Deciphering ancient ‘recipes’ from charred cereal fragments: An integrated methodological approach using experimental, ethnographic and archaeological evidence

Soultana Maria Valamoti a,b,*, Chryssa Petridou a,b, Marian Berihuete-Azorín d, Hans-Peter Stika d, Lambrini Papadopoulou b,c, Ioanna Mimi b

a LIRA Laboratory, Department of Archaeology, School of History and Archaeology, Aristotle University of Thessaloniki, Thessaloniki, Greece
b Center for Interdisciplinary Research and Innovation (CIRI-AUTH), Aristotle University of Thessaloniki, Thessaloniki, Greece
c Department of Geology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece
d Department of Molecular Botany (190a), Institute of Biology, University of Hohenheim, Stuttgart, Germany

ARTICLE INFO

Keywords:
Cereal foods
Archaeology
Malt
Bulgur
Prehistoric Greece
Bronze age
Mesimeriani
Scanning electron microscopy
Experimental charring

ABSTRACT

This paper assesses a series of experimentally generated cereal fragments with the aim to develop criteria for interpreting archaeological remains of ground cereals. Modern grain of einkorn and barley was subjected to processing by means of grinding, boiling and melting and then charred under controlled laboratory conditions. Neolithic replica grinding stones, cooking pots and hearths were used for the production of modern reference material, informed by ethnographic observations. In this way a range of different types of cereal fragments were generated. Our results are based on observations on the fracture surfaces of these cereals, using stereomicroscopy and Scanning Electron Microscopy (SEM). Diagnostic features for specific grain treatments have been identified that facilitate the interpretation of ancient foods using cereal fragments. Bulging of the fracture surface is the main criterion for the identification of fragments generated prior to charring as the result of ancient grinding. Parboiling of grain in a liquid towards the production of bulgur (boiled in water) or trachanas (boiled or soaked in milk/sour-milk etc) can be identified archaeologically and in certain cases, ground barley may be distinguished from ground malt. Charring ground grain during cooking in liquid or preparing wort for brewing is also potentially identifiable in archaeological material. Archaeological finds of ground wheat from Mesimeriani Toumba in northern Greece dated to the end of the 3rd millennium B.C. are interpreted as boiled grain, dried and ground, corresponding to some form of bulgur or trachanas. Our results contribute new information towards the identification of past culinary practices such as grinding, boiling and brewing with cereals.

1. Introduction

Grinding of plant food ingredients in prehistory is evidenced through stone tools together with plant micro-remains trapped on grinding and pounding surfaces retrieved from prehistoric sites in the Old World (e.g. Bofill et al., 2013; Dubreuil and Nadel, 2015). With the onset of farming, the processing of cereals for food by reduction into smaller particles must have been an essential component of the prehistoric cuisines of Europe: grinding or pounding of cereals would have had important dietary benefits, facilitating digestion and nutrient uptake by the human body (see for example Stahl, 1989). It is thus not surprising that various cereal recipes attested in ancient and traditional cuisines involve the preparation and use of cereal fragments. Besides reducing whole grain into smaller particles, processing of cereal grain by drying, cooking, sprouting and fermenting leads to a variety of nutritious, cereal-based foodstuffs, some of which have a long storage life, an important asset in traditional economies. Cereals can be consumed in many different ways including ground, parboiled and ground, ground, then boiled or soaked in milk or sour-milk (see for a review Valamoti, 2011) or left to sprout before grinding as is the case of ground malt used for brewing (cf. Heiss et al., 2020) while for some recipes the grain may be harvested unripe as is the Grünkern (e.g. Berihuete-Azorín et al., 2020). Examples

* Corresponding author. LIRA Laboratory, Department of Archaeology, School of History and Archaeology, Aristotle University of Thessaloniki, Thessaloniki, Greece.
E-mail address: sval@hist.auth.gr (S.M. Valamoti).

https://doi.org/10.1016/j.jas.2021.105347
Received 9 September 2020; Received in revised form 12 February 2021; Accepted 12 February 2021
Available online 8 March 2021
of such recipes are encountered in the ethnographic record, ancient texts and occasionally among archaeological finds. The archaeological recognition, however, of the culinary steps that may have led to charred archaeological finds of cereal fragments is at present rather limited.

The identification of cereal fragments generated prior to charring in the archaeobotanical record was first recognised by Knörzer (1981) and later Willcox (2002) and Valamoti (2002). A pilot experimental investigation of modern einkorn grains broken prior and after charring as well as with or without treatment with hot water, showed the potential for the archaeological identification of cereal grain grinding and of the archaeological identification of cereal grain grinding and of the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as and the experimental specimens used were generated with modern equipment, therefore very different to a prehistoric situation as andconstitute the material on which our observations are based (Table 1).

2. Materials and methods

In order to observe the fracture surface of cereal grains that have undergone various forms of processing, we generated a range of different types of cereal fragments. Besides considering the effect of grinding, we have also investigated two forms of treating cereal grain as part of a recipe: sprouting and parboiling. We generated a series of cereal specimens under (a) real life conditions and (b) experimental replication with Neolithic grinding and cooking equipment, informed by our ethnographic observations. Thus, for the purposes of this study, we have observed sprouted barley/malt, einkorn bulgur and trachanas as well as einkorn and barley grain without any treatment. All the grains from these categories were ground to generate cereal fragments which were subsequently charred under controlled laboratory conditions. In addition to variability in culinary treatments that might affect the features of cereal fracture surfaces, depositional processes related to charring conditions need also to be understood. Thus, besides this material, we have generated post-charring fracture surfaces by breaking complete charred grains from each category of variables. The aim of this is to compare fracture surfaces intentionally generated by grinding/pounding in the past to fracture surfaces induced accidently, post-charring, by means of trampling and/or archaeological retrieval. Moreover, the different grain categories we generated were brought into contact with heat in both a dry and wet state. All these charred fragments constitute the material on which our observations are based (Table 1).

2.1. Experimental material

2.1.1. Ingredients

Two cereal species have been used to generate the experimental material considered here: einkorn wheat (Triticum monococcum) and barley (Hordeum vulgare). Grains of these species were treated in various ways prior to charring as well as during charring (Table 1). Dehusked einkorn and hulled two-row barley (Hordeum vulgare L. var. distichum) were provided by a local farmer in northern Greece, Mr Giorgos Doumos who grows it in the Aridaia plain, in the region of western Macedonia. We used dehusked einkorn grain for the preparation of pligouri/bulgur, i.e. parboiled, ground cereal grain. This bulgur was subsequently used for the production of trachanas, in our case bulgur soaked in milk (see below). From different steps out of the “chaîne opératoire” of malt production, two-row hulled barley that had sprouted for 3 and for 5 days and then air-dried to stop the sprouting process, referred to as malt in this paper, was provided for the experiments by Durst Maltz, Heinrich Durst Malzfabriken GmbH & Co., in Bruchsal-Heidelsheim, Germany.

