

4 Our ‘daily bread’?

The origins of grinding grains and breadmaking

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The arduous nature of wild-cereal processing has been widely underestimated.
(K. Wright 1994, 257)

Introduction

Well-formed grinding slabs and mortars only begin to appear with any frequency in the Late Epipalaeolithic of the Levant, especially the Natufian. What does this technological change represent? Is this the first indication of cereal use? Is it the first indication of flour and bread production? Is it a response to increases in aridity or population pressure? Is it possibly related to the development of special cuisines or even brewing? In the following discussion, we hope to shed some light on these issues.

Today, bread and beer are often viewed as ‘profane’ foods, widely and cheaply available to people in all economic classes. But was it always so? We would specifically like to explore the possibility that one of the original roles of bread was as a relatively rare, costly, labour-intensive food that was only used for special occasions, notably for feasts. Such a role for beer has already been suggested elsewhere and need not be repeated in detail here (Arthur 2003; Dietler 1990; Hayden et al. 2013; Jennings et al. 2005). We concentrate instead on bread, first in terms of the desirability of cereals, then the costs and benefits of grinding cereals, the conditions leading to their uses, their roles in Epipalaeolithic diets and finally the history of their use.

The desirability of cereals

Although there are a number of significant differences between the various species of cereals, for the general purposes of this paper, we will treat them as an undifferentiated class. Overall, cereals are generally considered tasty and have a relatively balanced proportion of starch (c. 70 per cent), protein (7–22 per cent) and lipids (c. 3.5 per cent) together with a small percentage of moisture and bran (Shewry 2009). Wadley and Martin (1993) have also noted that the digestion of cereals by intestinal flora

and gastric fluids produces exorphins which elicits feelings of pleasure or even euphoria in high doses, leading to an innate attraction to cereals. The release of glucose into the blood system after ingesting refined cereal products may also create mild ‘highs’ and even lead to dependence (as discussed below). The fermentation of cereals, of course, has similar but much more pronounced effects due to the production of alcohol. Another important advantage of cereals is their ease of storage over long periods. Food storage with its complicated costs, benefits and effects tends to be overlooked or underappreciated by many archaeologists, although some authors have tried to draw attention to the dynamics involved and their importance (e.g. Wollstonecroft 2011, 146).

While the attractions of cereals may seem compelling, there are also some major disadvantages. The most serious obstacle in utilizing cereals for food is the hard, sharp, inedible and usually tenacious husk that encloses the grain to protect it. This must be removed before cereals can be consumed and to do this requires a specialized technology and considerable work. In addition, researchers have pointed out that hominins evolved for the most part in forests where fruits and tubers constituted the main foods. Cereal use occurred much later in the Palaeolithic so that human bodily systems are sometimes poorly adapted to the chemical components developed by cereals as defences. Researchers suggest that some of the anti-nutrients and reactive constituents of cereals evolved in order to create adverse effects in mammals or insects and thus dissuade them from consuming large amounts of cereal seeds. Due to the presence of these ‘defence’ chemicals, it is argued that certain proportions of human populations that consume cereals develop coeliac disease, dermatitis, rheumatoid arthritis, diabetes, canker sores, schizophrenia and other neurological problems (Cordain 1999; Shewry 2009). Consuming large amounts of cereals can also lead to vitamin and mineral deficiencies as well as deficiencies in some essential amino acids leading to associated health problems (Cordain 1999).

Costs and benefits of cereal preparations

Removing the husk

If the attractions of using cereals seem compelling, the costs of getting nutrition out of small seed packets must have seemed insurmountable to most of our ancestors for millions of years. Except for the brewing of beer (where a good amount of husk actually aids fermentation Hayden et al. 2013), the husk must be removed. Thus, the key to using any large quantities of cereal grains was finding an efficient way of removing the husks. As Pliny (in *Natural History* 18.122) noted ‘The grain is pounded in a wooden mortar to avoid the pulverizing effect of using a stone mortar’ (cited in White 1995, 39). Stone mortars and pestles crush the grains too much so that it is difficult to separate the grain particles from the chaff and significant amounts of the edible product are lost (Baudais and Lundstrom-Baudais 2002, 193;

Meurers-Balke and Lüning 1999). Unfortunately, wooden mortars and pestles do not preserve very well archaeologically so that it is difficult to tell exactly when wood dehusking mortars might have been invented, but the Upper Palaeolithic now seems the most likely time period (*infra*).

Average experimental dehusking times of one hour for a kilogram of wheat were compiled by Katherine Wright (1994, 246). In Hayden's experience in dehusking einkorn, some of the grains became dehusked at an early stage of pounding in a mortar, while other grains were much more resistant to dehusking even after prolonged pounding. Thus, with wild cereals having more tenacious husks than domesticated forms, there may have always been a certain residual proportion of grains that could not be dehusked in a mortar. An alternative method could have been the grinding of husked grains on a millstone and then sieving or winnowing out the chaff, as done with *t'eff* and other grains in Ethiopia, although it would seem that at least some of the finer fractions of chaff might remain in the resulting flour.

