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Reclaiming the Rotten: Understanding Food Fermentation in the Neolithic and Beyond

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Abstract

People have harnessed beneficial microbes to preserve, protect, and improve food for thousands of years. However, the significance and techniques of food fermentation are poorly understood in prehistoric archaeology. This paper explains what food fermentation is and discusses its relevance in an early farming context. It sets out the beginnings of a theoretical and material framework that can be drawn upon for further study of this crucial but overlooked aspect of prehistoric food cultures. Focus is on the British Neolithic, but the central concepts are applicable in other periods and places.

Keywords: fermentation, microbes, food preservation, Neolithic, dairy, grain, fish

1. Introduction

Archaeological study of fermented products has tended to focus on alcoholic beverages (e.g. Biwer and VanDerwarker 2015), particularly in relation to feasting and the development of agriculture (e.g. Dietler 1990; Jennings et al. 2005; Dietrich et al. 2012; Hayden, Canuel, and Shanse 2013). Scientific investigation of potential fermentation biomarkers has also been conducted primarily in the context of beer and wine production (e.g. Isaksson, Karlsson, and

Eriksson 2010; Manzano et al. 2016; McCool and Coltrain 2018). Nonetheless, archaeological interest in food fermentation is increasing, at least in terms of ancient cheese consumption (e.g. Salque et al. 2012; Greco et al. 2018; McClure et al. 2018). However, food fermentation is poorly understood in prehistoric archaeology due to the loss of knowledge that followed scientific identification of harmful bacteria and the shift to industrialised food preservation in the last two centuries. In addition, food procurement such as hunting has traditionally overshadowed food processing activities in gendered archaeological discourse. Therefore, this paper combines food science, anthropology, and applied experimental fermentation literature to create an interpretive framework. It aims to inspire and facilitate increased archaeological engagement with food fermentation, which is posited to have been critical and widespread on all continents from the Palaeolithic onwards. An important premise for this line of enquiry is that generalisation about culinary activities between contexts is possible due to the timeless relationship between food chemistry and processing technology (Wandsnider 1997; Gouin 1997). For example, heat processing of lean meat tends to involve boiling whereas roasting is preferred for fatty meats (Wandsnider 1997, 13), regardless of whether that fatty meat comes from a Neolithic pig in Europe or an eel in aboriginal Australia. The chemical composition of foods and the impact of various processing techniques do not vary much across time and space, which is why certain cross-cultural patterns emerge in the study of, in this case, fermentation (Katz 2012, 212).

Some of the implications arising are considered in the context of the British Neolithic and, to a lesser extent, the Mesolithic and Bronze Age. It is suggested that many of the core Mesolithic staples, including fish and starchy tubers, were probably often fermented, and that the Neolithic was not primarily a bread economy. Instead, grains were fermented and used in a variety of porridge-like dishes. Milk was generally not consumed fresh but fermented into various soured foods that would have been more easily digestible and storable. More

elaborate fermentation techniques such as baking, brewing, and cheese-making became important in the Middle to Late Bronze Age as one aspect of agricultural intensification and population increase.

2. What is Fermentation?

Fermentation is anaerobic metabolism by microbes, i.e. the process by which bacteria and fungi produce energy from nutrients (Katz 2011, 165). In a human food context, fermentation occurs when edible microbes produce enzymes that transform food substrates (such as lipids, carbohydrates, and proteins) into non-toxic products that we like to eat (Steinkraus 1997).

That is, many bacteria and fungi eat the same things we do, and in doing so they produce by-products that improve the quality of our food. The benefits of fermentation are that it preserves food, enhances its nutritional properties, generates new and pleasant flavours and aromas, and reduces the amount of harmful toxins. In other words, it is often better for us humans – economically, nutritionally, and socially – to eat foods that have already been digested by good microbes than to eat them ‘fresh’. Fermentation enriches our food by generating protein, essential amino acids, essential fatty acids, and vitamins (Steinkraus 1995, 3). This natural addition of nutrients is particularly significant in regions where access to a variety of nutritious food is limited due to, for example, climate or poverty. Moreover, fermentation processes generally require less resources such as fuel and labour compared to heat-altering techniques like steaming and boiling (Steinkraus 1995, 4). Not all food fermentations tick all the boxes; for example, fermentation of a particular food may be valued for its flavour although the nutritional benefit is marginal. This is presumably why many traditional cuisines include a variety of fermented foods. In terms of food preservation, fermentation is one central technique alongside salting, drying, smoking, freezing, and

pickling. These techniques are not mutually exclusive; for example, meat may be fermented prior to freezing, and fermented dairy can be preserved by drying. Pickled foods (i.e. preserved in acid) are often also fermented to some degree. Up to one third of today's global food intake is estimated to consist of fermented foods (Mintz 2011, 13).