2.1.2. Grinding tools

Fragments of einkorn grain, barley, malt and parboiled einkorn (bulgur) were generated by using a pair of experimental grinding implements manufactured according to relevant finds from Greek prehistoric sites (Fig. 1; for a detailed presentation of grinding tool types from prehistoric Greece see Bofill et al., 2020). The tools were both made of sandstone. Their active surfaces were formed through pecking in order to obtain the necessary rough texture. The grinding slab (28 cm long and 25 cm wide) had an oval shape and a use-surface concave in both axes (i.e. a shallow “basin-like” morphology). The handstone (12 cm long and 8 cm wide) was slightly rectangular with a use-surface convex in both axes.

2.1.3. Ethnographic bulgur (pligouri) and trachanas

Ethnographic-experimental bulgur and trachanas were prepared specifically for the purposes of this study by elderly women who produce them in the context of their household economy and regular culinary practice. This work was carried out in the village of Kosmati, located in the Grevena region, in western Macedonia, Greece (Fig. 1). The whole fieldwork was conducted during the last days of August 2017 and the beginning of September 2017. The aim was to explore food processing and culinary methods for the preparation of bulgur/pligouri and trachanas (Fig. 2) in order to improve archaeological interpretation of ancient food remains. The study of bulgur/pligouri and trachanas was made possible with the help of the late Mrs Sophia Papageorgiou who prepared them. Additional information was obtained through interviews and conversations with other women from Kosmati – Ms Dimitra.
Dehusked einkorn grain was first washed by immersing it in cold water in order to clean it from any remaining dust or grit. The washing procedure was repeated three times, discarding the water each time, in order to achieve a thoroughly clean grain.

The grain was subsequently parboiled in water for approximately 45 min to 1 h and when adequately swollen, it was strained and left to completely dry in the sun for approximately 4 days, as grinding requires dry material (Fig. 2). The duration of drying is closely intertwined with weather conditions. The grain was spread on a table in the open air, exposed to the high summer temperatures, while covered by a synthetic tulle, so as to be protected from animal pests, birds and dust. During the drying process, the grain was turned over several times by hand to allow thorough drying. When dry, the einkorn grain was winnowed. In case of non-existent or low-level wind, some artificial air flow needs to be created, which in our case was achieved using a broom. Finally, grain was cleaned from any other remaining impurities such as chaff, by hand-picking.

The grinding of the einkorn was performed outdoors by using the prehistoric replica pair of a grinding slab and a handstone (Fig. 1). A clean cloth was placed under the grinding slab in order to collect any grain that would fall during this task. Free curvilinear movements were employed under the close supervision of the village women who advised as to the desired grain particle size. The grain was fed to the grinding stone gradually, each batch corresponding to a handful.

After grinding, the particles were sieved with a plastic kitchen sieve of approximately 2 mm aperture (Fig. 3a). The coarse fraction, which was retained by the sieve was kept as bulgur/pligouri while the fine fraction was used to produce trachanas. The particles in the coarse fraction that corresponds to bulgur are larger than 1 mm, with their majority (91%) being larger than 2 mm.

The basic ingredients used for trachanas are the fine particles of boiled, ground einkorn grain (bulgur) and milk. Following that, the fine einkorn bulgur was placed in a metal round pan and stirred with the milk until it absorbed it, swelling in the process into lumps that were subsequently rubbed in small particles. The ratio is 1:1 (1 kg of wheat:1L of milk). Afterwards, the mixture was spread on the pan and slightly rubbed by hand to split those grains that stuck together; it was then placed on a table to stand for approximately 15 min in the sun in order to absorb the milk completely. Then the mixture was rubbed first by hand, then through a coarse sieve to dissolve the small lumps. Finally, the trachanas was spread on a table to sun-dry for at least one day (Fig. 3).

### 2.1.4. Experimental bulgur using neolithic replica cooking facilities

The experimental bulgur was generated using replicas of cooking pots and cooking installations encountered in Neolithic Greece (Dimoula et al., 2020). The bulgur was prepared following the traditional bulgur recipe recorded in different regions of Greece and Turkey (e.g. Ertug, 2018).

<table>
<thead>
<tr>
<th>Cereal species</th>
<th>Cereal component</th>
<th>Processing</th>
<th>Replication</th>
<th>End food product</th>
<th>State at heating point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>cracked wheat</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>cracked wheat</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>bulgur</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>bulgur</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>ethnographic</td>
<td>bulgur</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>ethnographic</td>
<td>bulgur</td>
<td>x</td>
</tr>
<tr>
<td>Einkorn</td>
<td>whole grains</td>
<td>x</td>
<td>ethnographic</td>
<td>trachanas</td>
<td>x</td>
</tr>
<tr>
<td>Barley</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>cracked barley</td>
<td>x</td>
</tr>
<tr>
<td>Barley</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>malt</td>
<td>x</td>
</tr>
<tr>
<td>Barley</td>
<td>whole grains</td>
<td>x</td>
<td>experimental</td>
<td>malt</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 1

Materials, processes and cereal food products considered in this study.

Fig. 1. Grinding dry, parboiled einkorn grain using a Neolithic replica grinding pair of stone tools; grinding performed by Danai Chondrou, under the instructions of Ms Sophia Papageorgiou, while Chryssa Petridou and Ioanna Mimi take notes of the process.

Karaletsiou and Ms Stavroula Panagiotopoulou.

Dekhusked einkorn grain was first washed by immersing it in cold water in order to clean it from any remaining dust or grit. The washing procedure was repeated three times, discarding the water each time, in order to achieve a thoroughly clean grain.

The grain was subsequently parboiled in water for approximately 45 min to 1 h and when adequately swollen, it was strained and left to completely dry in the sun for approximately 4 days, as grinding requires dry material (Fig. 2). The duration of drying is closely intertwined with weather conditions. The grain was spread on a table in the open air, exposed to the high summer temperatures, while covered by a synthetic tulle, so as to be protected from animal pests, birds and dust. During the drying process, the grain was turned over several times by hand to allow thorough drying. When dry, the einkorn grain was winnowed. In case of non-existent or low-level wind, some artificial air flow needs to be created, which in our case was achieved using a broom. Finally, grain was cleaned from any other remaining impurities such as chaff, by hand-picking.

The grinding of the einkorn was performed outdoors by using the prehistoric replica pair of a grinding slab and a handstone (Fig. 1). A clean cloth was placed under the grinding slab in order to collect any grain that would fall during this task. Free curvilinear movements were employed under the close supervision of the village women who advised as to the desired grain particle size. The grain was fed to the grinding stone gradually, each batch corresponding to a handful.

After grinding, the particles were sieved with a plastic kitchen sieve of approximately 2 mm aperture (Fig. 3a). The coarse fraction, which was retained by the sieve was kept as bulgur/pligouri while the fine fraction was used to produce trachanas. The particles in the coarse fraction that corresponds to bulgur are larger than 1 mm, with their majority (91%) being larger than 2 mm.