To grind or not to grind? Cost estimates

In reading the archaeological literature on the use of cereals, one often has the impression that there is a tacit assumption that grinding or pulverizing grains is required for their consumption. This is patently untrue as anyone who has eaten popcorn, hominy, grain rice, oat porridge, or wheat berries should know. However, grinding may be required for some small-seeded grasses which cannot be dehusked and must be ground, husk and all, to access the starches in the grains. In contrast, large seeded cereals can be dehusked using wooden mortars and pestles. Once dehusked, cereal grains can be simply boiled, cracked and boiled, sprouted and boiled or ground, coarsely ground or pounded to make gruels or porridges, or finely ground into flour for making breads or other baked items. Each preparation has its costs and benefits; however, we will focus on preparations that do not require further mechanical processing with grinding or pounding stones, versus those that do.

One of the reasons that our research began into this topic was an ethnoarchaeological observation made by Hayden in the 1970s in Maya villages. He noted that many Maya women traditionally spent between four and five hours per day grinding maize to make tortillas for their family meals (Hayden and Cannon 1984, 68). Energetically, this did not seem to provide enough benefits to offset the major costs in time and effort involved in grinding. The first step in our present research was to determine whether this situation was typical or atypical of grain use. Unfortunately, there are very few actual estimates in the ethnographic literature of the time women traditionally spent grinding cereals. There are a number of accounts that refer to the 'very hard work' of grinding grain into coarse flours (e.g. Richards 1939, 92). Other authors describe women spending their entire lives grinding (Bartlett 1933, 4) and women as being 'a slave to her *metate* . . . she spends many hours each day grinding and toasting' (Ember 1983, 290).

Although many such descriptions are vague, there are, fortunately, at least a few quantified accounts of grinding times. Egziabher et al. (1993, 224) report that dry grinding, followed by soaking and wet grinding of maize or barley consumed 23 hours per week for a family of five to seven in Ethiopia. If sorghum was used, only 17 hours of grinding were needed, while wheat required only 14 hours per week. These time estimates do not include costs of procuring or making grinding stones, time required for cleaning and maintaining the milling stones, sieving the flour, kneading dough or baking. In a composite work routine for a subsistence agricultural family, the authors recorded that grinding was done for three hours in the morning and two and a half to three and a half hours in the evening, with an additional three hours of ‘cooking and grinding’, for a total of about nine hours per day, although no grinding was done on the many religious (non-working) days (Egziabher et al. 1993, 225). Darcus obtained comparable estimates of grinding times from Tigrinya speaking groups in Northeast Ethiopia, with 5.5 hours spent grinding on 15 out of 28 days, beginning around 3 a.m. Teklu (2012, 35), working in another region of Tigray, reports women spending approximately the same amount of time grinding various grains. Two studies from Palestine likewise report grinding taking place during each night for two to three hours (Broshi 2001, 25; Dalman 1902, 13). Working in Mauritania, Roux (1985, 60) reported that it took, on average, 45 minutes to grind one kilogram of wheat and that household consumption averaged three to four kilograms per day (possibly more if the households that did not consume ground wheat were excluded, which is unclear in her book). Roux also described grinding as ‘very tiring’.

Horsfall (1983, 57, Table 4) also obtained some quantified estimates of time spent in grinding maize by women. She obtained estimates ranging from two to six hours of grinding a day as reported by several Highland Maya women. Over half of the women reported spending three hours per day, while the average was 3.5 hours per day. Other Meso-American ethnographic accounts report six to eight hours daily for the women of the Isthmus Zapotec in Mexico (Chiñas (1973, 41). Brumfiel (1991, 238) cites three additional sources (Lewis 1951, 41; Redfield 1930, 87; Whetten 1948, 305) to conclude that six to eight hours were spent daily by women grinding maize for their families. Bauer (1990; 2004) also estimates six hours spent daily by Teotihuacan women who would begin the arduous work at sunrise. This estimate was partly based on the observations of Miguel María de Azcárate in 1837.

In a similar vein, Dorsey (1899, 741) observed that “From her tenth year to her last it has been estimated that every Hopi woman spends on an average three hours out of every twenty-four on her knees stooping over a *metate*,” while Bartlett (1933, 28) places the estimate at three to five hours per day. Skeletal morphology, stress markers and pathologies in prehistoric women’s skeletons from the Southwest amply testify to the considerable time that women spent grinding meal (Crown 2000, 224). On the other side of the globe, in Burkina Faso, women were observed spending almost two

hours per day grinding and pounding grain (McSweeney 1979, quoted in Ember 1983).

In addition to these rare ethnographic accounts, archaeologists have conducted a number of grinding experiments which have been summarized and added to by Katherine Wright (1991; 1994, 246; 2000) in trials to produce coarsely ground flour (groats). Based on the data in her graphs, the average was about two hours of grinding per kilogram which may be slightly high due to some experimenters' inexperience or use of poor grinding equipment. In addition to the experiments cited by Wright, Samuel (2009, 464) conducted grinding experiments using various Egyptian grains and found that a kilogram of the hardest grain required 3–3.5 hours to grind. He estimated that about three hours of grinding would be needed every day for the bread needs of an ancient Egyptian family. Mona Wright (1993, 350) carried out grinding experiments with maize and arrived at values similar to those reported by others, i.e. one kilogram took about 1.3 hours. Barlow and Heck (2002) found that it took 7.4 hours to gather, dehusk and grind one kilogram of wheat into a coarse flour that still had considerable chaff. Finally, in our study Ansell undertook a series of experiments in which wheat grains were ground in both the dry and wet states. It took 2.5 hours to grind one kilogram of dry wheat grains to the point of producing fine and coarse flour in the ratio of 1:3. It also took 890 kilocalories to grind one kilogram. At this rate, with four kilograms of grain consumed by an average family per day, the grinding alone would consume an astounding 3,560 kcal. This must be an overestimate since even 'exceptionally active' individuals use only 3,822 kcal per day (Foxhall and Forbes 1982, 49). In contrast, it only took 1.7 hours to grind one kilogram of wet grain (soaked in water for 48 hours) and it took only 300 kcal to do so (with four kilograms being ground per family per day, this would require 1,200 kcal, still a hefty proportion of the grinder's daily calorie intake). While the wet grinding would seem to be most efficient, it was noted that the resulting paste stuck to grinding tools and hands and was difficult to clean off.

