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Reviewed Article:

The Ancient Magic of Malt: Making Malt Sugars and Ale from Grain Using Traditional Techniques

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The transformation of grain into malt, malt sugars and ale is a three step process. First, the controlled germination (malting), then 'mashing in' and collecting a sweet liquid known as wort and finally, the fermentation by pitching the yeast which converts the sugary wort into an alcoholic beverage. Each step requires different conditions for the process to work. They cannot be combined. Understanding these processes enables us to interpret the archaeological evidence for ale and beer brewing. This article considers how malt sugars are

made and discusses a range of 'mashing in' techniques from a practical, technical, and scientific point of view.

The process of 'mashing in' is done in a vessel called a mash tun. This is where the crushed malt and hot water are mixed together at about 65 – 67°C. The mixture is left for about an hour or an hour and a half, keeping a constant temperature throughout, to allow the conversion of grain starch into malt sugars by enzymes in the germinated grain. In some parts of Lithuania, Estonia, and Russia the completed mash is then baked in an oven to condition it (see figures 39, 40, 41). The high temperatures cause the sugars, amino acids and proteins to combine to create rich flavours, a process called the Maillard reaction. It is perhaps similar to ancient Egyptian or Sumerian techniques of making 'beer bread' in an oven. Keptinis could be a rare survival of this ancientmashing technique and might explain the wide variety of ancient Egyptian beers.

> "By doing these mashing experiments I realised that making malt sugars was, potentially, a grain processing technique that dates back to the first farmers of the Fertile Crescent, thousands of years ago. I demonstrated that a container is not necessary to make tasty malt sugars from malted grain. The basic and simple technique of gentle heating on hot stones and making sweet malt cakes and biscuits would precede pottery, possibly even going back to the Natufian era of the epi-palaeolithic. Making malt and malt sugars was one of the reasons

Background

This paper is presented as a historical narrative as well as being an explanation of basic 'mashing in' techniques. I aim to tell the story of the development of my understanding of how to make malt and malt sugars from the grain. I have learned from other experimental archaeologists, from ancient technologists and brewing scientists as well as from ethnographic research and the study of traditional style malting, mashing and fermentation techniques.

One of the common myths about the origins of beer thousands of years ago is that grain was perhaps left in a container, it got wet and, somehow, turned into beer. This is impossible. The conditions for making malt and malt sugars do not exist in this situation. The processing of grain into an alcoholic beverage is completely different to the fermentation of grape juice, honey and sugar. Grapes have a high level of sugars and natural yeast on the skin. Mead is made from diluted honey which is, again, a natural source of sugars. Country wines with ingredients such as dandelion, nettle, or parsnip always have plenty of sugar added. Yeast converts sugar into alcohol. The flowers or root vegetables are added for flavour or colour. Some flowers have medicinal properties and require alcohol in order to work. Other flowers are used as preservatives. Together with my husband Graham, who is a skilled brewer, we have made a few batches of ancient style ale using a handful of dried meadowsweet (*Filipendula*

for the origin of grain agriculture.

ulmaria) flowers instead of hops and we can say that it is an excellent preservative.

In this article we look at some of the different techniques of 'mashing in'. This is a term that all-grain brewers use to describe the process of making malt sugars from malted grain in the mash tun. Although there are a number of different techniques and the equipment may differ, the fundamental biochemical process of the enzymatic reduction from grain starch into malt sugars remains the same. As Graham the brewer says, "This is a universal 'law of nature' governed by the germination of grain. It applies equally to the here and now as it did to Ancient Egypt and Sumeria and as it did to its' origins in the Fertile Crescent (the land of milk and honey) many thousands of years ago. It is no longer practised in these regions due to religious influences, so it is easy to overlook its' antiquity as a cereal processing activity."

Grain is transformed into malt sugars by first turning it into malt (germinated grain) and then turning that malt into liquid malt sugars. Malting is a clever trick that diverts the grain's natural growth cycle and controls its' progress. The earliest archaeological evidence for malted grain dates to c13,000 years ago at Raqefet Cave, Israel (Liu et al. 2018, p.783,).

The process of 'mashing in' is another clever trick. This involves getting the malt to digest itself into malt sugars in the mash tun. Crushed malted grain is mixed with hot water and the enzymes produced in the germination process quickly digest the starch into sugars. This process takes about 1½ hours at a steady temperature of 65-67°C. The scientific explanations of malting, 'mashing in', and fermentation have only recently been understood (see Hough et al., 1982; Briggs et al., 1981). Maltsters and brewers have known the techniques for millennia but without understanding the biochemistry.

My interest in prehistoric brewing began in the late 1990s when I was taught that Bronze Age beakers were for beer consumption, a generally accepted idea. However, there did not seem to be anything written about how the beer was made, what the ingredients were or what equipment may have been used to make it. For my postgraduate research I began to look into these aspects. I was intrigued by the description of a 'black greasy residue' found in a food vessel in a Bronze Age cist burial at North Mains, Strathallan, Scotland (Barclay et al., 1983, pp.108-110,). The burial was of a young woman and dated to c 1540 BC. When analysed the residue was revealed as cereal based to which meadowsweet pollen was added. I was curious. Does this residue represent ale? If so, how was it made? Further research revealed that similar residues were found on 5000 year old Grooved Ware pottery sherds from a ceremonial site at Balfarg, Scotland (Barclay et al., 1993). These residues were described as a coarse cereal based preparation, with added meadowsweet, apparently a whole flower head. Again, could this be evidence of ale?

Brewing is a regular part of our home life, as my husband brews beer 'from the grain', not from beer kits or malt extract. We don't make our own malt. We buy sacks of commercial pale crushed malt from a malt supplier (See Figure 1). The 'mashing in' is done at home in our plastic mash tun. It has an electric heating element and a tap. We use a grain bag to line the mash tun and this acts as a filter. Mashing involves mixing the crushed pale malt with lots of hot water (See Figures 2 and 3). There is always a deliciously sweet aroma as he 'mashes in'. It looks like a magical process. But making beer is not a magical thing. It is a biochemical process. It is also an ancient and traditional technology.

Today there are many kinds of malt available for the brewer to use. This can be confusing for non-brewers. Liquid malt extract (LME) and dried malt extract (DME) are modern products, being concentrated and dried using modern industrial techniques. Roasted and caramelised malts are also a modern product, dating from the Industrial Revolution (Cornell, 2004). They are used to flavour and colour ale and beer and make up a small part of the grain bill, usually no more than 10%. Roasting the malt at high temperatures destroys the starch converting enzymes that are necessary to make the malt sugars in the mash tun. This paper is about using the sort of malt that has been made for millennia and that is known by maltsters and brewers as a 'base malt'. It provides all the necessary fermentable sugars in the mash tun. Barley, wheat, rye, oats and sorghum can all be malted and mashed to make a sweet wort for fermentation.

