

Ann-Marie Hansson

GRAIN-PASTE, PORRIDGE AND BREAD Ancient cereal-based food

The charred food remains that are frequently found on archaeological excavations constitute a rather neglected artefact group. These residues of human activity can provide valuable information on prehistoric diet both with regard to ingredients and to techniques of preparation. A classification of five, more or less fragmentary, findings of charred organic material from five separate Swedish archaeological sites, of different dates, is here presented. The results of macro- and micro-botanical as well as chemical analyses and a comparative study of types of cereal-based dishes known from Classical texts and Swedish ethnological records serve as a basis for classification. The article is mainly concerned with grain-pastes, porridges and bread.

Introduction

It is likely that plant foods have always constituted the greater part of the human diet except in the northern parts of the world, where a cold climate and long winters favour a short growing season. In these areas, a meat diet must have had greater importance (Renfrew & Bahn 1991:245).

Animal bones are one of the commonest finds on archaeological excavations in Sweden. As a result, it is mainly the animal part of the human diet which has hitherto attracted the attention of nutrition research in Sweden. Possibly another reason is the higher status of meat over plant food.

There are various indirect ways in which a plant diet can be traced. One method is the measurement of strontium isotopes in human bones from archaeological sites, since meat contains a lower amount of strontium than do plants. That is to say, information is obtained on whether plant foods were included in the deceased's diet, and if so, in what proportion to the meat content of that diet (Brown 1974:47; Brown & Keyzer 1978; Schoeninger 1979). The strontium/calcium (Sr/Ca) ratio has been used in palaeonutritional research (Szpunar et al. 1978; Runia 1987). Here the information that can be gleaned concerns the diet consumed during the individual's lifetime, but says nothing about which plant food-stuffs were used or how the meals were prepared.

In order to obtain additional information on the input of plant foods in prehistoric nutrition, one must go beyond the purely archaeological aspect of an excavation and call upon specialist methods of analysis. One of these

methods is the analysis of macroremains of plants, whereby it is usually cereals, sometimes remains of seeds, fruits, nuts or berries collected for food, which are examined. Food preparation however remains unknown.

Apart from the vegetal diet discernable through analyses of macrobotanical remains found in cultural layers, the intestinal content of bog bodies, or coprolites (fossilized faeces), there is a highly interesting group of nutritional source-material which can be considered as mainly composed of cereals. This is the charred bread which occasionally comes to light on archaeological sites in Sweden, and the remains of charred organic material with a bread-like structure but lacking any upper- or underside, which cannot be indiscriminately categorized as bread.

Bread and related dishes are consciously composed food where appearance and method of preparation have been determined by the prehistoric individual on the basis of criteria of which we know little. Some clues as to which ingredients, appearance and methods of preparation were used, can be gleaned from Classical texts and ethnological records in combination with the results of botanical and chemical analyses of archaeological finds of charred prehistoric breadstuffs and other food remains.

Carbonized faecal material sometimes resembles charred food, but can be distinguished often by ocular inspection if the original shape is retained. During microscopic analysis usually the presence of certain ova from intestinal parasites reveal that what one is dealing with is the faeces of humans (Körber-Grohne 1991:4).

The charred organic material which resembles bread, but which because of its fragmentary condition cannot

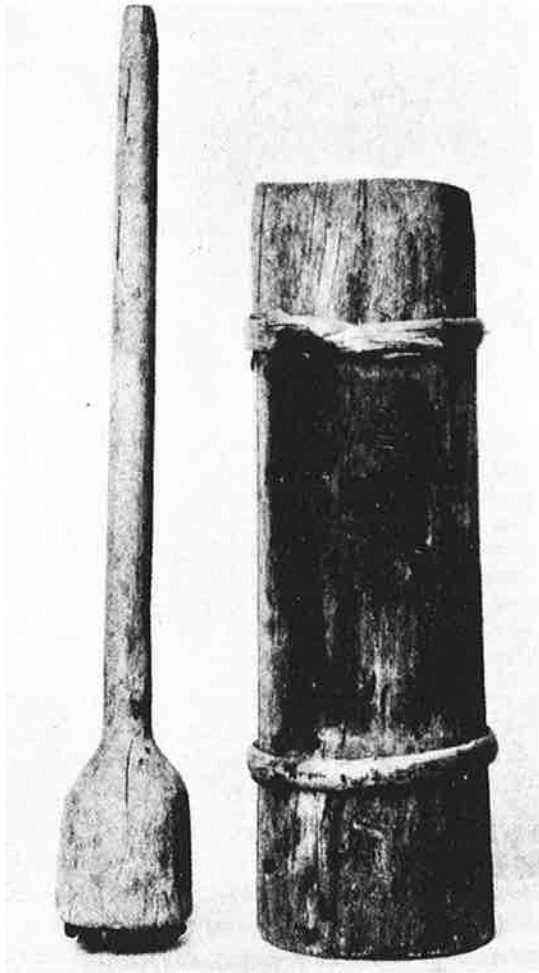


Fig. 1. Grain stamp (mortar) from Lappland, Åsele par. The vessel is 67 cm high. After Keyland 1989, I, p. 135, fig. 47.

without reservation be classified as bread, is of great interest. It is important to determine whether or not these organic remains are bread, and to classify the specific dish if possible.