In view of these costs, most researchers view the use of grass and cereal seeds as very low ranked foods requiring far too much effort to be worthwhile to exploit except under dire circumstances (Kelly 1995, 81–2; O'Connell and Hawkes 1981; Gremillion 2004; K. Wright 1991, 35–6; 1993, 36; 1994, 244). The !Kung avoided their use completely and Californian and Australian tribes only used them when forced to by necessity.

Determining grinding times for cereal grains is a complex undertaking, since times are heavily influenced by varietal husk or other characteristics, the size and materials of the grinding stones, fineness of the grind desired, age of the grinder, their skill, energy levels, amount of resting and probably other factors. However, despite these variables, between the unquantified anecdotes and the quantified observations, we can generally conclude with some confidence that grinding grains was a very labour intensive process requiring many hours of hard work per day for women in households. This fact is clearly documented in the skeletal deformities of some early women's

bones indicating long hours spent kneeling and grinding (Crown 2000, 224; Moore et al. 2000, 503). As already noted, the heavy work of grinding is not necessary for the consumption of cereal grains.

Are there any benefits to eating ground cereal preparations as opposed to whole cereal grains? As Katherine Wright (1994, 246) has put it: '[i]f the goal of cereal processing was minimization of labour (and maximization of caloric return per unit of time), processing would stop at dehushing and groat production would be avoided'. According to Cowell (1962, 86), this was in fact the case in the Roman Empire where '[t]he poorer citizens . . . preferred wheatmeal porridge or groats to bread; porridge meal did not need grinding and would not take so long to cook'. According to Pliny, early Romans also preferred porridge to bread, presumably for the same reasons (White 1995, 39). Of course, the use of grains for beer production would greatly reduce the dehushing and grinding or pounding time and energy involved, although a great deal of the nutritive value might be left in the lees and unconsumed by people. To obtain some benefit from the residues, they could have been fed to animals.

Nutritional benefits?

Perhaps sensing something of a disconnect between the energetic costs and the uncertain benefits of grinding cereals, a number of authors have proposed various benefits of grinding and have attempted to account for the adoption of grinding using several lines of argumentation. The most common is that superior nutrition is provided by grinding grain. Most recently, Eitam et al. (2015) have stated that bread is 'a major source of grain nutrition (much more than flour, groats, or porridge)' although they do not provide any documentation for this assertion. The main factor usually invoked for the putative higher nutritional values of ground grain is the claim that grinding increases the surface area of the consumed material making it easier and quicker to digest the nutrients in cereal grains as well as providing increased bioaccessibility (the proportion of nutrients that is actually released from an ingested food). In addition, it is argued that the effect of bran is reduced by grinding and sieving, thus slowing the passage of ground grains through the gut and allowing more time for nutrients to be absorbed (Stahl 1989; K. Wright 1993, 97; 1994, 243, 246).

There are several problems with these claims. It is clear that ground, refined cereal starches are more rapidly digested and absorbed into the blood stream as glucose. Thus, breads have almost double the glycaemic indices as whole grains. White and whole wheat breads have average glycaemic indices of 70–73. Breads with 75 per cent cracked wheat have average glycaemic values of 48, while boiled whole wheat grains have glycaemic values that range from 30–48. However, there is no data that we are aware of which show that the total calories absorbed before evacuation is any different for boiled whole grains versus breads. Refined flour products simply seem to get into the blood system faster (O'Dea et al. 1980; Thorne

et al. 1983). In fact, people generally use their molar teeth to chew whole grains prepared as boiled wheat berries, thus reducing them to a coarsely ground mash and adding digestive enzymes from saliva before digestion. The chewing effort for boiled whole grain wheat can be compared to that required to chew roasted sunflower seeds or peanuts or a piece of game meat. The range of particle sizes of chewed grains may be comparable to the particle size of coarsely ground groats and thus, the effect on digestion from grain size should not be notably different from most coarsely ground flour preparations.

It is true that some foods such as almonds in particular are not completely digested when consumed as masticated or coarsely ground particles (Ellis et al. 2004; Wollstonecroft et al. 2008, 20). However, different foods vary enormously in terms of the ease with which cell walls can be ruptured mechanically or hydrothermally to release lipids or nutrients. While almond cell walls are unusually resistant to rupturing, nutrients from other plant foods like potato become totally bioaccessible after only a few minutes of boiling (Wollstonecroft et al. 2008, 22). Even in the case of almonds, in vitro experiments indicate that larger particle sizes comparable to cracked wheat (2.58 mm) only reduced the digestibility of boiled wheat by 14 per cent (Edwards et al. 2014, 2755). We suspect that debraned rice and hominy would exhibit total bioaccessibility more like potatoes. Tellingly, the use of rice flour is strongly associated with specialty foods used on special occasions such as *mochi*, *dipatori* and various dessert cakes (e.g. Adams 2004, 61) – a topic to which we will return. However, the kinds of studies based on actual digests have not been carried out on cereals, nor have the effects of boiling or other processing treatments such as liming been examined for most cereals (see Wollstonecroft 2011 on the importance of processing plant foods). We would add that any availability of carbohydrates from unground starch sources would also be highly dependent on the degree of cooking and the amount of chewing before digestion.