All classes of food can be fermented, and ferments may be classified depending on food group; i.e. whether it is cereal, dairy, vegetable, fruit, meat, fish, or legume that is being fermented (Table 1). In the scientific literature, the ferments tend to be classified according to some combination of the type of food and the relevant microbe or process. For example, 'milks fermented with *lactobacilli*' may be distinguished from 'pickles fermented with *lactobacilli*' (Steinkraus 1997, 311). Lactic acid bacteria (LAB) are indeed the most common agents of bacterial fermentation (Haard et al. 1999). For example, LAB are the dominant microbes in a sourdough culture and these acids give the bread its sour taste (Lee 2011, 184). In addition to lactic acid fermentation, there is alcoholic, acetic acid, and alkaline fermentation (Steinkraus 1995, 3). However, scientific classification is challenging due to the immense variety of traditional ferments. Tamang and Kailasapathy (2010, vii) suggest that about 5,000 varieties of major and minor fermented foods are consumed across the world. Any attempt to map these out scientifically or anthropologically soon encounters a bewildering terminology that reflects the fact that most ferments were developed in small-scale domestic contexts (Figure 1). For example, Sudanese *mish* is a semiliquid milk product that takes one month to ferment, whereas *biruni* is similar but is consumed after three to four years. Egyptian *mish*, on the other hand, is a soft pickled cheese (Tamang and Samuel 2010, 17).

Humans did not invent fermentation; we learnt to harness it to our advantage (Katz 2012, 12). It is beyond the scope of this paper to examine how far back into the past our culinary collaboration with useful microbes expands, but Palaeolithic origins are likely given how

intricate, varied, and widespread fermented foods are on every continent. Histories of human-microbe collaboration have been explored primarily in the context of agriculture. For example, microbial genetics shed light on the co-development of certain yeasts and bacteria and agricultural products like bread and wine (LeGras et al. 2007; Gibbons and Rinker 2015). The central elements of domestication – human control over the diet, movement, and reproduction of the target species – can indeed be applied to our interaction with the relevant fermentation microbes (Mintz 2011, 18; Lee 2011, 175; Gibbons and Rinker 2015). However, the shift away from the notion of domestication as a one-way consolidation of human domination over other species to a more nuanced recognition of the coercive power of domesticates on human society (e.g. Pollan 2001; Zeder 2015; Scott 2017) is relevant also for the ‘micro-agriculture’ of culinary fermentation (Lee 2011, 175). In terms of archaeological dates, recently excavated evidence indicates that fish was fermented in the eighth millennium cal BC in Sweden (Boethius 2016), and some of the earliest evidence for alcohol production has been dated to the Chinese Neolithic of the seventh millennium cal BC (McGovern et al. 2004).

The word ‘ferment’ comes from the Latin word for ‘boil’ (Pollan 2013, 295), and it can be considered as a kind of cooking without heat. A Chinese agricultural text from the sixth century AD refers to liquid fermentation as *fei*, which also means ‘boiling’ (Sabban 1988, 49). Gas is a by-product of many fermentations – this is why traditional bread has ‘air’ holes, and a tin of fermented fish may explode. The work of Wrangham (2009) on the impact of cooking on human evolution highlighted that heat-alteration of food is effectively extrasomatic digestion. Food fermentation is another set of techniques that begin the digestion process prior to consumption. It is possible that much of the ‘cooking’ in Wrangham’s scenario was, in fact, fermentation. For tens – if not hundreds – of thousands of years, we have deliberately created environments that our favourite microbes thrive in, both

inside and outside our bodies. In terms of the microbes that live inside us, ongoing research on the significance of our gut microbiome for health and wellbeing (reviews: Rieder et al. 2017; Rowland et al. 2018) has resulted in intensified interest in food fermentation (e.g. Katz 2012). This is valuable for advancing archaeological understanding of prehistoric food preservation, which is crucial as the significance of fermented foods in human prehistory has been underestimated and underexplored.