The processes of 'mashing in' and fermentation

Figures 1 to 6 show our mash tun and how we 'mash in' and make beer at home. About 18lbs (8 kilos) of Maris Otter crushed pale malt is mixed with 5 imperial gallons (22 litres) of hot water to make a thick mixture, the mash (See Figures 2 and 3). This is left in the mash tun for about an hour and a half during which time enzymes in the malted grain convert the starch into malt sugars (See Figure 3). This is the saccharification process. The mash tun has a tap so that the sweet liquid wort can be run off and collected (See Figure 4). A clear wort can be obtained by first pouring cloudy wort and then hot water through the mash. These processes are known as lautering and sparging. Figure 5 shows the first runnings, from lautering, which are very sweet, containing 20% or more sugar. Sparging involves washing more sugars out of the mash by gently adding more hot water and collecting the run off. The sweet wort is then transferred into another container, the fermentation vessel.

We use a commercial yeast to start the fermentation (See Figure 6). We have also used kveik, a yeast obtained from farmhouse brewers in Norway. Yeast can be collected by skimming the foam from a fermenting brew, keeping it cool and then re-using this to start the next brew. Breweries do this today to collect and keep their yeast. The story of farmhouse kveik yeast and how it was brought to the attention of beer brewers worldwide has been told by Lars Marius Garshol (2020).

Fermented wort, on its own, does not keep. It is prone to infections by micro-organisms. To preserve it particular microbicidal herbs are added. This is the main difference between ale and beer. Traditionally, beer contains hops which need to be boiled whereas ale was preserved or flavoured with herbs which do not need to be boiled. Some of these herbs used in the past were medicinal, requiring an alcoholic base to be efficacious. Today, however, for most people the difference between ale and beer is blurred.

Hops have been used to preserve and flavour beer since medieval times. Previously, a variety of herbs were used by brewers. One of these is meadowsweet, a tall plant with white flowers that grows profusely in Scotland (See Figure 7). I have been told that it has been used by brewers on Orkney until recent generations. Other brewing herbs include bog myrtle, yarrow, and sage.

We have made ancient style ales using crushed malted barley and meadowsweet flowers instead of modern hops. The meadowsweet flowers were gathered on Orkney in late July and dried for storage and further use in subsequent brews. We have had positive comments from a number of tasters; they say our ancient ale tastes very good and that it is more like mead than beer or ale.

Mashing experiments

My first experiments aimed to find out whether I could make malt sugars using equipment that would have been available to Neolithic farmers, specifically, an earthenware bowl as a mash tun and an open fire as the heat source (Dineley and Dineley, 2000). Graham makes beer at home using Fawcett's Maris Otter malt, so we always have a sack of crushed malted barley in our house. I took some crushed malt from the sack and mixed it with water in an unglazed earthenware bowl, purchased from a garden centre. We used tap water. The bowl was about 10 inches (25 cm) in diameter and about 6 inches (15 cm) deep. We sealed the bowl by melting beeswax into the heated bowl and letting it soak in. I started the mashing experiment with cold water and heated the mixture slowly on hot ashes rather than over a flaming fire (See Figure 8). I also made a thicker mixture of crushed malt and water as 'cakes' or 'biscuits'. These were warmed on a hot flat stone beside the fire. I kept them constantly damp by dripping more water on them (See Figure 9). Water is a necessary part of the saccharification process, it is part of the chemistry. For the purpose of these experiments in making malt sugars, the source of the water is not important as long as it is clean and microbe free.

As both mixtures warmed up I got the same delicious, sweet aroma that Graham does when he 'mashes in' using our modern mash tun. The bowl mash became darker and tasted sweeter. I successfully made malt sugars using equipment that was available to grain processors of the early Neolithic. There was no need for thermometers or complicated brewing equipment. Making malt sugars from crushed malted grain is a simple process,

requiring only water and the application of heat. Containers are not even necessary because the barley 'biscuits' that were heated on a hot flat stone also made attractive and tasty malt sugars (See Figure 9).

I have done this mashing experiment many times since then and so it has become a demonstration. Of all the demonstrations that I have performed, one of the most successful was at the Eindhoven Open Air Archaeology Museum in the Netherlands, in spring 2010 (Dineley, 2011). This was part of a beer brewing workshop organised by EXARC. I achieved an excellent conversion of grain starch into malt sugar using a burnished bowl made by pottery expert Flor Buchuk Gil as a mash tun (See Figures 10 & 11). This bowl is 13 inches (33 cm) in diameter and 6 inches (15 cm) deep. At the Eindhoven demonstration the few sweet and tasty malt biscuits that had been made on the hot flat stone were quickly consumed by visitors to the event. People commented that the biscuits tasted delicious, almost like modern granola bars. The bowl mash was completed within an hour. I did not have the opportunity to gather wort to ferment it. However, the purpose of the demonstration was to show how to make malt sugars using simple equipment.

What is malt?

The bowl mashing and sweet biscuit experiments inspired me to learn more about malt and the malting process. A base malt is grain which has begun to germinate and which is then dried carefully. When I began my research I contacted James Fawcett, one of the owners of Thomas Fawcett and Sons. He gave us a tour of their floor maltings, explaining the process in detail to us (See as example Figure 12).

To make a base malt: harvested, threshed, and winnowed grain is steeped and regularly aerated for a few days. Grain is a living organism and needs to breathe, hence the aeration. When grain is left in a container without regular changes of water and air rests it will drown and go bad. One option for steeping is to leave the grain in a sack or fine basket in a shallow bubbling stream. This provides both oxygen and fresh water for the grain to begin to germinate. Barley is the most often used grain for malting but wheat, oats, sorghum and rye can also be malted. When the roots and shoots begin to show the wet grain is turned out onto the germination floor. As the grain begins to grow it must be turned and raked regularly. This inhibits the development of the shoot. When the rootlets and shoot (acrospire) have grown to about one third the length of the grain it is time to dry the malt. Floor malting is an ancient craft that requires the maltster to have skill, experience, and specialised knowledge (Dineley, 2015).

Floor malting technology goes back thousands of years (Liu et al., 2018). Malt can be dried in the sun or carefully, with warm air, in a kiln. It is crucial not to kill the 'spirit' of the grain, as described by Henry Stopes (1885) in his treatise on malt and malting.

In the summer of 1997 Graham and I visited the 18th Century Corrigall Farm Museum on Orkney. The custodian at the time was Harry Flett, an Orcadian farmer, maltster and beer brewer. He explained how he made his malt. It was the same process as at Fawcett's: steeping, aeration, floor germination, and careful kilning. Harry Flett gave us 25 kg of bere barley malt which he had made in the Corrigall Farm grain barn, the last batch of barley to be malted there. Bere is a landrace barley that goes back to Viking, medieval, or possibly earlier times (Wallace et al., 2018). The bere was germinated on the beaten earth floor of the grain barn and it was dried in the kiln. Using this malt we made a few 5 gallon batches of ancient style ale, adding a few ounces of dried meadowsweet flowers instead of hops. It tasted almost like mead.

