INFERRING THE TAPHONOMY OF CHARRED OLIVE STONES BY COMPARING THE ANATOMY OF FRACTURE SURFACES UNDER DIFFERENT BURNING REGIMES

Figure 1. Tell Tweini marked with red circle on the map

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INTRODUCTION

Abundant charred and often broken olive stones recovered from Bronze Age layers of Tell Tweini (ancient Gibala) at the Syrian coast (Figure 1) raised the question whether the olives found were originally crushed in the course of processing for oil or just charred and broken post-depositionally. It is suggested that olive fragments with fractures rounded along the edges (Figure 2) were broken during ancient times (Neef 1990) while post-depositional breakage is often recognizable by the sharp edges of the broken faces of the stones. So rounded fractures, but also dull fragmentation faces have been said to be indicative of breakage prior to deposition (Simchoni 2006).

Simulation of carbonization processes of plant materials (i.e. seeds and fruits), in order to aid the archaeobotanical analyses and interpretations are usually carried our in muffle furnaces ((Hopf 1955), (Helbaek 1970), (Körber-Grohne 1980), (Wilson 1984), (Kislev 1989), (Boardman 1990), (Wright 1998). Cereals and pulses (i.e. wheat and pea) are common archaeobotanical finds and have been accordingly stressed in experimental charring studies (for most recent advances see Braadbart 2004), but also other taxa and types of plant remains (see (Braadbaart 2008), (Mangafa 1996), (Margaritis 2006), (Margaritis 2008), (Wright 2003), (Märkle 2008), (Gustafsson 2000).

The current study included experimentally charred olive stones with the aim to observe the differences between olive stones broken before or after charring. The changes appearing on level of tissue and cell structure were observed with Scanning Electron Microscope (SEM). The experimentally obtained structures were next compared with the archaeological olive stones from Tell Tweini with recent or supposedly old fractures in order to describe criteria for their differentiation on archaeological material.

Figure 2. Fossil olive stone Tell Tweini, pit 942

MATERIALS AND METHODS

SAMPLE PREPARATION

Fresh olives (from cultivars for oil production) were harvested by hand from Syrian and Italian groves. The fresh olive fruits were crushed/pounded manually with stone mortar in laboratory conditions, in order to produce breakage surfaces. The whole and broken fruits were charred under a wide range of conditions in a muffle furnace. Such units achieve high temperatures in a short time, allowing rapid processing, and their temperature is easily controlled. Heat was fixed at 230, 330 and 430°C by oxic and anoxic conditions. The conditions inside the muffle furnace are not really anoxic, so various methods should be used to prevent the supply of air to the material. For the current study they were placed in containers covered by sand. Duration of heating was fixed at approximately three hours. The conditions were chosen mainly with the aim to simulate conditions resembling domestic fires. Treated (i.e. salted) olives were processed the same way.

ULTRASTRUCTURAL COMPARISON

First the objects were selected by viewing them under a ZEISS Axioskop reflectance microscope. They were sputter-coated with gold. A JEOL JSM 6400 microscope was used for the actual analysis and digital pictures were generated with SemAfore.

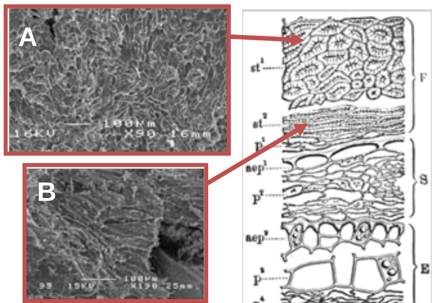


Figure 3. Microscopic structure of olive stone endocarp. A; SEM image of the st1 layer and B SEM image of the st2