3. Germophobia and Gender-Bias

Archaeological study of food fermentation has been limited for (at least) three reasons. Firstly, the identification of bacterial pathogens in the 19th century resulted in a ‘War on Bacteria’ (Katz 2012, 13) that greatly diminished our understanding of and engagement with *all* bacteria – not only the harmful ones. Katz (2012, 13) sums it up: ‘[t]he biological reality – that bacteria are our ancestors and the context for all life; that they perform many important physiological functions for us; and that they improve, preserve, and protect our food – contrasts sharply with the widespread perception of bacteria as our enemies’. Secondly, the loss of ‘folk science’ familiarity with the good microbes was exacerbated by 20th century industrialisation, which outsourced food preservation beyond the domestic setting. Wiest and Schindler (2011, 378) argue that ‘each dietary milestone in our past intensified the role of fermentation in our diets except the most recent – the move to the industrialised Western diet’. The lack of know-how has made it difficult to assess the scale and material traces of fermentation and other food processing techniques in the archaeological record. Thirdly, added to this is the fact that food procurement tends to dominate anthropological and archaeological study of food and economy at the expense of processing activities (Stopp 2002). This certainly applies in, for example, Mesolithic studies in Europe (Milner 2009, 49).

Stopp (2002, 39) argues that this is due to gender-biased research priorities as resource procurement tends to be associated with men whereas processing is often traditionally undertaken by women (e.g. in northern contexts: papers in Jarvenpa and Brumbach 2006; Spray Starks 2011; Frink and Giordano 2015). Consequently, it was the development of gender archaeology that placed cooking and processing on the agenda (Montón Subías 2002; Rodríguez-Alegría and Graff 2012). Similarly, in anthropology the understanding of food fermentation is ‘still almost nonexistent’ (Mintz 2011, 22) although that is changing (e.g. Fujimoto 2011; Yamin-Pasternak et al. 2014). In archaeology, a wider interest in food fermentation is also emerging. Potential lines of evidence for food fermentation include artefacts such as ceramic strainers, bowls and flasks (e.g. Bogucki 1984; Saul, Glykou, and Craig 2014, 208; Sibbesson 2018, 54), structural features like pits and gullies (e.g. Boethius 2016; Stopp 2002), lipids and proteomics in organic residues (Salque et al. 2012; Yang et al. 2014; Greco et al. 2018), charred remains of the food itself such as the bread from Neolithic Yarnton in Oxfordshire (Hey et al. 2016) and fermentation-induced modifications on environmental remains, like the acidified fish bones from Norje Sunnansund in Sweden (Boethius 2016). The possibility of identifying microbial ‘consumers’ through elevated nitrogen stable isotope values of human users of fermented foods has been explored, but with inconclusive results (Privat et al. 2005).

The limited engagement in the historical sciences with fermentation and related techniques is curious given that skilful food processing is in many contexts necessary for survival.

Moreover, food processing offers an excellent window into the past as the material and human resources required would have influenced – for example – settlement patterns, gender and power relations, technology and design, and demographic and individual health. Among Alaska’s Inupiat groups, marriages were traditionally arranged between families who lived in similar environments because the wife had to be familiar with the processing requirements of

the area's food species (Spray Starks 2011, 303). The knowledge required to safely ferment foods that are seasonally abundant – and therefore suitable for storage – is two-fold. Firstly, one needs to know how it is done and the time and materials that are needed to get fermentation underway. Secondly, even though fermentation can add nutrients to food it can also encourage pathogens. If equipment such as knives and containers are unsuitable or contaminated, or if the fermentation process is poorly controlled or not halted at the right time, harmful bacteria can thrive. Botulism is caused by neurotoxins produced by *Clostridium botulinum*, primarily in low-acid anaerobic environments such as meat and fish ferments (Katz 2012, 338). Outbreaks of botulism in Alaska have been linked to indigenous fermented fish and meat, although the risks seem to significantly increase when traditional containers are replaced with plastic ones, or when a food is introduced into a new region (Shaffer et al. 1990). In the past, disruptions to the mechanisms of transferring crucial fermentation knowledge to the next generation must have had far-reaching and sometimes lethal consequences.

4. A Bio-Cultural Frontier

Due to the potentially dangerous consequences of microbial action on food and our Pasteurian fear of microbes in general, most of us today consider 'rotten' food to be spoilt, unsafe for consumption. However, the difference between rotten and delicious is a matter of taste and tradition (Mintz 2011, 20). Following Katz (2011, 170) it is helpful to instead consider 'fresh' and 'rotten' as two ends of a spectrum. Between those extremes is a 'creative space' within which all 'cultured foods' sit. The term 'cultured foods' is useful as it embodies both the microbial cultures that created it and the human cultural contexts of its consumption. Archaeological exploration of that creative space in prehistory will require recognition that