To bolster the calorie/nutrition argument, a number of authors have suggested that the bran left intact on whole grains speeds up the passage of cereals through the gut, thus leaving less time for complete digestion to take place and resulting in the evacuation of some portion of the cereal nutrients before maximum absorption (Kraybill 1977, 492; Stahl 1989, 173; K. Wright 1993, 97, 1994, 243). These arguments are largely based on a study by Payler et al. (1975). However, Payler et al.'s conclusions are misrepresented to make the nutrition argument for grinding. It is true that they found that the addition of bran to diets reduced the time of food in the gut; however, this was only true for people who had pre-existing long 'transit' times of three or more days. The effect of bran on people with pre-existing short transit times of one day was to *increase* the transit time. It seems likely that the largely high fibre wild plant food basis of Epipalaeolithic hunter/gatherers would have resulted in normal rapid transit times for all foods. Hence, the addition of bran from boiled whole grains should have actually slowed the transit time and enabled more complete digestion, whereas

ground grains would not have had this effect. In any event, there is no hard data that we are aware of to indicate that the consumption of boiled whole cereal grains would have increased transit time through the gut to the extent that optimal absorption of nutrients would not have taken place. In fact, O'Dea et al. (1980) found that after four hours the absorption of glucose into the blood from ground and unground grain was the same, although the ground preparations resulted in much faster initial absorption. In addition to these considerations, Foxhall and Forbes (1982, 46–7) found that the dry grinding of cereals resulted in the loss of a significant amount of the protein and lipid component of the grains due to the fact that these components tended to stick to chaff fragments that were subsequently winnowed out of the ground materials. Thus, eating whole grains should have actually been more beneficial nutritionally than ground grain products.

Arguments that invoke population pressures or increased sedentism, territoriality, populations and consequent needs to extract more calories from a defined, circumscribed land area to explain grinding (e.g. K. Wright 1991, 38; 1993, 97; 1994, 253; 2000, 97) do not hold up if there really are no net caloric or other nutritional benefits to grinding cereal grains. If anything, grinding would make conditions much worse since many more calories would have to be expended to grind the grain and therefore more food would have to be obtained. The excessive time devoted to grinding would also preclude the exploitation of many other resources that could provide needed calories.

Although no one has considered the possible role of fermentation in leavened breads as providing significant nutritional benefits, it seems that the amount of fermentation involved in bread-making is too inconsequential to have much effect on overall nutrition derived from cooked grains. The nutritional contribution due to fermentation in the production of beers may be quite different, however.

Fuel costs

If there are no compelling nutritional differences between boiled whole or cracked grains and ground grains, what other factors could account for the excessive labour and energy involved in grinding grains? One of the more interesting suggestions has been that grinding reduces the cooking time for cereals and hence the fuel costs. This could be important where fuel was difficult to obtain. In contrast to the 30–60 minutes required to boil whole grains (time which can be considerably reduced if they are pre-soaked for one to two days, or even allowed to germinate, making them even more digestible), only about three minutes are required to boil coarsely ground groats into an edible porridge or paste (Richards 1939, 93). In the Southwestern United States, wood and water can be scarce and so it has been suggested that dry grinding was used to minimize these costs (Jenny Adams, personal communication). Similarly, in a Nepalese village with fuel limitations, a number of foods, including beans, were ground for rapid

cooking (Baudais and Lundstrom-Baudais 2002, 173). Egyptian grinding slabs at Wadi Kubbaniya dated to 19,000 BP appear to have been used for grinding tubers (K. Wright 1994), perhaps to release starches from fibrous matrices as with sea club-rush (Wollstonecroft et al. 2008), or possibly to conserve fuel. Unfortunately, we have no way of knowing how critical an issue fuel procurement was for Epipalaeolithic residents in the Levant or how much energy needed to be expended to procure enough fuel to boil several kilograms of cereal grain for an hour or so. However, we do know that the major Natufian sites were all in the Mediterranean Woodland zone (K. Wright 1994, 252) and that populations were not very large. Thus, judging from even larger modern ethnographic groups in similar zones, it would seem surprising that procuring fuel would have been so critical as to warrant the time and energy outlays typical of grinding cereal grains. Surely, a trek of one or even two hours to procure wood would be a better option than the hard labour involved in grinding for three to five hours.

Taste and lasting power

If fuel concerns were not critical in decisions to grind cereal grains, what other factors are left? If we examine the statements actually made by subsistence farmers, the reasons for the high desirability of ground grain food products revolve around their taste and hunger-allying properties. Interviews with Tigrinya speakers in Northeastern Ethiopia revealed that people prefer bread (especially their prestige bread, a fermented pancake bread called *injera*) to any porridge. They were asked, 'Why would you do all that work to make bread when you would just need to boil grains?' The responses were consistent and adamant that boiled grains would not fulfil or satisfy the hunger and further, how could anyone eat porridge several times a day, it would make one 'hateful' of that food. They argued this is not the tradition of their ancestors, grinding is the tradition. Some grains are roasted rather than ground, but these are considered 'snacks' when consumed, regardless of the quantity eaten. *Injera*, the dietary staple, appears to have a higher status than porridge and is typically served twice per day (afternoon and evening). It is considered a proper meal and a means to satisfy hunger. It should be noted that when *injera* is served, normally it is accompanied by a *wot*, (a sauce made from chickpeas and spices), warmed vegetables or, on special occasions, meat. It may, in fact, be these accompaniments that provide the enhanced satisfaction that makes *injera* a meal that confers satiety.