Malt does not always have to be germinated on a floor. Garshol (2020) describes some of the traditional malt houses of Norway. Barley is steeped in the stream then germinated on wooden shelves. For hundreds of years wooden cabins such as these have been used in Norway, Sweden, and Finland to germinate and dry the malt (See Figures 13,14,15).

See Traditional malting in Morgedal 2015: https://www.garshol.priv.no/blog/341.html

Biochemistry and physiology of grain germination

What happens in a germinating grain? Between 2000 and 2004 I had access to the library of the Satake Institute for Grain Process Engineering at UMIST, Manchester. The opportunity to talk to and learn from grain processing scientists was a great benefit to my understanding of malting and brewing science (for example Briggs et al., 1981; Hough et al., 1982).

Figures 16 and 17 are diagrams taken from from Bewley and Black (1994) and they are helpful for understanding the biochemical and physiological processes of cereal grain germination.. When grain is sufficiently wet and oxygenated, after steeping and aeration, the embryo releases a growth hormone, gibberellin. Beneath the husk is a layer of cells known as the aleurone layer. Gibberellic acid activates the aleurone layer cells to release several enzymes, including alpha and beta amylase. This begins the conversion of grain starch into maltose and glucose, the food source of the growing grain. Modification is the term used by maltsters today for this process.

Figure 17 shows this grain modification with rootlets and a tiny shoot (acrospire) emerging. The starchy endosperm is under modified (UM). The parts closest to the aleurone layer and embryo are wholly modified (WM). Further away, the endosperm is mostly modified (MM) or partially modified (PM). If the grain grew to have green shoots there would be very little starch left to be converted into sugars in the mash tun. It is useless as malt.

Archaeological evidence for malt

Carbonised grain has been found at a number of archaeological sites dating from the Neolithic onwards. In some of these discoveries, the archaeobotanical report states that the embryo is missing (Cordes et al. 2021). Given an understanding of grain germination physiology this is a strong indication that the grain had been malted and, depending on the context, had been carbonised because of a failed kilning. The malt house caught fire. Even recently, this is a common fate for a traditional malt house.

The largest assemblage of Neolithic carbonised grain found to date in Britain was discovered in the 1970s at Balbridie, the site of a large rectangular (26x13metres) timber building on the south bank of the river Dee in Aberdeenshire, Scotland (Fairweather and Ralston 1993). Thousands of carbonised grains were excavated. Initially interpreted as a medieval hall, it was later revealed to be an early Neolithic site. Radiocarbon dates range from c 4000 BC to 3400 BC when the building was destroyed by fire. It is a most intriguing site and is described as a place where grain was stored and processed. More details can be found here: https://canmore.org.uk/site/36669/balbridie

Professor Ian Ralston, one of the excavators of the site, let me have six of these tiny 6000 year old carbonised barley grains to study. One of the grains was examined using scanning electron microscopy. This was done by a research student of the Satake Institute for Grain Process Engineering, UMIST, Manchester (See Figures 18, 19, 20).

The embryo is missing (See Figure 18). The tiny grain was cut in half (See Figure 19). I am not sure what I expected to see, having been told that the structure of ancient carbonised grains would not be well preserved. A close up image of the aleurone layer was made (See Figure 20). I was surprised to see that individual aleurone layer cells had survived and were visible. It is possible to identify malting in ancient carbonised grains by looking at the morphological changes in the aleurone layer cells. This has been done recently (Heiss et al., 2020).

Mashing with hot stones

In the garden ‘hearth mashing’ experiments (Dineley and Dineley, 2000) I used beeswax sealed earthenware bowls as mini mash tuns. I made a small amount of sweet liquid malt sugars (wort). But the brewer needs to make plenty of ale for feasts and celebrations and therefore needs lots of wort.

I was inspired by the work of the Moore Group, archaeologists from Galway, Ireland. I first met the group in 2004 at a beer conference held in Barcelona. We discussed the possibility of using burnt mound troughs for brewing beer. Burnt mound troughs, or fulacht fiadh, appear in the late Neolithic and were used throughout the Bronze Age and even into Norse Orkney. They consist of a large horseshoe shaped pile of fire cracked rocks around a large stone or wooden lined trough in the ground. They are found throughout Britain and Ireland. These rectangular troughs can be around 3 feet (1metre) wide, 3 feet (1metre) deep and 6 feet (2

metres) in length. They are often sited in waterlogged ground. Their purpose is to heat large amounts of water (around 200 litres or 40 imperial gallons) using fire heated stones. Water would have been obtained from a nearby stream or river. The troughs were originally interpreted for boiling meat but animal bones are not associated with these sites. They are also interpreted as 'saunas' but it is not clear how this would work. (Quinn and Moore 2007).

At the World Archaeology Conference in Dublin, 2008, the Moore Group demonstrated how hot rocks could be used in a wooden trough to 'mash in' and make malt sugars. It was an impressive demonstration of hot rock mashing. The trough made an excellent mash tun. Figures 21, 22, 23 and 24 are some of my photographs of the event, showing how the trough was filled, how the rocks were heated and added to the crushed malted barley and water. The rocks were piled up at one end of the trough and the sweet dark brown wort was easy to collect, using jugs, to take away for later addition of yeast and fermentation.

More details here: https://merryn.dineley.com/2016/07/trough-mash-and-wort.html

In the summer of 2010 Graham and I were invited to the island of Bressay, Shetland, to work with Dr Lauren Doughton. For her doctorate she was investigating burnt mounds and troughs, looking into potential uses. These included dyeing wool, bathing, and brewing beer (Doughton, 2014). On a cold blustery June day we filled the replica stone trough with 200 litres of water. The trough was between one third and a half full. It was roughly 18 inches (45 cm) deep, 2 feet 4 inches (70 cm) wide and about 4 feet (1.25 metres) long. We heated rocks and rolled them down the slope using garden forks (See Figure 25). When the water was hot enough we added 50 kilos of crushed malted barley (See Figure 26). We found that it was easy to heat the water to around 75°C, a perfect temperature for the strike, the brewers term for adding the crushed malt to the hot water. This process reduces the temperature to the desired 65-67°C for 'mashing in'. The crushed malt was left in the hot water for about an hour by which time the saccharification was complete (See Figure 27). It was an ideal mash tun.

We collected the sweet dark brown wort using jugs, transferring it into a plastic fermenting vessel and added some commercial yeast. A handful of dried meadowsweet flowers were added later, after the fermentation was complete. We made a fine tasting golden coloured Bronze Age style ale (See Figure 28). It was one of the best ancient ales that we have ever made.