the wisdom of repugnance – the notion that feelings of disgust signal danger on some ancient, intuitive level – is in this case only a century old. Ethnographic accounts can help expand our limited imagination in this regard. For example, in his survey of food preservation in Siberia, Perry (2011, 242) describes how ‘[t]he Yakuts allow yoghurt to age and grow stronger through the summer, making a thick substance called *tar*, which they often enrich with other ingredients such as berries, wild sorrel, the bones of horses, cows and fish, and chopped, boiled sapwood. Lactic acid softens the bones to the consistency of gristle. In winter, the *tar* is frozen. For use, it is diluted and mixed with powdered sapwood to make a soup called *butugas*’. Also in Siberia, the Yukagir and Chukchi let reindeer blood freeze or ferment – depending on season – before eating it (Perry 2011, 243). Other fermentable animal parts include offal, fat, gall bladders, and hooves (Mintz 2011, 24). In Mexico, *huitlacoche* is a fermented delicacy originating from Aztec cuisine, made from maize infected with the fungal disease corn smut (Katz 2012, 214). Indigenous names for foods sometimes convey the strong smells produced through fermentation; for example, the native American Huron word *leindohy* translates as ‘stinking corn’, which is a delicacy made by leaving ears of corn in stagnant water for a couple of months (Tooker 1991, 69). However, such names for indigenous fermented dishes may in many cases have been assigned by European visitors. The Alaskan Inupiat dish *aurruq*, which is prepared by leaving salmon heads in pits for up to four months, is referred to as ‘stink-heads’ by outsiders (Spray Starks 2011, 307). Katz (2012, 364) retells an ethnographic account of two Inupiat elders discussing how they prefer to eat salmon heads; one likes them ‘green and slimy’ while the other gives them to the dogs when they have become that strong.

There is no doubt that fermented foods can evoke intense sensory and emotional responses – of memories, disgust, pleasure, or belonging. Pollan (2013, 309) points out that the most vigorously fermented foods tend to be acquired tastes: ‘[m]any of these foods occupy a

biological frontier – on the edge of decomposition – that turns out to be a well-patrolled cultural frontier as well’. A fascinating example of the interplay between socially contingent responses to sensory experiences and wider socio-political processes comes from the Bering Strait region, where Cold War-era Sovietisation of indigenous groups led to changes in ‘olfactory aesthetics’ and therefore a reduction in traditional marine fermented food consumption (Yamin-Pasternak et al. 2014). Today, a complex array of feelings towards ‘food with fragrance’ exists in the region, including both revival and continued rejection. Young members of the communities have reported that ‘they are proud, in accordance with traditional values, to honour and care for the elders so long as the time they spend with grandparents does not come too close within the dinner hour of the latter’ (Yamin-Pasternak et al. 2014, 633). Those who continue to eat the traditional foods can become preoccupied with extensive laundering of clothes and washing to reduce the negative impact that ‘markedly ethnic odors’ may have in schools and workplaces. This in turn places additional strain on already inadequate fuel and water resources (Yamin-Pasternak et al. 2014, 633). The Bering Strait study illustrates not only the power of food as a marker of identity, but also that food flavour and preference can have tangible, economic implications.

5. Fermentation and Early Farming

5.1 The Mesolithic-Neolithic Transition

It is sometimes assumed that food fermentation began with agriculture (e.g. Vaneker 2015, 161). This may be because food is fermented primarily in the context of storage, which is also strongly associated with the emergence of settled agriculture (Kuijt 2009). However, storage was and is widely practiced by non-sedentary foragers to mitigate against seasonal fluctuations in food species availability (Ingold 1983; Rowley-Conwy and Zvelebil 1989). It

is likely that pre-Neolithic food cultures in Britain involved a variety of ferments. The fact that fermented foods can be powerful symbols of group identity may be relevant in the context of cross-cultural interaction that followed the migration into Britain of groups from mainland Europe after 4,000 cal BC. The 'stinky' foods they encountered among their new neighbours may have included ferments made of starchy roots and tubers, nuts, birds, marine and freshwater fish. The latter is perhaps most convincing as evidence for fish fermentation has recently been documented in the Early Mesolithic in southern Sweden (Boethius 2016). This included a gutter feature and stakeholes, cut into clay on the shore of a lake, densely packed with fish bone (Boethius 2016, 173). Bark and plant fibre remains indicate that the feature had been lined and covered when in use, and this – along with the sheer density of fish bone and that many of them had been kept in an acidic environment – is convincing evidence of large scale fish fermentation (Boethius 2016, 176). A comparable recent example may be the fish fermentation pits dug by the Itelmen of Kamchatka in eastern Russia; here, the fish 'rots to such a degree that it has to be removed from the pits with a sort of ladle. The resulting rancid flavour is highly esteemed' (Perry 2011, 245). In addition to cut features, the fish, roe, and marine mammal meat and fat can be fermented in leather sacks (Perry 2011, 245), seal-skin 'pokes' (Frink and Giordano 2015), or simply in large mounds (Spray Starks 2011, 306). In winter, the exterior of such a mound would freeze while the fish ferments to varying degrees within the mound, thus creating different flavours and textures (Spray Starks 2011, 306). Was this a bio-cultural culinary frontier between different groups post-4,000 cal BC – is it possible that the decline in the use of coastal resources in the Neolithic record came about simply because these foods were too stinky for the new inhabitants?