Swedish ethnological research illustrates the multifaceted nature of bread usage. Appearance and ingredients could vary considerably and certain bread types were linked to certain festivities or served special functions (Keyland 1919; Campbell 1950; Olsson 1958; Berg 1960). A rich flora of cereal-based dishes such as porridge and blood bread (Sw. *palt*) existed alongside bread. Dishes which contained cereal-products, though not as the dominant ingredient, also occurred. Various mixtures of grain and chopped meat-products were common. Hash (Sw. *pölsa*) is one such dish which has survived into modern times. Dough enclosing meat or fish is also documented. This could be eaten both in baked form and as dumplings, cooked in water; examples include *kroppkakor*, *kams* and *klubb* (Keyland 1919, I:162, 163). There is a long list of such dishes and the type is not confined to Sweden; similar traditions are known from many parts of the world (Moora 1968:228). It is quite probable that the type also existed in prehistoric times.

In this paper I will deal with bread and such cereal-

based food which in structure and consistency could resemble bread in a carbonized and fragmentary state, such as grain-paste and porridge. The skills of crop-cultivation and the baking of bread using cereals, are both imports from southern lands, originally from the Near East, and therefore it will be necessary to discuss grain-pastes, porridge and bread even from that region.

Grain-paste

Grain-paste, preferably prepared from whole, crushed or partly ground cereal, can constitute the initial stage in porridge making, but sometimes it can be a dish in its own right. Since grain-pastes were not normally considered prestigious dishes, but rather part of the everyday diet, they seldom get mentioned in the Classical texts. In later written sources one can sometimes find the Greek word *mâza*, and the Latin word *puls*, usually translated respectively by the nonspecific terms "cake" and "porridge/meal-pottage". In actual fact, *mâza* was composed of a form of unbaked cereal-paste. The word *mâza* for example implies some type of kneaded food, but not bread (Hillman 1985:21), while the word *puls* seems to have been of a more general character and covered pastes of lentils and beans as well as cereals (Tannahill 1975:78f). If one reads through Pliny the Elder's recipe for Greek and Italian *mâza/puls*, one realizes, that it must have comprised an oily, salty and strongly flavoured paste rather than a porridge.

Pliny (23–79 AD) states: "The Greeks soak some barley in water and then leave it for a night to dry, and next day dry it by the fire and grind it in a mill. Some after roasting it more thoroughly sprinkle it again with a small amount of water and dry it before milling; others however shake the young barley out of the ears while green, clean it and while it is wet pound it in a mortar, and wash it of husk in baskets and then dry it in the sun and again pound it, clean it and grind it. But what kind of barley is used (...) they mix in three pounds of flax seed, half a pound of coriander seed, and an eighth of a pint of salt, previously roasting them all. Italians bake it without steeping it in water and grind it into fine meal, with the addition of the same ingredients and millet as well" (Pliny, *Natural History*, transl. Rackham 1971:237).

An advantage of these grain-pastes, where sometimes unripened cereals were used, was that they remained palatable over a long period. For long-term storage Pliny advised: "Those who want to keep it [the *puls*] for some time in store, put it away in new earthenware jars with fine flour and its own bran" (Pliny, *Natural History*, transl. Rackham 1971:237). Tannahill (1975:78f) has interpreted this to mean that the grain-paste should be covered with a coating of flour and chaff.

These grain-pastes were complicated to prepare, and Pliny's recipe for *mâza* can be compared to that for Turkish *bulgur*, which was similarly considerably time-consuming to prepare and involved the mixing of cereals

with milk products (yoghurt) before storing for long periods (Hillman 1985:3, 15). *Bulgur* is a dish which still exists (pers. comm. Karin Viklund, Umeå) and which probably has its roots far back in time.

Pliny's "kneaded things" (*mâza/puls*) seem to have been the everyday food of the greater part of the population in Rome and Greece, for as long as barley retained its importance (Moritz 1958:150), which seems to have been until the middle of the first millennium BC.

Another way of treating cereals, not unlike the preparation of Greek *mâza*, was to first sprout the unroasted cereals, whereby the starches became transformed into easily digestible malt-sugar. Preparation is very simple – wheat kernels, for example, are soaked in water for a few hours in a jar beside the fire. The cereal swells and becomes gelatinous (Tannahill 1975:38). This type of food is used still in many parts of the world.