Medieval Brewing

The 'mashing in' or saccharification process happens regardless of the type of equipment used and regardless of the nature of the heat source. Figures 29 to 33 are photographs from a beer brewing demonstration by Huib van der Stam and his colleagues at the EXARC Beer and Brewing Workshop at the Eindhoven Open Air Museum in 2010. Crushed malted barley was heated in the metal mash tun (See Figure 29). Wood was the fuel for the brick built mash

oven. When I asked the brewer how he regulated the temperature of the mash he answered with a wry smile. Time, experience, plenty of practice and skill, he said.

The team transferred the mash into the lauter tun using ceramic jugs at first, then they tipped the mash tun for the last of the mash (See Figures 30, 31). Their lauter tun had a removable metal mesh fitting at the bottom as a filter to contain the grain husks. The brewers were then able to lauter (See Figure 32). Not every lauter tun has such a fitting. It is a modern invention. Traditionally, juniper twigs or straw were used as a base for the barley husk filter (Laitinen, 2019; Garshol, 2020). Lautering means that they collected some cloudy wort and poured it over the mash using a paddle, so as not to disturb the grain bed and maintained this until the wort ran clear (See Figure 33). The best filter for the tiny bits that make the wort cloudy are the grain husks themselves, that is, the grain bed.

The brewers then heated water in the cleaned mash tun and carefully poured it through the mash. This is called sparging, the technique by which more liquid malt sugars can be collected by being washed out of the sweet mash. The brewers collected around five or six gallons of sweet clear wort. This was then transferred back into the mash tun, hops were added, and the hopped wort was boiled. It's the same process that we follow when we brew using our modern plastic mash tun and fermenting vessel.

The processes of 'mashing in', lautering, sparging, and hop boil took most of the working day to complete. The brewers collected the hopped wort in a plastic fermentation vessel and took it away to add the yeast later when they returned home. It was very busy with visitors at Eindhoven Museum and therefore it was difficult to take a photo of their mash oven.

The design of the Eindhoven team's mash oven is traditional. It is built with bricks. There are several illustrations of this kind of mash oven and metal mash tun in the House Book of Mendel, an early 15th century document (Trum, 2002). Commissioned by a wealthy family, this book contains many illustrations of crafts of the time. The image of Herttel Pyrprew is the oldest known picture of a named brewer (See Figure 34). In this image he might be 'mashing in' or maybe he is adding the hops to the wort and boiling the hopped wort. It's not clear from the illustration.

On Wyre, one of the Orkney islands off the north coast of Scotland a wonderful stone built early 13th century mash oven stands in the brew house of Cubbie Roo's Castle (See Figures 35, 36). The castle, or stone fort, was built for the Norwegian Kolbein Hruga c 1145. He had several children, one of whom became the first Bishop of Orkney. Bjarni Kolbeinsson was Bishop from 1188 until his death in 1223. His seat of power was on the small island of Wyre and this stone castle or fort was where he entertained his visitors. He improved the brewing facilities and had this fine stone mash oven installed. Such a grand metal mash tun and stone built mash oven signified his high status and importance in Orkney. It was the leading edge of mashing technology at the time (Dineley and Dineley, 2020).

Ethnographic evidence and brewing techniques: a living tradition

In some areas of Europe brewers still use the ancient and traditional techniques that they learned from earlier generations. Many of these techniques go back to medieval times, if not earlier. A wide variety of equipment can be used, for example, wooden mash tuns with hot stones metal cauldrons over a fire, usually used to heat the water (See Figures 37, 38). These photographs were taken from his blog with permission.
See https://www.garshol.priv.no/blog/345.html

Over the past few years these traditional techniques of making the malt and brewing ale and beer have been documented by beer historian Lars Marius Garshol (2020). Mika Laitinen, a skilled brewer, has also documented and demonstrated a variety of mashing and beer brewing techniques in his book Viking Age Brew (Laitinen, 2019). Both books are useful resources for anyone intending to recreate ancient ales.

Another ancient mashing technique is 'keptinis alus' and it is documented and described in detail in Laitinen (2019) and Garshol (2020). This involves making the mash in the usual way in a mash tun. The mash is then baked in an oven. The resulting baked mash is lautered and sparged in the usual way, providing a wort which can be fermented. This rare and unusual oven conditioning technique brings many flavours to the resulting beer. The keptinis loaves are baked for about three hours. Traditionally the mash was formed into loaves on straw mats but today the brewers use modern baking tins (See Figures 39, 40, 41).

See https://www.garshol.priv.no/blog/394.html for more details.

In some ways, a mention of keptinis takes this paper back to the beginning, where I made the sweet malt barley 'cakes' or 'biscuits' on a hot stone beside the fire. However, there are some very significant and important differences. The keptinis brewers mash in first, then they condition the mash by baking it in an oven. It is an obscure and rare style of mashing. My back garden mashing experiments involved mixing crushed malted barley with cold water and slowly heating the mixture in an earthenware bowl and on a hot flat stone beside the fire. My experiments and later demonstrations were about making malt sugars using only the simple equipment that would have been available to early Neolithic farmers. The keptinis technique of mashing and then baking allows the Maillard reaction (explained earlier) to have an effect. Figure 41 of the finished baked mash shows this very well. The dark colour of the baked mash affects the taste of the resulting beer. It is only the outside of the keptinis 'loaf' that looks burned and caramelised. Inside the mash is a much paler colour. I think this intriguing mashing and baking technique could be an explanation for ancient Egyptian 'beer bread'.

Conclusions

By doing these mashing experiments I realised that making malt sugars was, potentially, a grain processing technique that dates back to the first farmers of the Fertile Crescent, thousands of years ago. I demonstrated that a container is not necessary to make tasty malt sugars from malted grain. The basic and simple technique of gentle heating on hot stones and making sweet malt cakes and biscuits would precede pottery, possibly even going back to the Natufian era of the epi-palaeolithic. Making malt and malt sugars was one of the reasons for the origin of grain agriculture.

This idea is supported by recent archaeological discoveries indicating that making malt was a known technology of the earliest grain processors of the ancient Near East. At the Raqefet cave in Israel, evidence for malted barley was discovered by a team of researchers from Stanford University (Liu et al., 2018). They analysed residues from 13,000 year old stone mortars. Examination of grain starch granules indicated that the grains had been malted. The discovery of a stone trough at Gobekli Tepe, Turkey, a site dated to c13,000 years ago, with fire cracked stones within indicates that the hot rock 'mashing in' technique was also a known technology in the epi Palaeolithic (Dietrich et al., 2012).

Recent examination, using scanning electron microscopy of starch granules and aleurone layer cells within carbonised grains and carbonised cereal remains indicate that grain was being malted by early Neolithic communities in Denmark and also in the Neolithic lake villages (Cordes et al., 2021; Heiss et al., 2020). The examination of the 6000 year old carbonised grain from Balbridie, the site of a large rectangular timber building in Scotland and dated to c4000BC, shows a missing embryo and changes in the aleurone layer cells (See Figures 18,19,20). This supports the idea that people were making malt in Neolithic Scotland.