The dietary significance of starchy roots and tubers should not be underestimated; in the last two decades, scanning electron microscopy has enabled identification of charred tissue from underground storage organs of plants at a range of Mesolithic sites in temperate Europe

(Kubiak-Martens 2016). The root foods included true roots, tubers, rhizomes, and bulbs from species such as arrowhead, knotgrass, horsetail, common club-rush, and wild garlic (Kubiak-Martens 2016, 118-126). Ethnographic observation in northern Eurasia and North America suggests that these foods could be eaten raw or roasted (Kubiak-Martens 2016, 118). They may also be fermented, although the food fermentation literature tends to focus on species from tropical regions such as cassava, taro, and sweet potato (e.g Aidoo 1992), presumably because those are widely fermented today. However, fermentation of starchy tubers in the temperate Mesolithic need not be ruled out, particularly as it may be achieved by simply placing them in an anaerobic environment like a marsh for a few weeks (Wiest and Schindler 2011, 378). The food preserving potential of wetlands may have contributed to their appeal in the Mesolithic. Nuts and edible seeds are not widely fermented today, but given the ubiquity of acorns and hazelnuts it is worth mentioning that they can be fermented too. When consumed with other foods, nuts are often ground or crushed into a paste. Such a paste will sour to some degree if it is stored in a traditional container and environment. Katz (2012, 309) points out that leeching, which is done to acorns and other tannin-rich nuts, inevitably initiates fermentation, albeit briefly.

The idea that roots, tubers and nuts were sometimes processed and preserved by fermentation in the Mesolithic is tenuous but worth considering as a review of archaeobotanical remains from Scottish Mesolithic sites recently revealed intensive use of plants, including tubers of lesser celandine (Bishop, Church and Rowley-Conwy 2013). If some of these plants foods were fermented, the procedures involved would have been similar to how grain is likely to have been processed in the Neolithic. In the new social constellations that emerged in the Early Neolithic, such culinary overlap may have been significant. It may also be an area where the indigenous population influenced the food cultures that developed in the Neolithic.

5.2 Cereal Fermentation

The mechanism of introduction and the subsequent scale and significance of cereal cultivation in the British Neolithic have been much debated (e.g. Thomas 1988, 2004; Rowley-Conwy 2004). For the purposes of this paper, it is sufficient to note that the Neolithic economy is unlike that of both earlier and later periods. Identification of the same domestic species on Neolithic, Bronze Age, and Iron Age sites need not signal similar economic and culinary practices. A recent review of chronological and archaeobotanical evidence indicates that cereals were grown on a larger scale in the Early Neolithic compared to the more pastoral Middle-Late Neolithic and Early Bronze Age (Stevens and Fuller 2012), although that model does not apply in the north of Britain (Bishop 2015).

In any case, cereals need not be interpreted as evidence of baking. Given the relatively low numbers of querns on British Neolithic sites and the lack of bread oven equipment like that of the Late Bronze Age (Champion 2014), it is likely that most cereal was not consumed as bread. Bread can be unleavened but is generally a ferment involving either yeast or LAB (Tamang and Samuel 2010, 13). Cereals may also be fermented in a variety of other ways, with both yeast and bacteria, many of which are less fuel- and labour-intensive than baking. Today, fermented cereals are staples in Africa and Asia, and bread is only one component of a wide spectrum of cereal ferments (Haard et al. 1999). Fermented cereal foods that are not breads include gruels, porridges, non-alcoholic and alcoholic beverages, pancakes, and dumplings. Any cereal can be used. Traditional cuisines in Latin America contain an immense variety of maize ferments, and the same is true for rice ferments in East Asia. In Sub-Saharan Africa, grains such as millet, sorghum, wheat, and barley are used (Haard et al. 1999). For example, in Botswana the fermented variety of the sorghum porridge known as *bogobe* is called *ting*, and is softer than the non-fermented version (Haard et al. 1999). The preparation of *bogobe* follows the same general pattern of many simple grain fermented