Among the Bemba, the critical concern for food preferences is their hunger-allying properties, or 'burn' length. Only foods that have 'lasting power' (i.e. the time until the next pangs of hunger occur) are considered real foods. 'Lighter' foods are despised (Richards 1939, 51–2). Good lasting power can probably be equated with lower glycaemic indices while lighter foods probably exhibited higher glycaemic indices.

However, there are also problems with accepting these emic reasons at face value. Although taste is highly subjective, we believe that most people

would find that the boiled whole grains have more flavour than ground cereal foods even if Maillard reactions are generally considered to create appealing tastes in freshly baked crusts. Irrespective of the subjective taste differences, superior taste is rarely sufficient motivation to induce people to engage in adding onerous workloads. As James Woodburn (1966) noted, the Hadza envy their agricultural neighbours and the good taste of their foods, but all the same, they do not consider it worth the additional effort to cultivate plants. In addition, if the lasting power of food preparations was such a paramount consideration, one would expect boiled whole grains to be far preferred to breads or other ground cereal preparations. Boiled whole grains have much lower glycaemic indices than ground cereal preparations and subjectively, in Hayden's experience at least, have far greater hunger-allaying properties than breads – with hunger not returning for many hours after consumption of boiled whole grains. Oat porridges, in particular, have a reputation among hikers for their 'long burns'. Thus, in terms of flavour and hunger-allaying properties, one might expect that boiled whole grains would be the preferred form of cereal preparation with the most advantages and benefits.

Glucose highs

However, it is possible to perceive a kernel of truth behind some of the emic reasons given for grinding. Taste is not just the flavour of foods, but can also be used as a descriptor for the overall effects of food. In the preceding discussion, the most notable difference that we have been able to detect between whole versus ground grain consumption has to do with the rate of nutrient absorption and the rate of glucose increases in the blood. In effect, under conditions where calories are scarce and predominantly come in the form of low glycaemic foods, the ingestion of any high glycaemic substances might give rise to a very strong bodily reaction similar to a 'sugar rush' in Industrial societies. Industrial citizens may not notice much of a difference in eating breads because so many of our foods are high glycaemic in nature. Our circulatory systems are constantly flooded with high levels of glucose that would mask any effects of bread consumption. As Wadley and Hayden (in press) have suggested, Industrial citizens have developed a drug-like 'tolerance' for, and dependence on, high glycaemic foods. They even experience withdrawal symptoms when they do not get a regular dosage of such foods:

'Humans eat sweet, fatty, energy-dense foods in response to depression, stress and negative affect (Gibson 2012). These "comfort foods" (Dubé et al. 2005) induce "a psychologically comfortable and pleasurable state for a person" (Wansink et al. 2003). Sucrose acts as an analgesic (Blass et al. 1987), reduces stress (Ulrich-Lai et al. 2010) and reduces future-discounting (Wang and Dvorak 2010), with repeated consumption leading to tolerance and withdrawal effects'.

(Johnson and Kenny 2010)

Manufacturers of these foods are keenly aware that refined starches and sugars can be used to lure people into surrendering surpluses in exchange for these desirable foods.

In contrast to the daily surfeit of glucose producing foods today, under traditional hunting and gathering diet conditions, the effects of occasionally consuming high glycaemic foods like breads may have been very noticeable, with people experiencing bursts of energy, alertness, well-being and perhaps even euphoria (especially if combined with the production of exorphins) after consumption.

Prestige food

What we would like to suggest is that ground cereal grains made into breads or porridges were essentially some of the first prestige and value-added comfort foods of the Late Epipalaeolithic and Early Neolithic. They were very attractive and desirable, with good tastes and possibly addictive effects for some people, yet they were a great deal of work to prepare – far more work than most hunting and gathering people would ever consider to be worthwhile for a daily food. Hence, we suggest that their initial use was probably for special occasions like feasts where extra efforts were generally made to procure and prepare specialty kinds of foods to impress guests. Indeed, it seems far from coincidental that the first evidence for feasting in the Near East occurred in tandem or before the rise in importance of grinding stones (Hayden 2011; 2014). Although Katherine Wright endorsed the view that grinding increased the nutritional value of cereal grains, she also later realized that ground grain preparations could play important roles in feasting contexts (2000, 97). As seems to typify archaeological approaches in the Near East, she tried to construct a scenario in which population pressure and stresses led to rivalries and competition which in turn led to competitive feasting. However, as she herself acknowledges, there is no evidence of population pressure in the skeletal record and the increase in Natufian ground stone occurs during climatically favourable conditions when resources were relatively abundant (Maher et al. 2011, 5–6, 9, 16; K. Wright 1994, 252; see also Hillman 2000, 366, 370–1, 384, Moore et al. 2000, 480; who describe the ‘endless vistas’ and ‘vast supply’ of plant foods and the ‘more than sufficient’ ‘meat in whatever amounts were needed’).