The size and shape of container that can be used as a mash tun is not really important. In this article I have discussed mash tuns made from a range of materials and of differing sizes and shapes, from a 2 litre earthenware bowl to a 200 litre stone lined trough in the ground. The sweet malty biscuits that I made on a hot stone beside the fire did not even need a container. Malt sugars such as these could have been made by the first wild grain gatherers tens of thousands of years ago, leaving no archaeological trace, once they had discovered the trick of malting. Making malt from grain is a valuable skill that, once discovered, will not easily be lost. The question should not be 'bread or beer?' but 'who were the first maltsters?'

In conclusion, although different mashing techniques exist and different equipment is used the biochemical processes of the transformation of grain into ale remain the same, regardless of the type of equipment used. Understanding these fundamental processes enables the interpretation of the archaeological evidence for the manufacture of malt, malt sugars, ale and beer from the grain.

Acknowledgements

This article is based upon my presentation at the ERC funded PlantCult meeting “Ancient Beer: multidisciplinary approaches for its’ identification in the archaeological record” held at the University of Hohenheim, Germany 7-9th February 2019. See http://plantcult.web.auth.gr/en/research-eng/workshops/106-beer-workshop, Program and Abstracts.

Thanks to Graham Dineley, my husband, a skilled and experienced brewer. He has been brewing ‘from the grain’ for 38 years. This is a brewer’s expression for traditional style beer brewing using crushed malt. He does not use modern malt extracts or syrups. I am an archaeologist with a particular interest in ancient technologies. We work as a team in our research into ancient malting and brewing techniques. We think that gives us a unique perspective in the study of this particular ancient technology.

The Norwegian Farmhouse Ale Festival has been going for a few years. Because of the Covid pandemic it was held online for the first time in October 2020. There were live demonstrations of malting, ‘mashing in’, lautering, and sparging to obtain a wort and, finally, the pitching of the yeast. If you are interested in seeing malt, ale and beer being made by experts using pre-industrial equipment then I thoroughly recommend watching this event. See https://www.youtube.com/watch?v=eTDX6fds7EU

HOW TO BREW BEER WITH MASHING-IN TECHNIQUES (MERRYN & GRAHAM DINELEY)

Keywords beer

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Fig 13. A traditional Norwegian malt house. Copyrights by Lars Marius Garshol For more details see Larsblog: https://www.garshol.priv.no/blog/341.html

Fig 14. Inside the Norwegian malt house, with shelves for malting. Copyrights by Lars Marius Garshol. For more details see Larsblog https://www.garshol.priv.no/blog/341.html

Fig 15. Little 'gate' for scooping out the malt from the shelf. Copyrights by Lars Marius Garshol. For more details see Larsblog https://www.garshol.priv.no/blog/341.html

Fig 37. Farmhouse brewing in Latvia: a cauldron to heat water, wooden mash tun, hot stones to heat the mash. Copyrights by Lars Marius Garshol. See Larsblog for details: https://www.garshol.priv.no/blog/345.html

Fig 38. Farmhouse brewing in Latvia: heating the stones for the mash tun. Copyrights by Lars Marius Garshol. See Larsblog for details: https://www.garshol.priv.no/blog/345.html

Fig 39. Keptinis alus: the finished mash will be baked in the oven. Copyrights by Lars Marius Garshol. See Larsblog for details: https://www.garshol.priv.no/blog/394.html

Fig 40. Keptinus alus: the mash goes into a hot oven for a few hours. Copyrights by Lars Marius Garshol. See Larsblog for details: https://www.garshol.priv.no/blog/394.html

Fig 41. Keptinis alus is a rare technique. Baking the mash in a hot oven adds complex flavours to the ale. Copyrights by Lars Marius Garshol. See Larsblog for details: https://www.garshol.priv.no/blog/394.html

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FIG 1. OUR SACK OF CRUSHED BERE MALT. BERE IS AN OLD LANDRACE BARLEY DATING TO NORSE TIMES OR EARLIER. COPYRIGHTS BY MERRYN DINELEY

FIG 2. ADDING THE CRUSHED MALTED BARLEY TO HOT WATER IN OUR MASH TUN. COPYRIGHTS BY MERRYN DINELEY

FIG 3. THE COMPLETED MASH IN OUR MASH TUN. ALL STARCH HAS BEEN CONVERTED INTO MALT SUGARS. COPYRIGHTS BY MERRYN DINELEY

FIG 4. LAUTERING: WORT IS COLLECTED IN A JUG AND POURED BACK THROUGH THE MASH UNTIL IT RUNS CLEAR. COPYRIGHTS BY MERRYN DINELEY

FIG 5. COLLECTING THE 'FIRST RUNNINGS' OF CLEAR WORT. IT WILL BE TRANSFERRED INTO A FERMENTATION BUCKET. COPYRIGHTS BY MERRYN DINELEY

FIG 6. FERMENTATION IN PROGRESS. WE USED A COMMERCIAL YEAST. COPYRIGHTS BY MERRYN DINELEY

FIG 7. MEADOWSWEET (FILIPENDULA ULMARIA), A TALL PLANT WITH WHITE FLOWERS. WE USED THIS INSTEAD OF HOPS IN OUR ANCIENT STYLE ALE. COPYRIGHTS BY MERRYN DINELEY

FIG 8. GARDEN MASHING EXPERIMENT WITH BEESWAX SEALED BOWL, COLD WATER AND CRUSHED MALTED BARLEY. NOTE THE STARCHY WHITE LIQUID IN THE BOWL. COPYRIGHTS BY MERRYN DINELEY

FIG 9. FINISHED BOWL MASH AFTER GENTLE HEATING FOR AN HOUR. NOTE THE SWEET BROWN LIQUID (WORT). I MADE SWEET MALT BISCUITS ON THE HOT FLAT STONE BY THE FIRE. COPYRIGHTS BY MERRYN DINELEY

FIG 10. EINDHOVEN MUSEUM DEMONSTRATION: A SUCCESSFUL BOWL MASH AND SWEET MALT BISCUITS. COPYRIGHTS BY MERRYN DINELEY

FIG 11. THE SWEET MALT BISCUITS WERE EATEN BY VISITORS. NOTE THE STARCHY WHITE CRUSHED MALT BESIDE THE FIRE IN CONTRAST TO THE FINISHED DARK BROWN BOWL MASH. COPYRIGHTS BY MERRYN DINELEY

FIG 12. A MALTMAN RAKING THE MALT IN A FLOOR MALTINGS AT CRISP'S MALTINGS, GREAT RYBURGH, NORFOLK. COPYRIGHTS BY MARTYN CORNELL

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FIG 14. INSIDE THE NORWEGIAN MALT HOUSE, WITH SHELVES FOR MALTING. COPYRIGHTS BY LARS MARIUS GARSHOL. FOR MORE DETAILS SEE LARSBLOG HTTPS://WWW.GARSHOL.PRIV.NO