The basic ingredients used for trachanas are the fine particles of boiled, ground einkorn grain (bulgur) and milk. Following that, the fine einkorn bulgur was placed in a metal round pan and stirred with the milk until it absorbed it, swelling in the process into lumps that were subsequently rubbed in small particles. The ratio is 1:1 (1 kg of wheat:1L of milk). Afterwards, the mixture was spread on the pan and slightly rubbed by hand to split those grains that stuck together; it was then placed on a table to stand for approximately 15 min in the sun in order to absorb the milk completely. Then the mixture was rubbed first by hand, then through a coarse sieve to dissolve the small lumps. Finally, the trachanas was spread on a table to sun-dry for at least one day (Fig. 3).
2004; Valamoti, 2011; Psilakis and Psilaki, 2001), also observed at Kosmati. The grain was parboiled whole in water in two replica ceramic pots, a tripodic vessel and a carinated vessel; two types of cooking facilities were used when cooking with the carinated pot (Fig. 4). All pots containing the einkorn grain and water were placed close to the fire for some time before being placed directly on the hearth fire, in order to avoid damaging the pot. A mixture of 4L of water and 1.5kg of einkorn grain was used in the beginning of the preparation of each batch of bulgur. Three batches were prepared.

The first batch of bulgur was prepared in the tripodic vessel. The pot and its contents were placed directly onto the fire after 1 h and 50 min of warming close to it. During cooking, we added water twice, 1 L each time. The total duration of cooking was 2 h and 20 min and immediately after removal from fire, the pot contents were emptied and spread to dry in the sun. Cooking in the carinated vessel involved a shorter period of warming up (ca. 1 h) by placing it close to the fire prior to cooking proper; during cooking only 1L of water was added. It was cooked for 3 h, then the pot was removed from the hearth and immediately emptied. A third batch of bulgur was prepared in the same carinated cooking pot that was placed half-way inside the upper vault opening of a replica oven (see also Dimoula et al., 2020, Fig. 5f, p. 9). The warming up of the vessel lasted less, approximately 40 min, before it was placed to the oven vault opening and no extra water was added during the process. It was cooked for about 1 h and 40 min before the embers were removed and

Fig. 2. Flowchart of steps involved in the preparations of bulgur and trachanas observed at Kosmati, Grevena, August-September 2017.
Fig. 3. Bulgur and trachanas preparation at Kosmati: a) sieving of ground parboiled einkorn, b) the fine fraction, used for trachanas preparation, c) adding milk, d) sun-drying, e) rubbing by hand, f) rubbing through a sieve.

Fig. 4. Replica cooking pots and cooking installations used for the production of experimental bulgur: (a) carinated and tripodic pot placed in a replica hearth; (b) carinated pot placed on domed oven with opening at the vault.

Fig. 5. Plan and photo showing burnt house interior from Mesimeriani Toumba, end of the Early Bronze Age (2100-1900 B.C.; after Grammenos and Kotsos 2002, p. 240).
the pot was emptied. All three batches were mixed together and spread in the sun until they were completely dry. This grain was subsequently ground with the replica grinding stone as described above.

2.2. Generating fracture surfaces

The experimental fragments generated as part of the ethnographic and archaeological replication were prepared by the Neolithic replica grinding stones mentioned above. The handstone was operated in a ‘free’ curvilinear motion on top of the static grinding slab. For consistency, all grinding was performed by Danai Chondrou, aiming at getting coarse fragments similar to those obtained for the ethnographic bulgur following the advice of elderly, experienced women from the village of Kosmati. The majority of the particles generated from ground, untreated einkorn and barley were larger than 1 mm after charring (Table 2).

In addition to fragments generated as part of a food preparation sequence that were subsequently charred, we aimed to observe fragments of the experimental specimens generated post-charring. Identifying fragmentation prior to charring versus post-charring is very important for inferring past culinary practices. Thus, in addition to the fracture surfaces generated by grinding prior to charring we generated post-charring fracture surfaces. We achieved this by hand-breaking intact grains of every variable considered in the experiment.

2.3. Charring regime of experimental material

Charring of the experimental material was done following the protocol established by Berihuete et al. (2019). The different cereals and cereal preparations considered here were charred at the Institute of Botany of the University of Hohenheim (Germany) except for trachanas which was charred at CIRI-AUTh in Thessaloniki. According to our previous experience (Berihuete-Azorín et al., 2019), it was decided to carbonize them at 230 °C for 24 h. The heat treatment was performed with a Nabertherm Muffle oven, NA 15/65 with an accuracy of ± 7 °C. For this, Nabertherm crucibles of 11 × 7.5 cm were used. The procedure was the same for all variants tested, except for trachanas: one crucible with 60 ml of the dry material; one crucible with 60 ml of material soaked for 2 h in 60 ml of water and then drained; and one crucible with 60 ml of material soaked for 2 h, covered by water, not drained (Table 1). Trachanas was charred only as dried material. The crucibles were placed in the oven at room temperature. The 230 °C were achieved in the first 30 min and then the samples were charred for 24 h. They were all left to cool inside the oven.

2.4. Archaeological material

The archaeobotanical material from Mesimeriani Toumba originates from the interior of a house destroyed by fire. It was found as a pure concentration inside one of two adjacent similar vessels embedded in clay, next to clay structures and pots, the whole area most likely representing a house interior kitchen space with evidence for storage, grinding and cooking (Fig. 5; Grammenos and Kotsos, 2002, pp 62–63). This assemblage has been dated to the end of the Early Bronze Age: 2196–1925 BCE (Grammenos and Kotsos, 2002).

Table 2

<table>
<thead>
<tr>
<th>Ground einkorn</th>
<th>Ground barley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (ml)</td>
<td>Volume (ml)</td>
</tr>
<tr>
<td>&gt;2 mm</td>
<td>8.2</td>
</tr>
<tr>
<td>&lt;1 mm</td>
<td>9.7</td>
</tr>
<tr>
<td>&gt;500 μm</td>
<td>2.4</td>
</tr>
<tr>
<td>&lt;500 μm</td>
<td>1.3</td>
</tr>
</tbody>
</table>

2.5. Observation methods

After charring, the fragments obtained from the experimentally generated foodstuffs were examined at CIRI of the Aristotle University of Thessaloniki a) with the use of a Zeiss stereomicroscope with magnifications X6.5 to X50 and b) with SEM. SEM analysis and microphotography were performed at the Department of Geology using a JEOL JSM-840A and a JEOL JSM-6390LV. Samples were coated with carbon – average thickness of 200 Å – using a vacuum evaporator JEOL-4X. SEM images were obtained for two to four charred specimens per treatment on all types of fracture surfaces generated prior to charring. In order to control for variability among fragments generated post-charring, one to two fragments per variable were examined using both stereomicroscopy and SEM. For this last group of fracture surfaces, an additional 10 fragments of each of the following were examined with the aid of a stereomicroscope: einkorn grain and both types of bulgur charred under both regimes; the aim was to assess variability within each category of specimens. This examination did not add any further features regarding post-charring fracture surfaces.