dishes around the world; the grains are washed, dehulled, soaked in water, left to ferment, and then cooked as porridge, baked, steamed, dried, or fried as pancakes or flatbreads. Grains are often pounded or ground to a paste before or after fermentation, and sometimes sprouted (Katz 2012, 212). This is why starchy tubers and grains are similar; the former are often prepared 'in porridge-like ways' (Katz 2012, 226). It is the addition of water that activates the bacteria and fungi that are naturally present in both whole and milled grain (Katz 2012, 218). This is why a sourdough starter begins to ferment but dry flour does not. The fermentation period for grains tends to be shorter than for many other foods; the grain-water mixture or paste is generally only fermented for one to three days. Mould may be allowed to form in order to add flavour (Katz 2012, 212), like with some European cheeses. A sourdough starter can also be used to enhance the flavour of porridge, as in the Polish thin porridge called *zur* (Kowalska-Lewicka 1988, 35).

The reasons for fermenting cereals include that it removes antinutrients and toxins, makes it easier for our bodies to absorb minerals and amino acids, and reduces cooking time and thus fuel (Haard et al. 1999). Crucially, it also enhances and diversifies the flavour of the core staple (Mintz 2011). Agricultural diets tend to be centred on a core complex carbohydrate, which can be either cereal or tuber but is generally bland in flavour. Fermentation often brings strong and varied flavour to such cuisines, and both the core staple and its accompaniments can be fermented (Mintz 2011, 16). Dietary stable isotope data from Mesolithic and Neolithic human remains in Britain and elsewhere indicate, amongst other things, that Neolithic food cultures were less diverse and more restricted than in the Mesolithic (Katzenberg and Weber 1999; Richards and Hedges 1999; Schulting and Richards 2002; Milner et al. 2004; Lidén et al. 2004; Cramp et al. 2014). Is it possible that one outcome of the increasingly homogenous diets was intensification of food fermentation? Nonetheless, baked bread may have been only a minor category of cereal foods eaten in

Neolithic Britain. It is entirely plausible that gruels, porridges and other dishes made of fermented grain were far more common.

5.3 Soured Milk Foods

Faunal (e.g. Legge 1981), organic residue (e.g. Evershed et al. 2008), and genetic (e.g. Gerbault 2013) lines of evidence for dairying demonstrate that milk foods were central in Neolithic food cultures across much of the Old World. In combination, they indicate that the consumption of dairy tends to predate the ability to comfortably digest it (Gerbault 2013, 154). In adults without the lactase gene, lactose in milk is fermented in the colon, causing cramps, bloating, and diarrhoea. This effect can be reduced or avoided if the milk is fermented prior to consumption (Solomons 2002; Silanikove, Leitner, and Merin 2015). There is also some evidence that milk fermentation with kefir grains and certain LAB strains may inhibit growth of the bacteria that cause tuberculosis (Mariam 2014; Macuamule et al. 2016). It is unsurprising, therefore, that pastoralists tend to be ‘users of sour milk, yoghurts and cheese’ (Mintz 2011, 22). In Britain, dairy foods were used from the Early Neolithic onwards (Copley et al. 2005; Cramp et al. 2014), and it is likely that milk was often fermented prior to consumption. Fermentation reduced the impact not only of lactose intolerance and possibly tuberculosis but also of seasonal or logistic fluctuations in the availability of fresh milk (Rowley-Conwy 2011). For example, primitive cattle breeds do not produce milk all the time, and people would have needed portable protein-rich foods during travels away from their communities.

Many of us today are familiar only with pasteurised milk, which has been heated to make it safer to consume and last longer. However, pasteurisation not only kills pathogens but also eliminates or at least reduces the range and quantity of bacteria that are good for us and

helpful for milk processing. Raw milk naturally contains lactic acid bacteria that spontaneously begin to ferment the milk if left to sit. The container used can also contribute useful bacteria cultures, especially if used repeatedly for that purpose. Traditional milk ferments are made either by such spontaneous fermentation or by adding a 'starter' kept from a previous batch (Kroger, Kurmann, and Rasic 1992, 63). Some plants, including acorns, figs, and cumin seeds, can also be added as starters (Katz 2012, 199). The dairy ferments we buy today have had an industrially produced and standardised bacterial culture reintroduced after pasteurisation. The type of starter culture used depends on what the intended product is. Pasteurisation does not require particularly high temperatures; less than 100°C is standard – the precise temperature depends on what is being pasteurised and for how long the temperature is maintained. It is perhaps unlikely – although not inconceivable – that Neolithic people sometimes heated their milk for safety reasons. In terms of heating milk it is worth noting that thick yoghurt is created by slowly heating milk to at least 82°C and then letting it cool before adding the starter and keeping it at around 45°C for at least three hours (Katz 2012, 186-187). That would have been a fuel-expensive approach in north-west Europe, so yoghurt may not have been a common ferment among Neolithic communities in Britain. Instead, dairy foods relying on spontaneous fermentations and less maintenance may have been more common. In Sudan, a fermented camel milk product called *gariss* is made by adding fresh camel milk to skin bags that hang from the saddle of a camel (Dirar 1992, 29). The camel's movements shake the milk, which ferments naturally and is consumed as needed. Fresh milk is added at the same rate as the soured product is drunk, to ensure a constant supply. This soured milk liquid is traditionally only consumed by men (Tamang and Samuel 2010, 17).