After Winton and Winton 1932

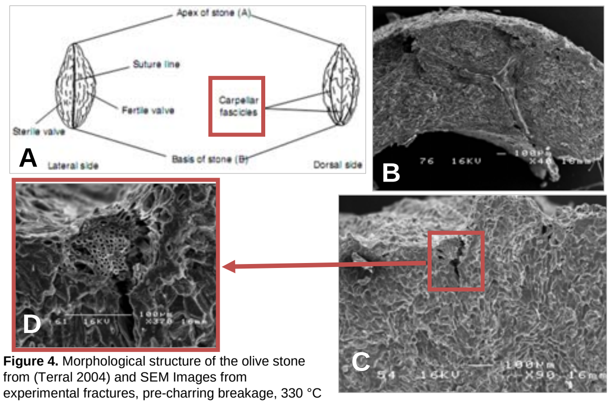


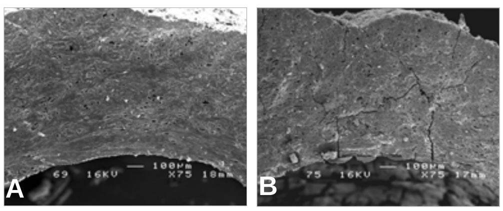
Figure 4. Morphological structure of the olive stone from (Terral 2004) and SEM Images from experimental fractures, pre-charring breakage, 330 °C

RESULTS

On the SEM images produced from the experimental and archaeological olive stones we first identified the most relevant cell layers and compared differences visible.

The endocarp (Figure 3) constists of three layers: (1) outer stone cells (st1), which are large, isodiametric or transversely elongated, often with a large lumen, (2) inner stone cells (st2), which are narrow and transversely elongated, and (3) parenchyma (p1) more or less compressed. The layers of the seed coat (S), endosperm (E) and cotyledons (C) are more complex. SEM overview was given (Figure 3 A and B) as aid to observe the structures mentioned on experimentally charred olive stones. Another characteristic structure for the olive stones is the carpellar fascicle which is a groove in the olive stone surface (Figure 4). The fissure apparently continues to run through the entire cross section of the stone, and two of these extensions can join together as is the case here (Figure 4, B). In the experimentally charred olive stones the structures related to the carpellar fascicles are remarkably better preserved than the surrounding cells.

Figure 5.



overview of cross sections (conditions: experimental, post-charring breakage, anoxic, 400°C)

olive stone cross section surface (conditions: ancient, post-charring breakage), piece broken from whole olive from pit 942, Tell Tweini.

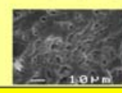
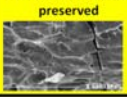
	230°C	330°C	430°C
anoxic			
broken after charring	cell structure well preserved and visible 	cell struct. still visible, cells partly merged 	cell structure not visible, cells completely merged 
broken before charring	cell structure well preserved and visible	cell structure well preserved and visible	cell structure partly preserved and visible
oxic			
broken after charring	cell structure visible, but cells partly merged	cell structure not visible, cells completely merged	olive stones turn to ashes
broken before charring	cell structure well preserved and visible	cell structure partly preserved 	olive stones turn to ashes

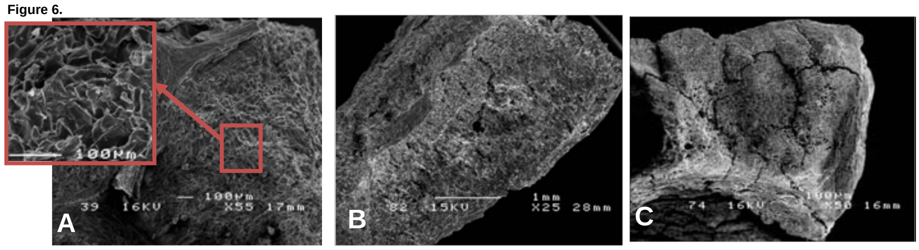
Table. 1. Preservation of the cell structures in the fractured surfaces

The degree of alternation of the morphological structures of the olive stone breakage surface is illustrated in Table 1. At 230 °C there is no visible difference between the pre-and post charring breakage – the cell structure is in both cases clearly distinguishable. Clear difference between the pre- and post-charring fractures is visible in olive stoned charred by 330 and 430 °C. The cell structure is still visible by the pre-charring fractures, while the post-charring surfaces are more or less smooth, with not anymore visible cell structures.

When we turn up the heat, the dissimilarities between 'anoxic' and 'oxic' surfaces becomes more pronounced. At 400°C for instance, a freshly cracked post charring anoxic surface is very smooth, with oval depressions as remnants of some cell cavities (Figure 5, A). Conversely, oxygenated sections become even more "chaotic" and blurred at higher temperatures (Figure 6, B, Table 1).