3. Results

The observations on the charred materials focused on the morphological features of the fracture surface. Our experimental design and observations conducted on the cereal fracture surface focus on three main factors that may influence this surface: a. treatment to which the grains were subjected, b. conditions of charring, c. timing of fragmentation in relation to charring of the grains. The effect of different grain treatments as steps of a recipe (sprouting, soaking, parboiling, grinding) and the effect of fracture prior to or post-charring have been observed on the fracture surface; any differences and/or overlap have been recorded. The morphological features of fracture surfaces as well as overall behaviour of fragments such as remaining loose or forming agglomerations during charring are summarised in Table 3. The experimental grinding generated both longitudinal and transversal fracture surfaces which were first observed in order to examine whether fragmentation type can have an effect on the features of the fracture surface. Based on the SEM examination, there were no significant differences. We did not observe any differences between fragments charred after they had been soaked in water and then drained and those fragments immersed in water when introduced in the oven; they have therefore been grouped in one broad category described as ‘wet’ in Table 1. In this section, we first present the results on the fracture surface of the experimental fragments which we then compare to the archaeological material from Mesimeriani Toumba.

3.1. Experimental material

The main aim of this experimental investigation is to understand the ‘biography’ of a cereal kernel in relation to treatments it has received as part of processing and cooking and modifications induced due to charring conditions, as well as unintentional breakage during or after deposition. We have therefore organised the presentation of our experimental results as follows: (a) cereal fragments generated by activities prior to charring, (b) fragments generated post-charring. Within the first category we have organised the presentation of the results first by type of charring conditions and then by considering different types of treatment as part of culinary practice, starting from grinding untreated grain and moving to parboiled and sprouted grain (malt).

3.1.1. Fragments generated prior to charring

3.1.1.1. Charring of dry specimens

3.1.1.1.1. Features observed by stereomicroscopy. All fragments generated prior to charring and exposed to heat in a dry state,
demonstrated a bulging fracture surface (Fig. 6) except for malt (Fig. 7).
Bulging occurs on cereal fracture surfaces when kernels are exposed to
heat: the heat causes the revealed starchy endosperm to expand beyond
the pericarp outline. Bulging is a consistent feature of cereal fragments
generated prior to charring that correspond to ground, untreated grain
as well as parboiled ground grain. This bulging is clearly visible both
with the aid of a stereomicroscope as well under SEM observation (see
below). Bulging can vary in its intensity from mild to very pronounced
and it appears to vary depending on grain species and previous treat-
ment of grain as part of a food preparation sequence; there is also
variation among specimens of the same category of treatment (Fig. 8).
Thus, it is subtle in ground einkorn grain and more pronounced in barley
grain. In the ethnographic bulgur, for example, it can vary from mild
bulging that only slightly exceeds the pericarp ridge, to very pro-
dounced, clearly expanding above the pericarp ridge. A very small
percentage of grain fragments may not demonstrate bulging; thus, for
example in untreated, ground and charred einkorn, 8% of the total 447
fragments of the parboiled grains which often are also shiny (Fig. 11c).
In trachanas, the fracture surfaces appear similar to bulgur, under a
stereomicroscope as regards bulging, showing a glassy but not shiny
surface (Fig. 11b) and very often, fine particles are attached on the
surface of larger fragments (see below, SEM observations). The shiny/-
matt distinction of the fracture surface is a qualitative one that takes
place at the stage of macroscopic observation; as explained below this
feature requires further SEM observation in order to contribute as a
diagnostic feature of certain grain treatments (see below). Ground
barley and ground einkorn do not show a glassy surface but one that is
mat (Figs. 8a and 11a) and occasionally marked by bumps and fissures
(Fig. 10). These bumps and fissures may be the outcome of the me-
chanical action on the grain kernels during grinding with the replica
Neolithic grinding stones.

3.1.1.2. Features observed by means of SEM. In addition to bulging,
visible also under SEM (see above Fig. 6), specimens charred after
exposure to heat in a dry state present a series of characteristic features
on the fracture surface as regards the microstructures observed under
the SEM. Fracture surfaces of ground einkorn and barley grains show a
variable surface within individual fragments: areas where starch gran-
ules are to a great degree fused into a continuous matrix, with the
boundaries between individual granules still discernible, and areas
where granules appear less distorted (Fig. 12a–d). Thus, patches with
some starch gelatinisation are observed in untreated, dry-charred cereal
fragments (Fig. 12a and c). This variability of level of gelatinisation, in
the material we have examined appears among different specimens or
among areas of the same specimen, and is more evident in the case of
einkorn compared to barley which demonstrates more uniform areas
with signs of gelatinisation. Due to the fact that we used only one batch

![Fig. 6. Stereomicroscope and SEM images showing example of bulging fracture surface (bulgur, charred under dry conditions). Arrows pointing to pericarp line.](image)
of einkorn and barley, from the same farmer, it is unclear whether this difference we have observed between barley and einkorn is related to species differences in starch composition or whether it could be related to different landraces or growing field conditions.

In specimens that had been parboiled as part of their processing prior to grinding, i.e. bulgur and trachanas, starch gelatinisation is clearly visible throughout the fracture surface and not in patches as is the case in ground einkorn and barley. This is of course understandable as starch in bulgur and trachanas was already gelatinised prior to contact with heat and subsequent charring. Thus, both types of experimental bulgur as well as trachanas prepared at Kosmati demonstrated a highly homogenised, glassy surface when examined under the SEM (Fig. 12e–h).

3.1.1.2. Charring of specimens while wet upon contact with heat

3.1.1.2.1. Features observed by means of stereomicroscopy. When specimens were charred after being soaked or immersed in water, as described in the methods above, the formation of lumps/agglomerations of fragments appears as a distinctive feature of all types of fragments exposed to heat while wet. In the case of bulgur, ground barley and observed in the SEM in specimens pre-treated with a liquid as part of their preparation (bulgur and trachanas) are most likely those responsible for the overall glassy and occasionally shiny appearance observed under stereomicroscopic examination, for the same reasons noted above. Unlike all other specimens, ground malt charred in a dry state is distinct also when examined under the SEM in various ways: the fracture surface of ground malt maintains the structure of grain endosperm without serious modifications (Fig. 12i and j).
ground malt, these agglomerations are quite loose while those of ground einkorn appear as fragments in a matrix and for this reason it was not possible to select individual fragments for examination (Fig. 13). Bulging, a diagnostic feature for dry-charring is also a feature of wet specimens at the point of contact with heat, this time characterising all types of specimens including malt. This bulging fracture surface occasionally gives the impression of charred fragments of parboiled grains (see above) yet, most of the specimens of all variables give an impression of ‘melting’ of the starchy endosperm, oozing out from the endosperm and thus connecting individual fragments; most fragments have glassy, undulating surfaces consisting of hollow and bumpy areas. Macroscopically, all kernels, including ground malt, showed in addition to bulging a shiny/glassy surface. Although wet malt is overall slightly different to bulgur mainly as regards irregularity of surface (Fig. 14), there is considerable overlap; thus this irregularity does not constitute a distinctive feature of fracture surfaces of ground malt charred while being wet or soaking.