Cheese may not have been a major component of fermented dairy foods in the British Neolithic. The perforated ceramics that are sometimes present in LBK pottery assemblages

and generally interpreted as cheese-strainers or sieves (Bogucki 1984; Salque et al. 2012) do not feature in the British Neolithic. Instead, Neolithic pottery in Britain is fairly homogenous in terms of size and shape, particularly in the Early Neolithic (Sibbesson 2018, 49). This indicates that they were well-designed for other culinary purposes, which were relatively standardised and widespread, and complemented by other technologies made of organic materials. The non-sterile and porous surfaces of leather, wood, and ceramic containers would have housed beneficial fermentation bacteria. Pollan (2013, 342-343) tells the story of a cheese-making nun in Connecticut who obtained a degree in microbiology and designed an experiment to prove to a health inspector that cheese made in wooden barrels contained fewer pathogens than that made in a stainless-steel vat. This is because some of the good bacteria, like LAB, live in the wood itself – especially after cheese has been made in the barrel a few times – as well as in the starter and the milk itself. Harmful bacteria cannot compete against such numerous opponents. Neolithic pottery was probably used in these ways. Certain vessels were probably used again and again, and smaller vessels may also have been used to keep starter cultures. Such starters may also have been exchanged, and brought to new communities through marriage. A well-maintained traditional starter culture can be kept for many years and is a valuable asset (Katz 2012, 190). In traditional Polish cuisine, each household had a clay pot containing the sour flour-water liquid used to make *zur*, and it was deliberately not washed between uses (Kowalska-Lewicka 1988, 35). *Zur* was eaten daily but associated mainly with fasting, and the end of fasting was celebrated by ‘killing’ the *zur*-pot through breaking or burying it (Kowalska-Lewicka 1988, 35).

5.4 A Taste of Place

Small-scale food storage was widely practiced in both the Mesolithic and Neolithic (Cunningham 2011) and this would have included ferments. The often strong flavours and

aromas of fermented foods can become mnemonic markers of other seasons and places (Mintz 2011, 15). This effect may be enhanced by the fact that specific flavours can be difficult to reproduce in new places due to subtle geological and environmental characteristics of specific regions; a phenomenon captured by the concept of *terroir*. Originally a viticultural concept, other drinks and foods are today also explored in gastronomic literature in terms of *terroir*. It is relevant in, for example, artisanal cheese production since the taste, colour, and consistency of milk are influenced by the animal's grazing environment. Familiarity with the landscape in the Neolithic would have included the flavours associated with places and seasons. Albala (2011, 31) argues that in addition to the factors that are generally considered to characterise *terroir* – such as climate and soil type – bacteria is 'the crucial factor in determining taste'. In a Neolithic context, this may be relevant not only for dairy but also in terms of foods stored and processed in pits. Pits are the most frequently encountered type of feature on Neolithic and early Bronze Age sites in Britain (Anderson-Whymark 2012, 187), but their use for food processing and storage is little understood (Cunningham 2005). Food fermentation is one aspect to consider in that context, since the ethnographic fermentation literature frequently mentions pits and other dug features (e.g. Perry 2011; Yamin-Pasternak et al. 2014; Frink and Giordano 2015). Food can be buried both in order to encourage fermentation and to slow it down. The primary purpose of refrigerators is to inhibit fermentation, which eventually spoils food (Katz 2012, 337). Prior to refrigeration, people cooled their foods by, for example, placing it in cellars, springs, and holes in the ground. It is beyond the scope of this paper to explore whether the increased rate of pit digging in the British Neolithic could be interpreted along these lines, but a couple of examples of connections between food preservation and wider demographic, political, and economic circumstances are worth noting. Howey and Frederick (2016) have demonstrated how food processing activities can intensify in response to social and ecological stressors

such as population increase. Specifically, in the aftermath of migration and economic change during the Late Precontact period in the Great Lakes, territorial systems with less permeable boundaries emerged. The need to maximise resources within more restricted areas resulted in intensified food storage and processing (Howey and Frederick 2016, 38). Archaeologically, this process is reflected in an increased number of cache pits.