Ethnographically, feasting is avoided when there are food stresses. Feasting is predicated on surplus production and only occurs under conditions of plenty (Hayden 2014). Thus, we suggest that the nutritional stress model used to explain the popularity of grinding stones in the Natufian should be abandoned. In its stead, we propose that grinding was widely adopted in the Late Epipalaeolithic either to prepare flour for baking bread or porridges, or for grinding malted barley to brew beer. At this point, it is impossible to distinguish between these alternatives; however, all of these cereal preparations make a great deal of sense as prestige foods in the context of feasting among complex hunter/gatherers.

If this scenario resembles the actual events, it would help to explain the high status and role of bread in traditional subsistence communities and as food fit for the gods. Leviticus 2:4–8 refers to wheat offerings to the gods, while Jeremiah scolds women for offering bread to the gods. Similarly, in Mesopotamia bread is referred to as god's food (Mitchell 2004, 134, 147, 177) and even Christ referred to bread as his body (still today consumed sacramentally as a 'host'). Goulder (2010, 359) muses that leavened bread may well have been a delicacy in the fourth millennium. Arabic medieval travellers in Africa report bread as a luxury item (Lyons and D'Andrea 2003, 523), while in Ethiopia, Darcus found that *injera* made with *t'eff* is still considered a prestige food for honoured guests and special occasions while other decorated leavened breads like *embesha* are used at weddings and given to priests. In Medieval England, the term, 'lord', meant 'he who guards the loaves' (derived from Germanic 'hlafweard' or 'loaf-ward'), while 'lady' was literally 'one who kneads bread' (Harper 2001–2016). In Greece, Paul Halstead (personal communication) pointedly observed that in rural communities, a feast without meat is the sign of a poor household indeed; whereas a feast without bread is simply unthinkable. Hayden's experience in French rural communities mirrors this view. Why did bread play such a critical role in the worship of gods and the role of the elites? Why is bread still such an essential element in traditional feasts? We suggest that it is precisely because for a very long time it was a highly desired but very costly type of food to produce and that this tradition has continued until today in communities involved in subsistence production. This tradition includes the unique attribution of a human-like spirit to wheat (Hayden 2014). Similar developments characterize the initial use of rice in the Far East and its enduring essential role in all feasts (Hayden 2011a).

If bread played this kind of a prestige role initially, what accounts for its more banal 'profane' role suitable for workers and slaves in many Classical and early African state contexts (Foxhall and Forbes 1982; Lyons and D'Andrea 2003, 522–3) and for the poorest people in modern societies? We suggest that, as with any prestige material, bread was initially highly desired by all, but only available to the rich and determined. Under these conditions, those who were more disadvantaged constantly tried to find ways to access the desired foods resulting in technological innovations or new social arrangements that made some desired foods more affordable. Thus, today, the luxury white bread of the Medieval elites has become the banal white bread of nations; the chocolate used as currency by Aztec elites has become the bane of obesity; the wine and beer of Mesopotamian rulers has become the cheap drink of the multitudes. Wherever technologically feasible, prestige technologies spread to be embraced by the general populace. Everyone wanted to be seen as important and close to elite status. No one wanted to be at the bottom of the social pyramid. Thus, people strove to imitate what were initially elite prestige practices and consumption habits. In the Industrial societies of the nineteenth and twentieth centuries, all proper households strove to imitate feasting serving wares of higher classes so that sets of finer

china used on special occasions were widespread in almost all proper households. We suggest that bread played a similar role in Neolithic societies.

Elites, too, tried to find ways of decreasing the cost of some prestige items so that they could use items viewed as prestige goods to extend their spheres of debt and influence as far as possible. In Classical and earlier times, the key to producing bread on a large scale was probably the creation of larger milling stones as well as the establishment of pronounced power differentials so that slaves and prisoners could be forced to do the arduous work of grinding grain for general production and use. We suggest that after a few thousand years of producing breads exclusively for feasts in Natufian times, all but the poorest families began to insist on the production of bread so that they were not viewed as inferior or as undesirables.

It seems likely that women, in particular, may have been manipulated to accept the additional arduous work of grinding on a regular basis in order to enhance their marriageability and to increase the value of any bride prices that a family would receive. In tribal societies, arranged marriages involving substantial wealth exchanges or bride prices are common, as are measures undertaken to enhance the value of the potential brides, including bodily deformations (necks elongated with metal rings, oversized lip or ear plugs, foot binding, clitorrectomy or infibulation, special training, sequestering from the sun and scarification or tattooing). Young girls could be brought up with grinding grain as an expected chore. Newly married women often had to accept workloads imposed upon them especially by older women in their husband's households. Even today, in Ethiopia, women are given their first set of grinding stones when they marry (generally when in their early teens). The grinding stones are provided either by the woman's parents, her in-laws, or her husband. Given such circumstances, it is perhaps not surprising that grinding grain on a regular basis became 'normal' fare for all self-respecting households in subsistence communities and that the lack of bread became a sign of extreme poverty. Even in Plato's time, gathered bulbs and greens were considered the standard fare of poor country folk (Foxhall and Forbes 1982, 74–5).

The evolution of grinding

While we find these arguments persuasive, it is also true that seed grinding occurs in cultures like those in arid Australia lacking competitive feasting and perhaps any kind of feasting at all. How can these observations be reconciled with the above observations on the costs and benefits of grinding cereals? As previously noted, there now appears to be a consensus that consumption of grass seeds represents extreme work (Gremillion 2004; Kelly 1995, 81–2; O'Connell and Hawkes 1981; K. Wright 1991; 1994; 2000). If this tenet is correct, there are only two conditions that should result in the adoption of grinding to process grass seeds: a lack of higher ranked foods (food stress) and efforts to show off wealth or control of labour (prestige technologies).