Grain-pastes are an instructive example of a type of food which is unlikely to leave any trace in the archaeological record, since the paste was often prepared and kneaded immediately on eating. Possible remains which could survive would be the cereal grain lost during roasting or too heavily roasted and so discarded. Perhaps a house-fire could cause the storage-jar containing the stored grain-paste to carbonize and be preserved.

Porridge

In common with grain-paste, porridge is mostly a low status food, for everyday use, but with some exceptions. From Swedish ethnological sources we know that on special occasions, such as feasts where one was expected to bring along food or as gifts to women in childbed, porridge could become a high status dish. Such porridge (Sw. *förningsgröt*, lit. "visiting porridge") would represent the best the household could produce. Ingredients consisted often of wheaten meal cooked in milk, while sugar and eggs were added if such were available. Sometimes the consistency of this festive-porridge was rather thick and it was poured into a wooden mould with decorated bottom. When the porridge cooled and was turned out from its mould, it was beautifully decorated on the upper side (Keyland 1919, I:22, 160; Bringeus 1987:15). Festive porridge for special occasions is also known from across the Baltic Sea, from Estonia (Moora 1991:325, 328). Swedish ethnological literature records many varieties of porridge.

As already mentioned, the first stage in porridge-making can constitute grain-paste. It was not unusual in Sweden during the early 19th century to consume porridge of whole or crushed cereals (the same ingredients were used in the preparation of grain-pastes), with a cooking-time of several hours. The crushing process which preceded cooking, often involving a large wooden mortar (Sw. *grynstamp*, "grain-stamp") (fig. 1), recalls Pliny's account of how the cereals were crushed before making grain-pastes during Classical times. Mortars of



Fig. 2. Two figures pounding pestles in a mortar. Tomb of Antefoker at Thebes (no. 60), Twelfth Dynasty (Middle Kingdom). After Samuel 1993, p. 277, fig. 1.

similar form to these Swedish ones are also documented from ancient Egypt (fig. 2) (Samuel 1993:277). In Sweden this specific mortar type (*grynstamp*) is considered to be a traditional utensil with a long ancestry (Keyland 1919, I:134).

Clearly grain-paste and porridge share several common elements. The main difference between these two dishes is whether or not the ingredients are cooked. This definition of porridge as cooked, has been employed by Keyland (1919, I:11). It is to be noted that not only must porridge be cooked, but it must also have a relatively solid consistency and contain a high proportion of cereals. This is the definition that seems to have been current in the Swedish farming community over the last centuries. (Though according to ethnological sources both mashed potato and creamed fruit-syrup could exceptionally be called porridge.)

This kind of distinction is archaeologically useful, since porridge does not require a higher temperature than boiling point, 100°C, while bread is usually baked at 200–300°C (Hillman 1986:104). With the electron spin resonance (ESR) method it is possible to measure the highest temperature to which a material has been subjected in the past and also the duration of that heating. It is thus analytically possible to distinguish between porridge and bread. This method was used in the examination and identification of a charred griddle cake found in the gut of a British Late Iron Age/Roman-period bog body – the "Lindow Man", perhaps from the first century AD (the results from radiocarbon dating have been conflicting, see Brothwell 1986:17) (Hillman et al. 1985; Renfrew & Bahn 1991:244, 396). In Sweden the method can only rarely be applied, since almost exclusively only charred food-remains survive here.

In the Slavic area, a number of porridge-like dishes are known, some of which were leavened. Traditional sagas and songs suggest that these have a long ancestry (Keyland 1919, I:12). Keyland's term "porridge-like" for these, implies that they are most likely grain-pastes or transitional forms of grain-pastes and porridge.

The Roman army is recorded as having eaten both porridge and a coarse but tasty, wholesome bread (*panis militaris*) (Davies 1978:548f). For porridge, emmer wheat (*Triticum dicoccum*) would seem to have been specially employed. It is assumed that the Roman army's basic diet was similar both in Britain and Germany (Dickson 1989:135).

Bread

The distinction between bread and grain-paste or porridge in archaeological contexts demands a definition of prehistoric bread.

Definition of prehistoric bread

Ingredients: Consisting mainly of ground food plants, usually cereals, with the addition of a liquid and sometimes a leavening substance.

Preparation: Working-up into a dough, followed by baking in an oven or oven-like construction, or roasting at or on an open fire, on embers or in ashes.

This definition of archaeological bread differs somewhat from the ethnologist Alfa Olsson's definition of later Swedish bread, where only cereals should be used (Olsson 1958:53).