3.1.1.2.2. Features observed by means of SEM. When fragments were observed with the use of SEM, soaked/immersed bulgur showed the same characteristics as when charred in a dry state as described above: the endosperm appears highly fused into a homogeneous matrix, with heavily distorted starch granules or boundaries between granules still visible only in some areas. The same features are observed in the SEM micrographs of wet ground barley and malt (Fig. 15).

3.1.1.2.3. Fragments generated post charring. Fragmentation after charring is, in most cases, distinct: a common feature shared by all experimental specimens is the absence of bulging. Fracture surfaces demonstrate varying topographies and there is significant overlap of visible features between different specimens and charring environments. Fracture surfaces generated post charring can display the following features: porous surface, patches of homogeneous surfaces or irregular surfaces with fissures and cavities (Fig. 16); several of these characteristics may occur on a single fragment. Due to this overlap we did not proceed to any inferences as regards post charring fracture surfaces and prior treatment except for the cases of (a) bulgur and (b) soaked/immersed grain subsequently charred, examined with SEM. Both (a) and (b), the former irrespective of dry or wet state prior to charring, when broken after charring, present occasionally patches of fused endosperm with a glassy, homogeneous appearance, slightly bulging or with bumps.

3.2. The archaeological material

The Mesimeriani Toumba sample consists of 72 ml of fragments, 90% of which are smaller than 1 mm (Fig. 17). A large number of these fragments exhibits a glassy/shiny surface (see also Valamoti 2002, Fig. 2). A closer re-examination of this material shows that among the concentration of fragments, small lumps of agglomerations of fragments exist. Some of the fragments have a more pronounced bulging than others which have a subtle bulging (not exceeding much the pericarp line) that can be detected only after very careful examination with a stereomicroscope, further confirmed by SEM (Fig. 18a and b). When
Fig. 12. SEM micrographs of ground cereal products charred under dry conditions demonstrating various degrees of gelatinisation. Untreated ground einkorn: a) starch granules more or less fused, with individual granules or granule boundaries still visible b) starch granules mildly distorted after charring. Untreated ground barley: c) highly fused matrix, d) starch granules still visible after charring. Ethnographic (e) and experimental (f) bulgur: highly gelatinised fracture surface. Ethnographic trachanas: g) highly gelatinised fracture surface, h) bran and starchy endosperm fragments attached on fracture surface. Ground 3-day malt (i and j): lack of gelatinisation.
observed under the SEM, starch appears to be highly fused in a homogenous matrix; occasionally features such as oval, shallow depressions were discerned which may correspond to traces of heavily modified starch granules embedded in a highly gelatinised endosperm matrix (Fig. 18c and d) as was already observed in an earlier pilot study (Valamoti et al., 2008).

4. Discussion

4.1. Experimental material

Based on the above results, a series of diagnostic features have been observed on the experimental specimens. We discuss the main traits that we have observed on fracture surfaces of different cereal species, preparations and charring conditions. These are summarised below and presented in the form of a key and a table aimed to contribute towards the archaeobotanical identification of cereal grain treatments as part of cooking in the past (Fig. 19, Table 4).

- a. Presence of bulging. Cereal grain (einkorn and barley) fragmented prior to charring is always bulging on the fracture surface, except in the case of dry ground malt. In all remaining cases, bulging is visible irrespective of state of grain upon contact with heat (dry/wet) and parboiling of grain prior to grinding. Bulging of the endosperm can vary in intensity among individual grains of the same category of treatment. In addition to bulging, gelatinisation of starch is observed macroscopically, appearing as a glassy surface which, under the SEM, appears as a homogeneous surface that may be visible on the whole fracture surface or on parts of it. When this homogeneous, glassy surface appears only as a few patches on the fracture surface, it is more likely that gelatinisation is due to charring and not to parboiling of the grain.

- b. Absence of bulging. The distinction between prior and post-charring fragmentation of cereal grains is possible on the basis of presence or absence of bulging: bulging does not occur when fragmentation takes place post-charring, caused for example by post-depositional disturbance and/or retrieval by flotation.

- c. Glassy surface. Cereal fragments generated from parboiled grain or cereal fragments soaked or immersed in water, before charring, show a glassy surface both when examined with a stereomicroscope and under the SEM. This is probably caused by the gelatinisation of starch present in cereal endosperm. As there is considerable overlap in the features observed on the fracture surface, no specific features could be identified as distinctive of parboiled grains vs wet grains coming in contact with heat and becoming charred.

- d. Presence of lumps/agglomerations of fragments. The formation of agglomerations, when fragments are wet or immersed in a liquid upon contact with heat, is the main feature we have identified as able to discriminate these from fragments originating from parboiled ground grain at a dry state upon contact with heat. On the other hand, if agglomerations were the original form in which foodstuffs had been prepared and stored, as is the case for example with variants of *trachanas* such as the Cretan *xinochondros* and *chachla* from the island of Lesbos (Valamoti and Anastasaki, 2007; Valamoti,
this distinction will be very difficult to make. The ‘melting’ effect we observed with endosperm oozing out and fragments sticking to each other may be used as an identification criterion for fragments that were wet/soaking/boiling when in contact with fire. We did not observe any significant differences between grain par-boiled in water, then ground, and the ethnographic trachanas made of bulgur that was immersed in milk. Lumps of stored, dry bulgur and trachanas would differ from fragments soaking or boiling at the time of contact with heat (see above (c)) as they would lack the ‘melting’ effect.

The study attempted here aims to move beyond the state of the art as regards the archaeobotanical identification of foods based on cereal fragments. It has addressed questions left open by previous pilot studies.

Fig. 15. SEM micrographs of ground barley (a, b) and malt (c, d) soaked, then charred. Highly fused matrix with heavily distorted starch granules visible.

Fig. 16. SEM micrographs of experimental wet einkorn (a) and ethnographic bulgur (b and c). Fracture surface generated after charring. Overview (upper row) and detail of starchy endosperm (bottom row; starch granules distorted (St), fused matrix (M)).
and expanded considerably the range of the variables investigated. The fragments studied here were generated using a replica Neolithic grinding tool set and correspond to what would have likely been produced in a prehistoric context and not to fragments produced in a modern laboratory situation using metal means to fragment the grains (knife: Valamoti, 2002; modern cereal mill: Valamoti et al., 2008) as was previously the case.