Some sort of grinding in the Australian arid area may extend back to 30,000 BP when the first grinding stones are claimed to appear (Fullagar and Field 1997). Although M. Smith (1988) doubts that grindstones were used for processing earlier than 12,000 BP on morphological grounds, Fullagar and Field (1997, 304–5) report preliminary identifications of phytolith, starch and use polishing consistent with the processing of grass seeds. Following O’Connell and Hawkes (1981) and M. Smith (1986), the use of grass seeds, in turn, is related to conditions of increasing aridity and the need to incorporate progressively lower ranked, more costly foods, into the diet. Many of the grass seeds used ethnographically by Australian Aborigines were small-seeded species with very hard coats. In order to make any use of these seeds, we think these would be difficult to dehusk using wooden mortars and pestles in the fashion used for cereal grains, although we know of no experimental or ethnographic observations on the topic. Wooden mortars for such uses are not reported ethnographically in Australia, although grass seeds were apparently pounded up with great difficulty in stone mortars and pestles (M. Smith 1986, 30). Grinding such small seeds into a paste (with or without baking) appears to be about the only way to make them edible. Despite the high cost of using these foods, the repeatedly noted advantages are their wide availability and the fact that they store exceptionally well due to their hard protective coatings adapted to survive the most arid conditions. Thus, they could be harvested and stored for use during starvation periods.

A similar situation appears to be represented in the Near Eastern Upper Palaeolithic at Ohalo II where considerable quantities of charred small grass and cracked cereal seeds (morphologically the same as *burgul*, i.e. cracked wheat) were associated with a hearth and a very modest unshaped grinding stone dated to 23,000 BP (Kislev et al. 1992; Nadel et al. 2006; 2012; Piperno et al. 2004; Snir et al. 2015; Weiss et al. 2004). This occupation would have occurred under glacial maximum conditions with high relative aridity, low lake levels and presumably stressed resource conditions. On the basis of starch grain analysis, similar use of grinding stones for seed processing has been reported for stones dating to at least 30,000 BP from Kostenki 16 (Uglyanka) in Russia (Revedin et al. 2010). Similarly, Aranguren et al. (2007) have recovered starch residues (predominantly rushes and grasses) from a grinding stone at a site in Italy dating to the Gravettian, 25,000 years BP. Thus, it seems likely that the use of grass seeds by grinding, or at least crushing, was originally developed in the Upper Palaeolithic as part of a backup subsistence strategy to weather times of severe food crises. This would explain why frequencies of grinding stones are very low and their sizes are small and/or lack morphological indications of regular use or design. It therefore seems that grass seeds were rarely used and perhaps only to the extent absolutely necessary in the Upper Palaeolithic (Storck and Teague 1952, 18–20).

This same strategy may have also been followed by Late and Epi-Natufian groups inhabiting the hyper arid areas of the Near East. However, as strategies and techniques for using grass seeds developed over time, ways of

dehusking the larger seeded grasses such as cereals must have been discovered – especially employing wooden mortars and pestles. This would have opened up the possibility of boiling whole grains for foods and a less costly way of using cereal grains for food (1,980 kcal per hour return for boiled whole grains as opposed to a mere 980 kcal per hour for dehusked and coarsely ground wheat – based on data in K. Wright 1994, 247). As indicated by the *burgul*-like cracked cereal remains 23,000 years ago at Ohalo II (Snir et al. 2015, 63), the use of boiled whole or cracked grains may have continued for thousands of years during times of resource stress without being very visible archaeologically except for the occurrence of fire-cracked rock beginning in the Upper Palaeolithic, although archaeologists generally assume that fire-cracked rocks were used for extracting bone grease rather than boiling cereals. We postulate that in developing the porridge use of cereals to cope with conditions of scarcity, people may have discovered the more desirable, glucose-enhancing and other derived effects of cereal consumption, especially if porridges sometimes fermented and people began to experiment with ways to further enhance these effects for special occasions under more resource-abundant conditions.

With the emergence of complex hunting/gathering societies in the Epipalaeolithic, new socioeconomic competitive forces made these labour-intensive and desirable features of cereals extremely useful, particularly in the context of feasts used to impress and indebt guests. The ultimate result, we think, was the periodic production of beer and bread. However, due to the high costs of these products, they were only normally produced by relatively wealthy individuals with surpluses and some control over labour. Tellingly, M. Smith (1986, 30) reports that grass seeds in arid parts of Australia were used to finance group ceremonies. She attributes this to the need to procure more food within a given foraging radius to support larger than normal numbers of people; however, one must wonder if these were not, even then, considered as prestige foods.

By the Early Natufian, an unprecedented increase in ground stone occurred, primarily in the form of mortars and pestles, but with some well-formed grinding stones as well (K. Wright 2000). *Stone* mortars and pestles, especially of the small size of most Natufian examples, are unsuited for dehusking cereal grains (Lundstrom-Baudais et al. 2002, 193; Meurers-Balke and Lüning 1999), although *wooden* pestles used in medium size conical stone mortars appear to effectively remove husks at least from wild barley (Eitam et al. 2015). The larger and medium-sized stone mortars used with stone pestles would have been well suited to crushing grain with chaff for use in brewing. Most of the smaller mortars and pestles are the size equivalents of mortars and pestles used by ethnic groups today for processing condiments and/or salt and the same may have been true of the Natufian use of small mortars as K. Wright (2000, 101) has mused. This would make good sense since more elaborate cuisines and food preparations may have developed in feasting contexts.