FIG 15. LITTLE ‘GATE’ FOR SCOOPING OUT THE MALT FROM THE SHELF. COPYRIGHTS BY LARS MARIUS GARSHOL. FOR MORE DETAILS SEE LARSBLOG HTTPS://WWW.GARSHOL.PRIV.NO

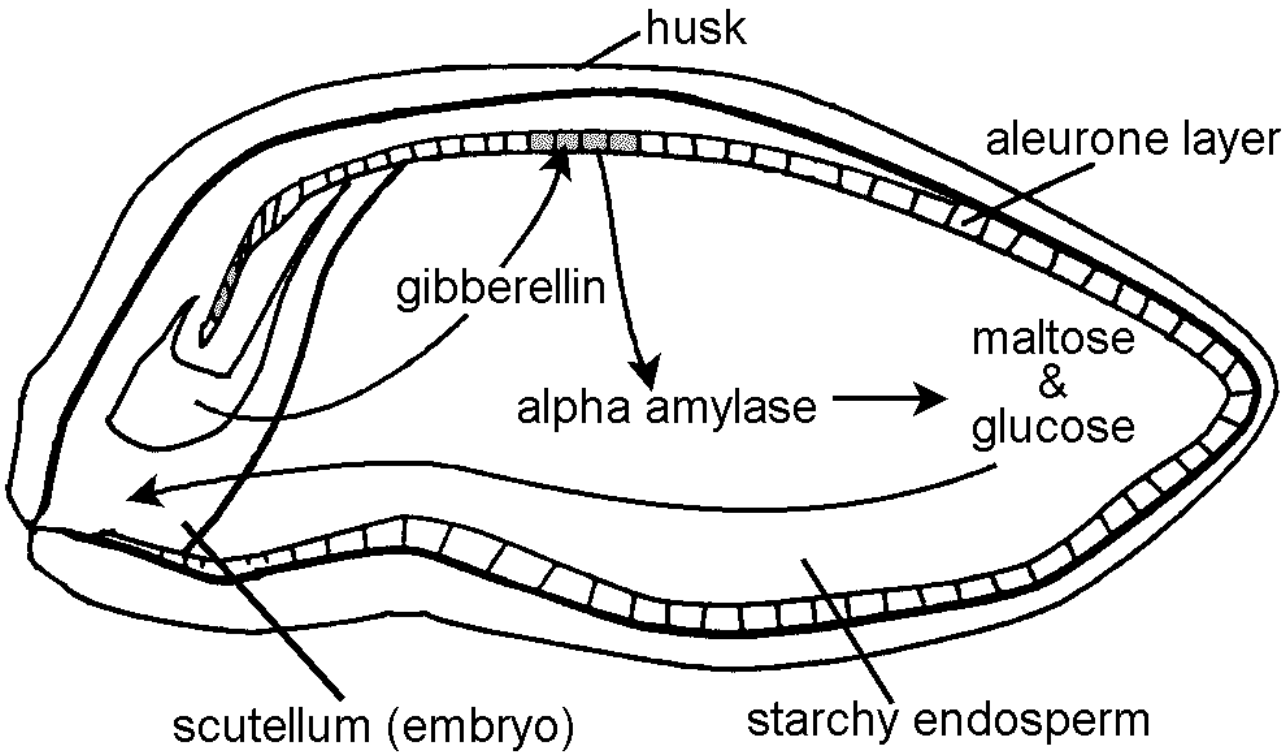

FIG 16. SECTION THROUGH A BARLEY GRAIN SHOWING GERMINATION BIOCHEMISTRY AND PHYSIOLOGY. SEE TEXT FOR DETAILS. (BEWLEY AND BLACK 1994)

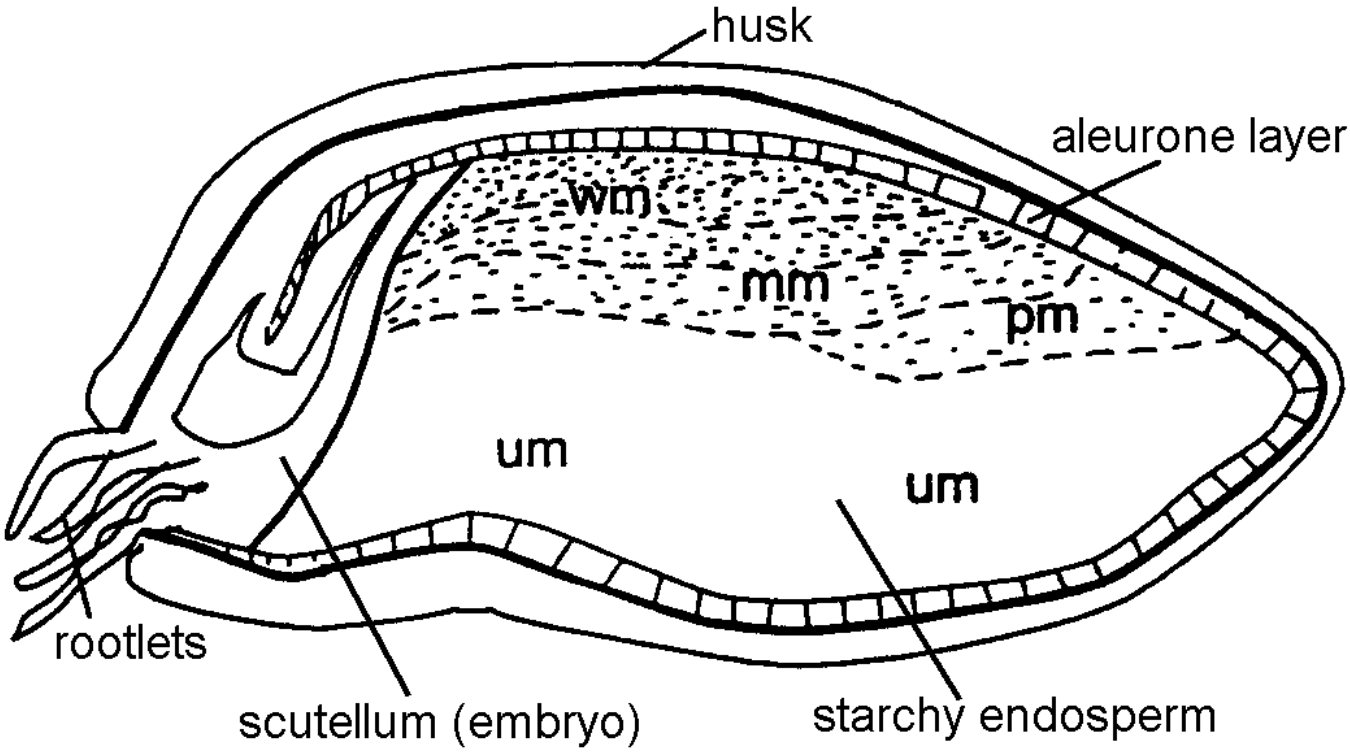

FIG 17. SECTION THROUGH A GERMINATED BARLEY GRAIN SHOWING DEGREES OF MODIFICATION. SEE TEXT FOR DETAILS. (BEWLEY AND BLACK 1994)