The features observed on fracture surfaces of cereal grains experimentally generated for the purposes of this study allow for a distinction among charred specimens between certain grain treatments and/or charring conditions. At the same time, our work reveals considerable limitations due to overlap in some observed features. Based on the results presented above, previous studies are confirmed and new insights that help interpret archaeological cereal fragments have been obtained. Bulging of cereal endosperm, a feature considered indicative of grinding/fragmentation prior to charring by previous studies (Valamoti, 2002; Willcox, 2002), is confirmed by our results. The wider range of variables considered here has allowed us to observe that the degree of bulging can vary from mild to extreme, depending on cereal species and treatment of grain with a liquid as part of a food preparation sequence.

Fig. 17. Cereal fragments from Mesimeriani Toumba: (a) concentration (left), (b) lumps (top right), (c) detail (bottom right).

Fig. 18. SEM micrographs of cereal fragments from Mesimeriani Toumba. Upper row: fracture surfaces with varying degrees of bulging a) pronounced, b) mild; Bottom row: details of starchy endosperm gelatinised morphology.
such as soaking or boiling. Only in malt that was charred dry, bulging was almost entirely missing.

As some gelatinisation was also observed in dry, untreated ground grain as the result of charring, we call for caution against over-interpretation: some overlap between gelatinisation caused by the water content of grain itself upon contact with fire (Fig. 12a and c) and gelatinisation caused by a short duration of parboiling in a liquid (see Valamoti et al., 2008, Figs. 4 and 13) is to be expected on the basis of current and former observations. Therefore, identifying cereal fragments as bulgur, as opposed to cracked wheat would require a substantial number of fragments, loose, with visible bulging and their majority demonstrating, under the SEM, a homogeneous, gelatinised, glassy fracture surface. Fragments with only patches of gelatinised endosperm could correspond either to cracked wheat or to bulgur that did not parboil long enough to become fully gelatinised.

Extreme starch gelatinisation can be confused with ground cereal grain, including malt, coming in contact with heat while soaking or boiling: the grain would undergo the ‘boiling’ stage prior to eventually becoming charred. The presence of agglomerations of fragments and a melted endosperm, in this case would help to infer the presence of a liquid at the time of contact with fire. Archaeological context could also contribute towards distinguishing the two. Dry barley and malt when charred show differences on the fracture surfaces and potentially they could be discernible in archaeological material. When soaked or immersed in water, however, they share features that do not allow their distinction.

Ground malt, unlike all other specimens, when charred in dry conditions, was not fully blackened, and the endosperm structure appeared similar to that of uncharred grains (Fig. 12i and j). One might wonder as to the degree of archaeological preservation of malt charred dry in low temperatures (cf. Braadbaart et al., 2004). This difference between malt and untreated barley in our experiments could be due to the lower water content of the first one as well as modifications induced due to sprouting in the cereal endosperm. Clearly, preservation of the features we observed in malt needs further investigation under different charring regimes. Changes due to charring visible on a macroscopic level, as well as changes on the morphology of cereal grain endosperm, have been documented by numerous experimental studies (Berihuete-Azorín et al. 2019, 2020; Braadbaart 2008; Braadbaart et al. 2004, 2005; Charles et al., 2015; Valamoti 2002; Valamoti et al., 2008). As we only explored

---

**Fig. 19.** Key characteristics of fracture surface with diagnostic value for the archaeobotanical identification of cereal fragments.

---

**Table 4**

<table>
<thead>
<tr>
<th>Cereal fracture surface</th>
<th>Observation level</th>
<th>Bulging feature</th>
<th>Other features</th>
<th>Figures</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>STMC non bulging</td>
<td></td>
<td></td>
<td>16</td>
<td>broken after charring</td>
</tr>
<tr>
<td></td>
<td>SEM non bulging</td>
<td></td>
<td>variable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>STMC non bulging</td>
<td></td>
<td>variable with gelatinised patches</td>
<td>16</td>
<td>broken after charring, wet or parboiled</td>
</tr>
<tr>
<td></td>
<td>SEM non bulging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>STMC non bulging</td>
<td></td>
<td>irregular, non modified endosperm</td>
<td>7.12i, j</td>
<td>ground malt, dry</td>
</tr>
<tr>
<td></td>
<td>SEM non bulging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>STMC bulging</td>
<td>patchy gelatinisation</td>
<td></td>
<td>10, 12a-d</td>
<td>ground grain, untreated, dry</td>
</tr>
<tr>
<td></td>
<td>SEM bulging</td>
<td></td>
<td></td>
<td></td>
<td>ground grain, untreated, wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>parboiled grain, ground, dry/wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ground malt, dry/wet</td>
</tr>
<tr>
<td>5</td>
<td>STMC bulging</td>
<td>glassy</td>
<td></td>
<td>14a, 15a, b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEM bulging</td>
<td>uniform gelatinisation</td>
<td></td>
<td>9a, 12a-h, 14b</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S.M. Valamoti et al.
one charring regime, we need to alert for caution and the need for further experimentation under different charring conditions, ideally also observing decay over time. This would help understand the taphonomy of malt which, in our charring experiments, was not fully blackened.

Although a single study cannot cover the full range of possible variation as regards charring conditions that could potentially occur in an archaeological context, the selection of variables considered here, provides a reliable basis for observing changes on cereal fragment surfaces induced by processes (sprouting, boiling, grinding) and state of grains prior to charring (dry, wet). Of course, the overall charring environment, for example whether grain was exposed or contained in a vessel, moisture of grain upon contact with heat, charring temperatures, the speed of temperature increase, the presence or absence of oxygen are also likely to affect the final appearance of the cereal fragments. Variations in the intensity of bulging among the cereal fragments we have examined, ranging from slightly bulging to clearly bulging could be an outcome of the low heating temperatures we used, as it has been attested by previous experimental studies that bulging of the fracture surface becomes more pronounced in samples exposed to higher temperatures (cf. Valamoti, 2002, Fig. 3, for more pronounced bulging of fracture surface on cereal fragments charred at 350 °C, see also Szymanski and Morris, 2015).

In cases where agglomerations of fragments into lumps are present, these may demonstrate a loose structure with many voids, easily broken off into smaller agglomerations (barley, bulgur and malt) or, they may form an agglomeration of lumps of fragments in matrix (ground einkorn grain). This may depend on the granulometry of the ground cereal component and perhaps may be related to the presence or absence of chaff as the agglomerations with large fragments or chaff were of a more loose structure. This may explain why in wet bulgur, where the fragments are big, they remained more or less distinct from each other after charring, while in untreated ground einkorn the finer particles generate a matrix into which the larger einkorn fragments become embedded during charring. Based on this, we propose that archaeobotanical finds of cereal fragments in matrix could correspond to coarsely ground cereals mixed with a liquid to form a porridge or a dough used towards the preparation of some foodstuff.