Fujimoto's (2011) study of enset starch fermentation in south-west Ethiopia is another example of the socio-economic dimensions of food fermentation. Enset is a herbaceous plant of the banana family and an important food crop in Ethiopia. The starchy paste made from its corm and pulp is widely fermented, despite the fact that it can be harvested all year round, does not require fermentation for detoxification and can be eaten just boiled, and that fermentation is costly in terms of labour and time. Enhanced flavour is clearly one benefit, but it was also found that population density and intensity of cultivation were the most significant factors in determining the extent to which enset is fermented (Fujimoto 2011, 117). Small groups that practice less intensive cultivation tend to avoid the most time-consuming fermentation processing. Such a connection between cultivation intensity, population density, and food processing investment may be applicable in prehistoric contexts. In Britain, do labour-intensive, fuel-expensive, and time-consuming techniques like baking, cheese-making, and brewing emerge in association with agricultural intensification in the Mid-Late Bronze Age? In contrast, a porridge made of fermented grain does not require much input of time, effort, or fuel. The grains are simply soaked for a day or two and cooked fairly quickly. Fish and meat can be left in a mound or a pit to ferment. These kinds of ferments do not depend on sedentism. Instead, they facilitate both mobility and attachment to certain places.

6. Conclusion: Towards an Archaeology of Cultured Food

Fermentation is the biological transformation that all organic matter goes through naturally in order to be recycled; be it a body in a grave, food waste in a compost, or cabbage in a sauerkraut crockpot. There is a window of time within that decomposition process that we can capture and use to our advantage. Humans mastered culinary symbiosis with microbes very early on, and the ‘cold-boil’ of fermentation should be central in the study of the co-evolution of humans and cooking. The ‘cooking ape’ hypothesis (Wrangham 2009) would then hinge less on dating the first evidence for control of fire. Instead – or in addition – potential evidence for fermentation could be explored further. This will require importing more detail from the scientific, ethnographic, historical, and experimental fermentation literature than the brief sketch offered here. The suggestions made in the context of Mesolithic to Bronze Age food fermentation need to be tested against available evidence, and the variety masked by terms such as ‘bread’ and ‘cheese’ could be unpicked. Increased attention to possible structural and environmental fermentation evidence during fieldwork and post-excavation would also be valuable (e.g. Boethius 2016; Hey et al. 2016), along with continued experimental food fermentation using replicas (e.g. Hendy et al. 2016) and integration of molecular and artefactual evidence (e.g. McGovern et al. 2004; Salque et al. 2012; Saul, Glykou, and Craig 2014). Scientific work on protein in archaeological residues (Yang et al. 2014; Greco et al. 2018) and microbial genetics (LeGras et al. 2007; Gibbons and Rinker 2015) clearly has potential to contribute a great deal more.

The latter line of enquiry has traced some of our most familiar fermentation microbes back to the emergence of agricultural foods. However, the ‘domestication’ of certain microbes in that context does not rule out pre-agricultural food fermentation. Instead it is likely that agricultural diets became dominant at the expense of other, more diverse culinary processes and associated microbes. More recently, the shift to industrially produced food further

restricted and homogenised the repertoire of culinary microbes for the sake of food safety and standardisation. Katz (2012) argues that bringing fermentation back into a domestic context can help us reclaim and rediscover more varied microbes and associated flavours and health benefits. Similarly, for archaeology there is value in rediscovering cultured foods.

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Table 1. Examples of fermented products, with source food and region for the lesser known ones. Some have only recently become more widely known in the West due to increased interest in traditional ferments (e.g. kefir, kombucha, kimchi). Some products were traditionally always fermented (e.g. chorizo, cod liver oil) but their modern industrially-produced equivalents are often preserved in other ways (this also applies to butter). Legumes were traditionally only fermented in East Asia.

Figure 1. Sequences of milk (cow, goat, sheep) preservation in historic-period Scotland demonstrate: the co-existence in pre-industrial domestic settings of well-known, widespread products and regionally specific products; that the majority of dairy products have either always or sometimes undergone fermentation (in yellow); and that soured milk in particular tends to be an important product in its own right and for its many derivatives. Some products were specific only to certain parts of Scotland (e.g. ‘ost-milk’ was a Shetland product). Some

products (including 'clocks' and bubbly 'bland' stored in casks) were associated with wealth, whereas others (including hot 'bland') were mainly consumed by the poor. Based on information in Fenton 1988.