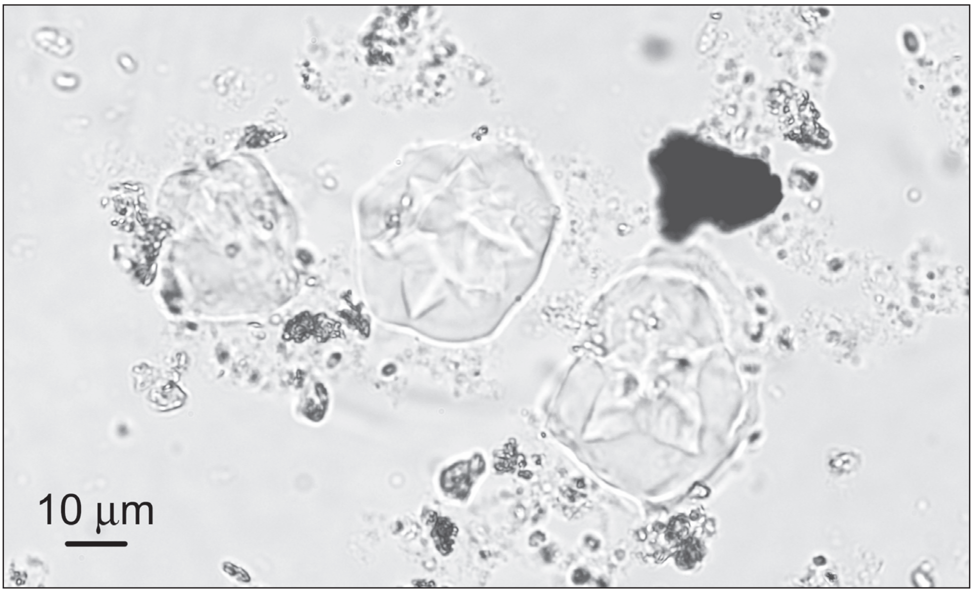

Fig. 3. Gelatinized and swollen starch grains from the Paglicci grinding stone.

scarcity of phytoliths may be due to the grinding of plant portions which do not produce large amounts of silicified bodies, such as cereal caryopses after dehusking.

The study of grinding tools provides further information inferred from the size distribution of the plant remains on the surface of the grinders, since different parts of the tool may collect remains of different sizes. Together with traces of use, the distribution of the remains suggests the usage motions of the grinder and, consequently, may also provide valuable information for studies on the human anatomy. Indeed, asymmetrical developments of the arms are detectable in females from the Mesolithic to the Iron Age and may be the direct consequence of the change in the grinding methods (Sladek & al. 2016).

Finally, we must emphasize the cultural relevance of the grinding process (Revedin & al. 2015), which provided humans with an edible product which was not only easy to preserve but also easy to transport, a characteristic of primary importance for nomadic populations of hunters and gatherers.

Plant remains in dental calculus

While we always find a larger quantity of starch grains than phytoliths on grinding tools, when we analyze dental calculus the quantities of both can vary a great deal. Tartar incorporates minute particles and fragments of whatever is present and whatever is introduced in the oral cavity. This is due to its chemical nature and process of formation (Warinner & al. 2015) that make the calculus act as a trap for various debris and become a veritable archive of information on the lifestyle, health state, hygiene, activities, and dietary habits of the ancient populations. Obviously, the kind of the information obtained depends on the nature of the residues found on the calculus (Radini & al. 2017).

Over the past two decades, dental calculus has become the object of an increasing number of investigations. Concerning plant remains embedded in the tartar matrix, studies on human and non-human teeth has provided valuable data for reconstructing a comprehensive view of diets in the past (e.g. Lalueza Fox & Pérez-Pérez 1994; Lalueza Fox & al. 1996; Henry & Piperno 2008). In Italy, analyses of dental calculus are not numerous. Nonetheless, the study of plant remains in dental calculus may complement the information obtained through other examinations. At the Grotta dello Scoglietto, a cave located on the Western slope of the Uccellina Mountain range, Italy, the analysis of the teeth of nine individuals has demonstrated the consumption of cereals such as wheat, barley and millets during the Copper-Bronze Age (Mariotti Lippi & al. 2017). These finds have enriched our knowledge of the food spectrum already shown by the previous analysis of stable isotopes (Varalli & al. 2015).

As already mentioned, starch grain analysis offers the opportunity to collect data about plant exploitation and alimentary uses and the treatments and manipulations of plant matter. This information may be inferred also from grains recovered in dental calculus. Regarding phytolith analysis, these remains may confirm and enrich the known list of the plants that were introduced in the oral cavity, for dietary or not dietary purpose (Radini & al. 2016) or even accidentally.

As in the case of the starch grains, it must be noted that morphological studies on the phytolith morphology are scarce and a single taxon may produce a wide variety of phy-

Fig. 4. Bulliform cells/phytoliths in a leaf of *Festuca exaltata*: note the difference of size of the adjacent cells. (courtesy Prof. A. Papini, Dr. D. Attolini and Mr. C. Tani, involved with the author in studying the phytoliths of *Festuca*).

tolith morphotypes: a phenomenon indicated as "multiplicity". Moreover, the same morphotypes may occur with a wide dimensional range in the same part of the plant (Fig. 4). At the same time, similar morphotypes may be produced by different taxa - "redundancy" - both related and unrelated. And, finally, despite attempts (see for example Madella & al. 2005), scholars have still not developed a univocal nomenclature for the different morphotypes, and this is an obstacle for the comparison of phytoliths found in diverse archaeological sites.

In conclusion, even with these limitations, the study of starch grains and phytoliths has allowed us to highlight our ancestors' ability to manipulate food already during the Stone Age. And the study of the starch grains attests to the use of wild cereals – more exactly oats – in Europe over 30,000 years ago. All this, well before the beginning of agriculture.

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