The observations based on stereomicroscopy and scanning electron microphotography presented above offer a means of distinguishing between different forms of ancient cereal fragments that could correspond to specific food preparation practices. At the same time, they alert against over-interpretation as various factors such as the humidity of the grain prior to charring (dry, soaked and drained, immersed in liquid) can drastically affect the morphology of the grain.

The study attempted here offers a means to identify in the archaeobotanical record different food preparations such as ground grain, bulgur, ground malt and boiled whole grain. Even when overlap of some features exists, bulgur is distinct from coarsely ground grain and malt, if charred in dry conditions. Parboiled grain (as in bulgur or boiling during a fire accident) broken after charring is also potentially distinguishable by patches of shiny areas on the fracture surface and extreme starch gelatinisation visible under the SEM. In the case of ground malt in water, the presence of many husks might be a slight hint for ground malt. Another potentially diagnostic feature of malt and/or fermentation of malt may be the presence of amylolytic pores in starch granules as has been observed in desiccated remains from ancient Egypt that contained starch granules with a characteristic “pitting” (Samuel, 1996; Fig. 4) and recently identified as “amylolytic pores” in charred finds from Viking Denmark (Cordes et al., 2021). Yet, the malt specimens we have examined did not bear such evidence for this ‘pitting’ or amylolytic pores. Thin aleurone cells, a recently introduced criterion for the identification of archaeological malt (Heits et al., 2020), could also be used as a means to identify malt. As this, however, may depend on various factors such as the duration of sprouting, the absence of aleurone thinning from cereal fragments would not necessarily be indicative of the absence of malt. A more reliable identification of malt can be achieved by detecting signs of sprouting observed under a stereomicroscope (see for example Valamoti, 2018; Valamoti and Stika, 2019) though ground malt would rarely preserve traces of the sprouted embryo.

4.2. On the track of the earliest bulgur

In light of the experiments, the bulgur-like fragments of Mesimeriani Toumba do not correspond to dry, stored cracked wheat since they demonstrate a glassy surface when observed with a stereomicroscope and extreme gelatinisation under the SEM. It is unlikely that they correspond to ground dry malt as they do not have a rugged, irregular fracture surface. Thus, they could correspond either to bulgur stored in the house during its destruction by fire or, to ground wheat/ground malt/bulgur, mixed with a liquid at the time of its destruction by fire. The near absence of agglomerations of fragments and the absence of the melting effect, however, diagnostic features for fragments that came in contact with heat while wet, renders the second interpretation very unlikely. It is therefore safe to conclude that these fragments could not correspond to stored, ground malt or to ground malt soaking in water as part of a fermentation process to produce beer; nor could they correspond to ground grain or bulgur soaking/boiling in water. The cereal grain fragments found in a clay pot at Mesimeriani were most likely a stored concentration of predominantly (90%) small cereal fragments (<1 mm) generated prior to charring, from grain that had been parboiled and dried rather than grain that had been wet upon contact with heat. The size range of the Mesimeriani fragments is also of interest as it reveals yet another aspect of the culinary practices at the site, the sieving of ground parboiled grain. Some fragments are even smaller than 500 μm and correspond to 36% of the total fragment concentration.

Starch gelatinisation and the resulting glassy appearance is most likely related to duration of parboiling. It is of interest here to note that the long parboiling of the experimental and ethnographic bulgur resulted in highly gelatinised grain endosperms (Fig. 12e and f) while those of the Valamoti et al. (2008) pilot study, whereby grain had parboiled for 35 min, resulted in more variable gelatinisation effects within the same grain fragment, from very mild to significantly modified starch granules. There seems to be a gradient in patchy gelatinisation under boiling for 35 min and the extreme gelatinisation of the experimental bulgur (see above). The variable level of glassy surfaces on the fragments in the Mesimeriani assemblage as well as variable levels of gelatinisation could suggest a short duration of parboiling. The small size and limited presence of fragments bigger than 1 mm suggests either that the grain had been initially ground to finer particles than those observed at Kosmati or, more likely, that the assemblage charred in the Mesimeriani pot corresponds to the fine fraction of bulgur sieving which in the case of our ethnographic observations was reserved for trachanas preparation. After grinding, any bigger fragments might have been reserved by sieving, for another preparation and thus stored elsewhere.

Grinding in prehistoric Greece is clearly evidenced through finds of stone tools shaped for this purpose from Neolithic and Bronze Age contexts, spanning the 7th to the end of the 2nd millennia BC. A recent study shows variable spatial and temporal patterns as regards grinding and pounding equipment and underlines the significance of this step towards food preparation (Bekiaris et al., 2020; Ninou et al., in prep.). The archaeobotanical finds of cereal fragments studied here reveal more complex processes, beyond the mere grinding of cereal kernels, processes involving the pre-cooking of grain, their grinding and sieving aiming for a specific fragment range, all suggesting the transformation of grain into a more elaborate food ingredient. The size of archaeologically encountered fragments, intentionally generated as part of a specific culinary preparation as well as the liquids with which cereals might have been mixed is expected to vary, depending on recipe, person operating the grinding equipment, circumstances of food preparation, types of sieves used, etc. In our ethnographic observations at Kosmati, two size grades of fragments were recorded, the coarse one, over 2 mm, reserved
for bulgur, and the finer fraction, used in the preparation of trachanas. Ancient textual information and ethnographic observations in the eastern Mediterranean suggest the use of three size grades of cereal fragments, intended for the preparation of different foodstuffs (e.g. Valamoti, 2011 for a review, also Wilkins and Hill, 2006) further highlighting the potential variability in culinary practices of the past.

Finally, we cannot exclude the possibility that parboiling to produce the Mesimeriani finds took place in a liquid other than water. Milk could have been used to boil cracked wheat or bulgur towards the production of trachanas (Valamoti, 2011). In our ethnographic observations at Kosmati, trachanas was prepared by mixing bulgur with milk, in other parts of Greece, cracked wheat is directly parboiled in milk (e.g. Valamoti and Anastasaki, 2007; Valamoti, 2011).

Our experimental specimens confirm that at the end of the 3rd millennium BC a very sophisticated preparation, a complex recipe that required parboiling and drying of the grain prior to grinding, was being employed. This foodstuff was also the outcome of sieving after grinding visible in the rather homogeneous fragment size range. The shiny appearance of the Mesimeriani finds fits better to the initial interpretation as parboiled grain, dried and ground, i.e. some form of bulgur or trachanas or a similar product (cf. Valamoti, 2002; Valamoti et al., 2008). Both preparations are precooked cereals, foods with a long shelf life and easy to convert to a dish, a form of prehistoric “fast foods” as they require little cooking time and fuel compared to uncooked grain (Valamoti, 2011, p. 19). Their production takes advantage of the Mediterranean summer dry heat, a necessary prerequisite for drying foodstuffs for long-term preservation, as well as the availability of freshly harvested cereal grain. Parboiling of cereal kernels would offer an additional advantage as kernels become less vulnerable to insect attack (personal observations on stored experimental specimens, also Bayram, 2006). The Mesimeriani finds reveal the prehistoric roots of food preparations known in the Aegean and circum-Mediterranean countries such as bulgur and trachanas, cooked cereals that go beyond the mere production of cracked wheat that results by the mere grinding of grain. Each type of food consisting of cereal fragments has different culinary uses, cracked wheat for example is used to thicken soups while bulgur is used for more sophisticated dishes such as stuffed vine-leaves, while trachanas is a balanced, full meal in its own right (Valamoti, 2011).