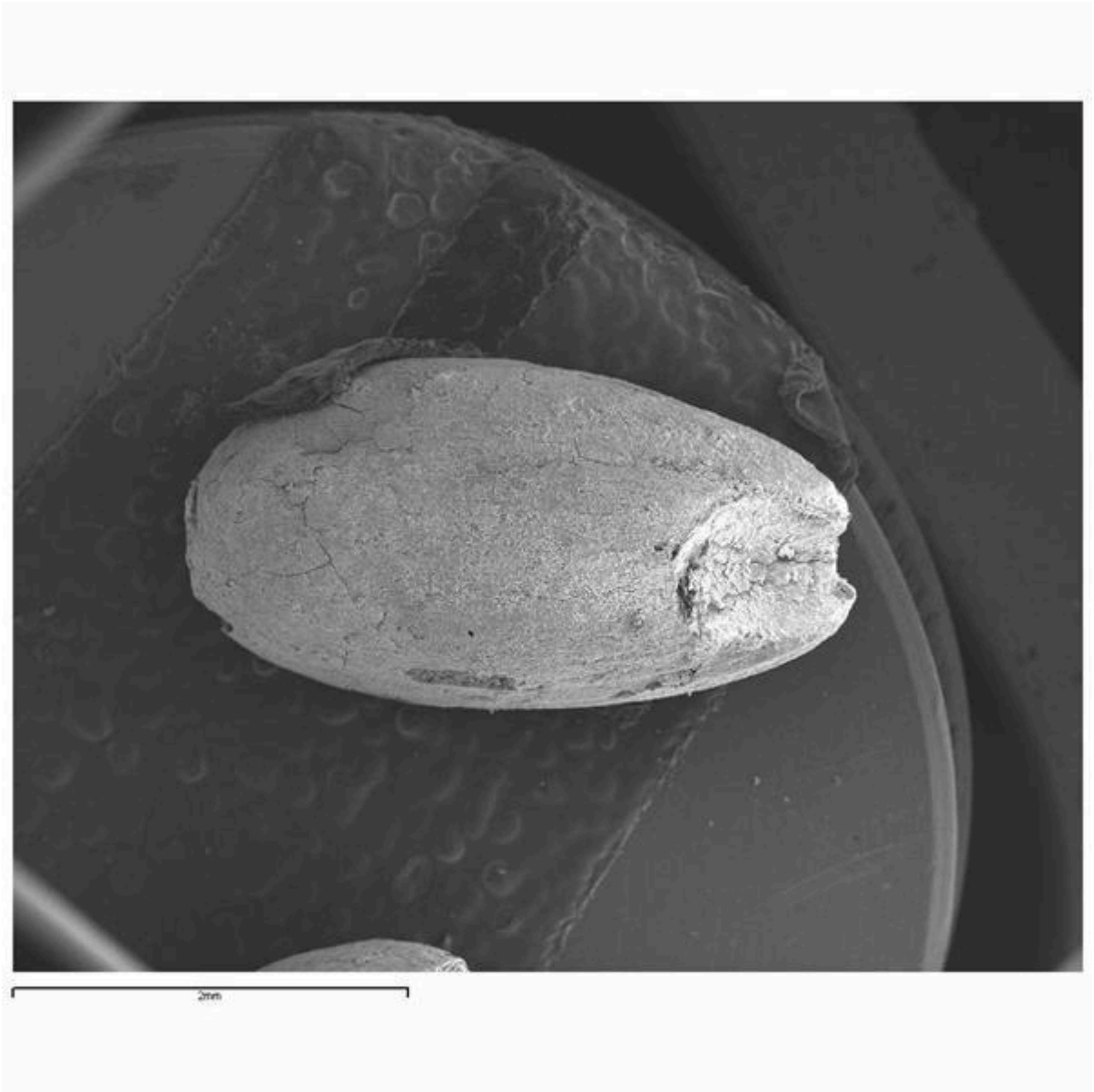

FIG 18. SEM OF 6000 YEAR OLD CARBONISED GRAIN FROM BALBRIDIE EXCAVATIONS. NOTE THE MISSING EMBRYO, INDICATING GERMINATION HAS BEGUN. COPYRIGHTS BY SATAKE CENTRE FOR GRAIN PROCESS ENGINEERING, UMIST, MANCHESTER