By Late Natufian times, grinding stones exhibit definite increases in frequencies and probably sizes (K. Wright 1994; 2000; 2001), although most

sites have only one or no reported grinding stones – indicating that the use of these tools was infrequent and involved relatively small volumes. However, even in ethnographic communities that rely on grains, a surprisingly large percentage of households may not have grinding stones (Roux 1985, 67). Wright further notes that ground stone, whether mortars and pestles or grinding stones, are strongly associated only with the larger Natufian settlements with stone architecture and burials, suggesting that the use of these tools may well have been in the context of funerary or other important feasts (K. Wright 2000, 92, 97). This makes good sense in terms of the observations we have presented above. Such feasting might be expected to occur predominantly in the larger sites with prestige architecture. Given the generally low frequencies and small size of both mortars and grinding stones as well as the minor importance of cereals at most Late Epipalaeolithic sites (Hayden et al. 2013; Savard et al. 2006, 190–2), it seems evident that the use of ground or brewed cereal products was far from a daily occurrence and was probably reserved for special occasions like feasts where the goal was to display as much wealth and labour control as possible to invited guests, whether in the form of specialty foods or drinks, elaborate architecture, prestige carvings, or even human sacrifices (Hayden 2009; 2011; Hayden et al. 2013). The fact that these trends began in the Early Natufian in times of abundant food availability and that there is no indication of nutritional stress in skeletal remains is a strong indication that the notable increase in the use of ground cereals in the Natufian was not the result of survival needs.

The use of grinding stones continues to increase in PPNA times (K. Wright 1993, 97), perhaps representing the transition to more regular feasting and use of ground cereal products. However, based on dental wear, even in Late Natufian times, at least some individuals seem to have been consuming large amounts of gritty ground cereal foods (P. Smith 1972). These individuals may have been those most prominently involved in feasting activities and preferentially buried at the principal sites with the most feasting activity. K. Wright (2000) suggests that there was a change in social organization between the PPNA and PPNB communities as reflected in the outside versus inside locations for grinding grain. However, Roux (1985, 37) observed that a preference for grinding grain inside houses was not due to any social concerns, but simply a desire to avoid winds that dispersed ground flour from dry grain. Any change from outside to inside grinding locations may thus simply reflect a shift from wet grinding to dry grinding techniques.

Conclusions

We hope to have shown that while the basic labour-intensive technology of grinding grass seeds into pastes to cope with dire food conditions may have begun in the Upper Palaeolithic and been used only under stressful conditions, the proliferation of grinding stones in the Late Epipalaeolithic archaeological record was probably due to entirely different conditions related to social developments based on the use of surpluses in aggrandizer strategies like feasting among complex hunter/gatherers. Due to the

high costs of dehusking and grinding cereal grains into suitable flours for making porridges and breads, we argue that these food preparations only became regularly used when socioeconomic inequalities and some control over labour emerged, in particular for periodic feasting events meant to showcase individual or group success and power. There appears to be no nutritional justification for spending the many hours every day required to convert cereal grains into fine or even coarse flours. Given the high costs documented, viewing the Late Epipalaeolithic and Early Neolithic use of cereal grains as 'profane foods' according to some archaeologists should be rejected (e.g. B. Smith 2001, 212).

Cereals may have also been used for brewing beers for feasts since feasting is the almost universal context for using beer ethnographically due to its high production costs. Mortars and pestles as well as grinding stones could have been used in processing grains for brewing. While not reported ethnographically, it seems possible that the processing of cereals in early times could have made use of all dehusking and grinding products. In our experience, dehusking is often easily achieved for a certain proportion of primitive grains while another proportion is highly resistant to husk removal in wood mortars. Similarly, a proportion of ground grain becomes very finely ground while another proportion remains as coarse bits resistant to further reduction. However, if separated, all of these fractions could be easily used: any remaining husked grains could be cracked in stone mortars and used for brewing; the successfully dehusked grains could be used for boiling whole or they could be ground up; the fine flour could be used for making breads; and the coarse flour could be used either for porridges or for brewing. Such a strategy would have minimized the diminishing returns of persistent pounding and grinding until all grains were processed to a single desired end product like fine flour and it would have maximized the use of all grain products. Such a strategy of using different ground products for different kinds of foods seems to have been employed by Romans who used only the finest sieved flour for the best cakes (White 1995, 40).

There are still many unresolved issues in the study of cereal use and ground stone uses. We need much more precise data on the exact nutritional advantages and disadvantages (including uptake in the gut) of simple boiled whole or cracked grains versus ground grain preparations. Standardized initial quantities of dry grain need to be established in individual experiments. We need a more comprehensive quantitative model of factors affecting grinding times. We need to know more about initial use of grinding and seed use during the Upper Palaeolithic. We need to know whether brewing was an integral part of Natufian feasting. We need to know more about the processing of small-grained grass seeds. We need more residue analyses of ground stone and perhaps DNA analyses of residues. As K. Wright concludes (2000, 117), we need more research on the social environments of food production. And, we would add, we need many more fundamental observations of traditional uses and processing of cereal grains and other grass seeds. Hopefully, it is not too late to still obtain some key insights from traditional subsistence farmers.

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