Besides concentrations of loose cereal fragments such as those from Mesimeriani, lumps of fragments can be encountered archaeologically (cf. Valamoti et al., 2019a). Agglomerations of archaeological cereal fragments, fused together as individual fragments or into a matrix, could correspond to unsieved, ground grain, mixed with a liquid to form a foodstuff. This mixture could be part of the preparation of a porridge cooked in a pot or dough baked in an oven or a pan, in the form of different types of cereal foodstuffs such as rusk, cakes, breads etc., ready for immediate consumption or dried and stored for later use. Among these finds, lumps formed intentionally could be dried and stored for piecemeal consumption as is the case with different forms of trachanas (see above, Valamoti, 2011). Trachanas has a long shelf life and is very nutritious, suitable for toddlers and the elderly (Valamoti, 2011). Yet, trachanas is not the only type of food that could occur archaeologically in the form of lumps of cereal fragments. Dried sourdough, dried malt cakes (Damerow 2012; Zarnkow et al., 2011) or dried rusk made of ground cereals, kneaded in the form of a cake (cf. ancient Greek maza) could have been stored for later use, yet it is expected that such preparations would have a distinctive structure, something currently under investigation (Valamoti et al., 2019b; Petridou in preparation).

5. Conclusions

The results of an integrated experimental, ethnographic and archaeobotanical approach presented in this paper, offer a reliable methodological tool for a more comprehensive understanding of cereal foods of the past. Cereal fragments generated as part of specific culinary transformations can be identified in the archaeobotanical record when charring occurs in low temperatures. Our approach has integrated archaeobotanical evidence with experimental replication informed by archaeology (replica grinding tools, pots, cooking installations) and ethnography (traditional bulgur and trachanas preparation) and thus offers an unprecedented basis for the exploration of a much wider range of variables that concern changes in the morphology and topography of fracture surfaces of cereal kernels. We have examined different species, grain treatments and charring conditions and observed fracture surface through stereomicroscopy and SEM identifying reliable diagnostic features for a range of distinct cereal food preparations corresponding to simple (ground grain) or more complex recipes such as ground malt, bulgur and trachanas. The diagnostic features put forward in this paper present a basis for comparisons with archaeological finds that can be of wide applicability to archaeobotanical investigations of past culinary practices. The Early Bronze Age finds from Mesimeriani Tomba examined here are interpreted in light of our experiments as clear evidence for parboiled grain, ground and sieved.

Our study enables a better understanding of past culinary practices using cereal fragments. Rather than lumping all cereal fragments in a general term ‘bulgur’ as is often the case in the archaeobotanical literature, our results show that it is possible to discern different cereal grain foodstuffs through the traces left from processing steps on fracture surface. In this way we can, potentially, infer specific culinary practices that correspond to different recipes, provided ancient charring conditions allowed for a good preservation of the archaeobotanical material. Different food preparation processes combined with specific charring conditions may lead to similar features on archaeological remains of cereal fragments, therefore inferences on past culinary practices should not be made on the basis of only a few fragments and without careful consideration of the archaeological context. At the same time, one needs to keep in mind that the range of culinary variability as expressed in recipes having cereals as the main ingredient is vast, thus in no way should this study be considered as the key to unlock all the recipes behind charred cereal food preparations encountered archaeologically. The potential and limitations of our approach rest in the diagnostic features and points of caution, especially where overlapping features occur.

Further investigations could broaden the scope by including different liquids, mixing processes (fermentation, double baking, drying) and charring regimes in the variables affecting the archaeological identification of past cereal food preparations. The timing and origins of such cereal food preparations as well as the factors that may have led to their invention are of great interest as food preparation is closely related to practical issues of feeding smaller or larger families or groups of people as well as to culinary identities expressed through specific ways of transforming an ingredient into a recipe and a meal. We hope that our work makes an important contribution towards unlocking prehistoric foodways and culinary changes across space and over time.

Declaration of competing interest

The authors declare that there is no competing interest.

Acknowledgements

This research has been funded by the European Research Council, in the context of Project PLANTCULT “Identifying the Food Cultures of Ancient Europe”, conducted under the European Union’s Horizon 2020 Research and Innovation Program Grant Agreement no. 682529, Consolidator Grant 2016–2021. Without the generous funding of the ERC it would not have been possible to expand the 2002 and 2008 pilot studies conducted at the Aristotle University of Thessaloniki in order to develop a methodological tool for the archaeological identification of cereal food preparations based on cereal fragments. This work forms part of a PhD thesis conducted by Chryssa Petridou at the Aristotle University of Thessaloniki. The retrieval of the archaeobotanical
material presented here has been funded by the Greek Ministry of Culture, the Institute for Aegean Prehistory and the Aristotle University of Thessaloniki who are gratefully acknowledged. SMV would like to deeply thank Delwen Samuel for her seminal work and her input, as reviewer to the Valamoti 2002 paper, an influence that has inspired the work undertaken in this paper. We wish to thank Stavros Kotsos and Dimitrios Grammenos for entrusting us with the study of the Mesimeri material. We wish to thank the late Sophia Papageorgiou, the Institute for Aegean Prehistory and the Aristotle University of Thessaloniki, and Toni Palomo who helped with the design and construction of the grinding stones that were used to grind the modern reference material. We are also grateful to Danai Chondrou for guiding the specimens used in this study. Anastasia Dimoula, Maria Ntinou, Sandra Prevost-Dermarkar, Evi Papadopoulou, Evita Kalogiroppoulou and Yannis Stagkidis contributed towards the design and preparation of the replica pots and cooking facilities used for the production of the experimental bulgur. Fig. 2 was taken by Georgina Pratts-Ferrando. The photo of the burnt house from the Early Bronze Age site of Mesimeri was kindly provided by the excavators, Dimitrios Grammenos and Stavros Kotsos. Trisyevgeni Papadakou made final edits to the English text. Giorgos Kapetanakis helped with travel and photography. Tassos Stavros Kotsos. Trisevgeni Papadakou made final edits to the English text. Giorgos Kapetanakis helped with travel and photography. Tassos Bekiaris helped with the preparation of the Figures in their final format while Christoph Herbig, Mustafa Bayram and Malik Larsson kindly provided relevant literature. Last but not least we are grateful to Robin Torrence, Amy Bogaard and three anonymous reviewers for their valuable comments on an earlier version of this manuscript.

References