Some archeologically excavated olive stones were also analyzed by SEM. A stone fragment that seemed to have been broken pre-charring was selected based on surface relief which had smooth edges and coarse surface (Figure 2 and 6, C). This fragment was more fragile than the experimentally charred ones, probably owing to soil conditions or temperature and oxygenation fluctuations. Cell cavities of variable size are still visible on the fracture surface, though at some places seem to have been eroded. The archeological olive stone broken on purpose (Figure 5, B) looked entirely different than the former and resembled Figure 5, A to a remarkable extent, confirming the validity of our experiment. Again this old stone, like the other one, is more porous and easily destroyable (many cracks), and is marked by concretions which appear as particles on the surface.

Figure 6.



A. Overview and detail image of an olive stone cross section surface (conditions: experimental, pre-charring breakage, anoxic,230°C).

B. overview image of an olive stone cross section surface (conditions: experimental, pre-charring breakage, oxic, 330°C). The piece is almost crumbling down to ashes.

C. ancient olive stone in cross section surface (conditions: ancient,supposedly pre-charring breakage). Note uneven surface (i.e. more relief). from tomb 1085, Tell Tweini

DISCUSSION

Crop processing studies in archeobotany have advanced past their initial focus on cereals and pulses. Separate models have been constructed for grape (Mangafa 1989, Mangafa et al. 2001, Margaritis 2006) and olive (Adam-Veleni and Mangafa 1996, Margaritis 2008), based on a combination of ethnography, archaeobotanical research, and charring experiments. Broken olive stones are often thought to be indicative of olive oil extraction and such residues have been recognized in various excavations ((Neef 1990), (Galili 1997), (Sarpaki 1999), (Simchoni 2006), (Salavert 2008)). Margaritis and Jones (2008) aimed to detect at first hand the breakage pattern of the olive fragments before and after charring, due to the fact that different characteristics have been described by different authors on the same question. The basic characteristic indicating fragmentation prior to deposition was said to be their porous matt fracture faces, in which the edges were not jagged. But since the potential presence of rounded fracture faces very much depends on conditions during deposition and the context of preservation, and since it is not unusual that a single archeobotanical sample contains plant remains in varying states of preservation (Wilson 1984), these criteria might be too vague to really divide assemblages into pre- versus post-charring breakage groups. The fracture surfaces themselves were not clearly enough illustrated: no surfaces of archeological origin were viewed, to make comparisons, and also experimentally charred stones broken after the treatment were not viewed. By using SEM we were able to identify exactly which cell layers survive carbonization, and how they were altered (Figures 5 and 6, Table 1).

Using this information, we also found indications for the combined effect of temperature and oxygenation on the morphology of the breakage. At lower temperature (200°C) the difference between oxic and anoxic treatments (comparing Figure 6), as well between pre- and post-charring breakage is negligible, but when temperature rises to 300°C the cell patterns of oxygenated surface become more disordered and start disintegrating (Figure 3, B). At 400°C, the majority of the olive stones charred under higher oxygen concentrations even turned to ashes completely. Together with the observation that specimens become more brittle when charred at higher temperatures, it is clear that anoxic charring at relatively low heating has the highest preservation potential. As might be expected, excavated whole stones that were broken as part of the experiment showed morphologies very similar to this treatment (Figure 6), confirming the archeological validity of our experiment. On the other hand, supposedly old archeological fractures looked entirely different (uneven surfaces and eroded cell walls, Figure 5, C) possibly due to direct contact with the heat and the deposited on them fine particle from the sediments.

These inferences are all very preliminary, as we wanted only to explore the utility of this new method for the investigation of charred archeological olives.

CONCLUSIONS

- •The presented experiments confirmed that scanning electron microscopy provides good possibilities for investigating aspects olive oil production related with the post processing remains.
- •The currently presented charring experiments adds contribution that could lead to more rigorous interpretations of archaeologicaly recovered fragmentation surfaces and hence to estimate possible oil processing remains.
- •In order to really draw conclusions, more observations have to be made under multiple combinations of treatments and sufficient sample replicas have to be investigated to be statistically sound.

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