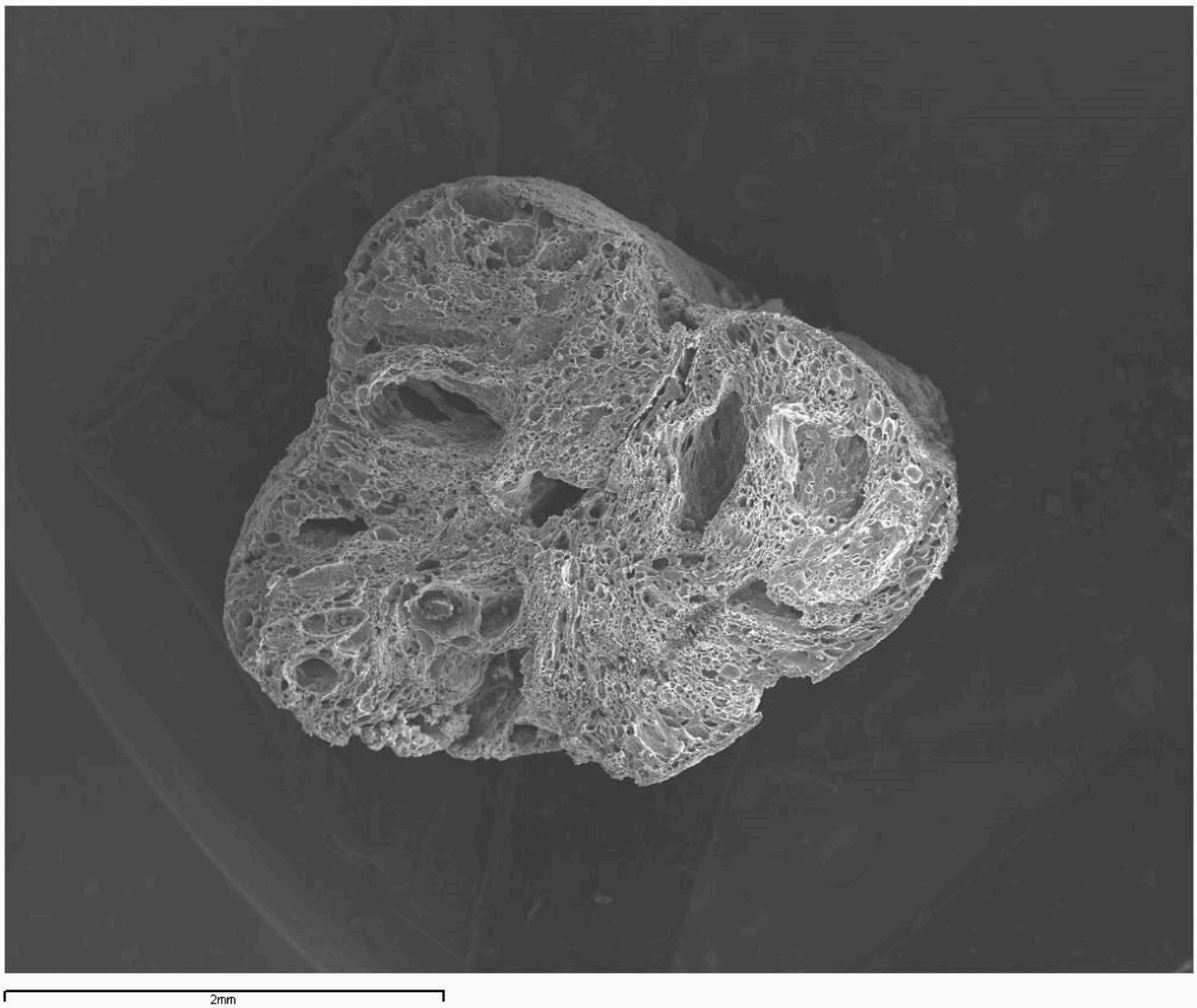

FIG 19. SECTION THROUGH 6000 YEAR OLD CARBONISED GRAIN FROM BALBRIDIE EXCAVATIONS. COPYRIGHTS BY SATAKE CENTRE FOR GRAIN PROCESS ENGINEERING, UMIST, MANCHESTER

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FIG 21. DEMONSTRATION AT THE WORLD ARCHAEOLOGY CONFERENCE 6, DUBLIN, BY THE MOORE GROUP. FILLING THE TROUGH WITH WATER. COPYRIGHTS BY MERRYN DINELEY

FIG 22. THE MOORE GROUP HEAT THE STONES FOR THE HOT ROCK MASH AT WAC 6, DUBLIN. COPYRIGHTS BY MERRYN DINELEY

FIG 23. HOT ROCK MAGIC AT WAC 6: THE SACCHARIFICATION AS GRAIN STARCH IS TRANSFORMED INTO MALT SUGARS. COPYRIGHTS BY MERRYN DINELEY

FIG 24. SWEET WORT IN THE TROUGH AT WAC 6, READY FOR COLLECTION AND TRANSFER TO THE FERMENTING VESSEL. COPYRIGHTS BY MERRYN DINELEY

FIG 25. THE HOT ROCK TEAM AT THE REPLICA TROUGH, BRESSAY, SHETLAND. COPYRIGHTS BY MERRYN DINELEY

FIG 26. ADDING CRUSHED MALTED BARLEY TO HOT WATER IN THE REPLICA TROUGH, BRESSAY, SHETLAND. COPYRIGHTS BY MERRYN DINELEY

FIG 27. SWEET WORT IN THE REPLICA TROUGH, BRESSAY, SHETLAND, READY TO BE COLLECTED AND TRANSFERRED TO THE FERMENTING VESSEL. COPYRIGHTS BY MERRYN DINELEY

FIG 28. OUR BRESSAY BREW: WE ADDED COMMERCIAL YEAST TO THE WORT AND A FEW MEADOWSWEET FLOWERS INSTEAD OF HOPS. COPYRIGHTS BY MERRYN DINELEY

FIG 29. THE MEDIEVAL MASH TUN AT EINDHOVEN MUSEUM. CRUSHED MALT AND WATER ARE HEATED TO MAKE MALT SUGARS. COPYRIGHTS BY MERRYN DINELEY

FIG 30. HUIB VAN DER STAM AND COLLEAGUES DEMONSTRATE TRANSFERRING THE MASH TO THE LAUTER TUN USING JUGS. COPYRIGHTS BY MERRYN DINELEY

FIG 31. THE LAST OF THE MASH IS TRANSFERRED TO THE LAUTER TUN BY TIPPING THE STILL HOT MASH TUN. COPYRIGHTS BY MERRYN DINELEY

FIG 32. LAUTERING: CLOUDY WORT IS POURED THROUGH THE MASH UNTIL IT RUNS CLEAR. COPYRIGHTS BY MERRYN DINELEY

FIG 33. A CLOSE UP OF LAUTERING: WORT IS POURED OVER THE MASH PADDLE TO AVOID DISTURBING THE GRAIN BED. COPYRIGHTS BY MERRYN DINELEY

FIG 34. EARLIEST IMAGE OF A KNOWN BREWER, HERTTEL PYRPREW C1425, FROM THE BOOK OF MENDEL (TRUM 2002).

FIG 35. 13TH CENTURY AD STONE BUILT MASH OVEN AT CUBBIE ROO'S CASTLE, WYRE, ORKNEY. A METAL MASH TUN WAS HEATED BY A FIRE. COPYRIGHTS BY MERRYN DINELEY

FIG 36. STEPS OF THE MEDIEVAL MASH OVEN AT CUBBIE ROO'S CASTLE, WYRE, ORKNEY. THE BREWER CLIMBED THESE TO ADD CRUSHED MALTED BARLEY TO HOT WATER. COPYRIGHTS BY MERRYN DINELEY

FIG 37. FARMHOUSE BREWING IN LATVIA: A CAULDRON TO HEAT WATER, WOODEN MASH TUN, HOT STONES TO HEAT THE MASH. COPYRIGHTS BY LARS MARIUS GARSHOL. SEE LARSBLOG FOR DETAILS: HTTPS://WWW.GARSHOL.PRIV.NO

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FIG 39. KEPTINIS ALUS: THE FINISHED MASH WILL BE BAKED IN THE OVEN. COPYRIGHTS BY LARS MARIUS GARSHOL. SEE LARSBLOG FOR DETAILS: HTTPS://WWW.GARSHOL.PRIV.NO

FIG 40. KEPTINUS ALUS: THE MASH GOES INTO A HOT OVEN FOR A FEW HOURS. COPYRIGHTS BY LARS MARIUS GARSHOL. SEE LARSBLOG FOR DETAILS: HTTPS://WWW.GARSHOL.PRIV.NO

FIG 41. KEPTINIS ALUS IS A RARE TECHNIQUE. BAKING THE MASH IN A HOT OVEN ADDS COMPLEX FLAVOURS TO THE ALE. COPYRIGHTS BY LARS MARIUS GARSHOL. SEE LARSBLOG FOR DETAILS: HTTPS://WWW.GARSHOL.PRIV.NO