Most important to remember when distinguishing between grain-paste/porridge on the one hand and bread on the other, is that bread is *baked* and the ingredients are for the most part *ground*. Since we know that bread is baked even by non-agrarian populations (Thomson 1949:22f), our definition of bread must allow for the use of plant ingredients other than cereals.

During the early history of cultivation, grain-pastes and porridges were complemented by simple forms of unleavened flat bread including a type which could serve as a containing dish, so-called *Schalenbrot*, a dough or thick porridge or grain-paste which is pressed as an open shell over a heated stone and baked that way. Such "bread" has been found in the Swiss lakeside villages, from the earliest levels dating to Late Neolithic times (Heer 1866; Keller 1866:40; Maurizio 1916:91ff; Adrian 1951:73; Währen 1978:547; 1989:84). In ancient Egypt, the various kinds of bread included one with crater-like depressions (Adrian 1951:73; Währen 1963:24). Both the lakeside village bread and the Egyptian bread can have served as containing dishes. In such cases it is impractical to use a thin porous bread, as the container needs to be able to hold fat and liquids (figs. 3–4).

Within bread research, the use of unleavened bread is



Fig. 3. Under and upper sides of a "Schalenbrot" (x0.5) baked on wheat mixed with barley. Note the impressions of whole barley grains. Robenhausen, Switzerland. Late Neolithic Period. After Maurizio 1916, p. 92 and Adrian 1951, p. 72.

considered to have preceded leavened bread since the latter requires some form of oven-construction for baking. Unleavened bread could be baked in hot ashes, on embers, on heated stones or on a grid. Not only the baking technique but even the bread content is presumed to have undergone a development from coarse meal flour containing sand from the quernstone and other possible intrusions, to a white and finely sifted wheat-flour. The earliest simple breads using roasted meal or coarse flour and water, sometimes with a little fat, are considered to have been unleavened flat breads similar to modern Mexican *tortillas*, Scottish oatcakes, Indian *chapati*, Finnish *rieska*, etc. This type of bread is best when fresh and warm since it hardens on cooling (Lerche 1981:179). It has the advantage however that it can be dried and stored to have in reserve.

In some investigations of charred prehistoric bread there has been a tendency to categorize bread qualitatively. Unleavened bread containing barley has been considered to have had lower status, while bread baked from wheat which in addition has a certain porosity, has been considered of higher status. This is not contradicted by ethnological evidence, but caution must be used when classing the different bread types as "superior" or "primitive". There are many exceptions to these standard quality assessments. Perhaps such categorization has been influenced by the Icelandic poem-fragment *Rigsthula* which survives in the *Poetic Edda*, considered to have been composed during the 14th century (von See 1981:94 ff). Certainly this is the poem most referred to by prehistoric diet researchers.

Rigsthula describes how the god Heimdall, here calling himself Rig, travels around among the humans on Earth. He visits the three social classes: thralls, farmers and nobles, whose distinctive social circumstances are characterized in poetic form with regard to diet and especially the various types of bread which distinguish each class. Unfortunately the passage dealing with the bread of the farming class is missing. That of the thralls is described as "densely baked, heavy and filled with bran". The bread of the nobles on the other hand is described as "thin loaves, white of wheat". (*The Poetic Edda*, transl. Collinder 1972:147ff)

An example of the complexities involved in categorizing different bread-types, is the so-called *skrivbröd*

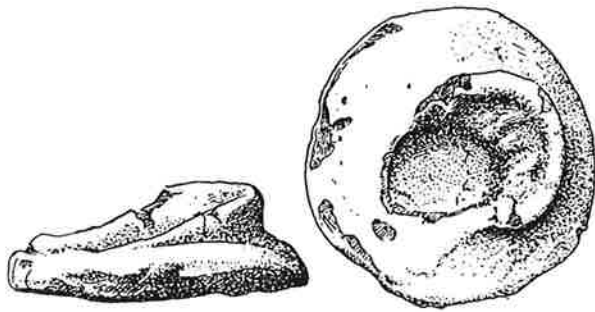


Fig. 4. Bread with crater-like depression from a tomb in Thebes, Upper Egypt, New Kingdom, c. 1000 BC. Diameter c. 13 cm. a) sideview b) upper view. After Adrian 1951, p. 73 and Währen 1963, p. 25.

(lit. “writing bread”) from western Sweden (Olsson 1965). This bread, were it to be found as burial bread on an archaeological excavation and analysed, would be classified as a very simple everyday bread, since it is an unleavened flat bread made on barley flour. But in reality such bread was reserved for special occasions, according to Swedish traditional records. Thus by a simple process, a commonplace bread was transformed into a thing of high status and ceremony. This bread was usually made as follows: an unleavened flat bread made from a dough on barley flour or rye flour, was partly baked and thereafter brushed-over on its upper surface with a mixture of egg, milk (cream), flour and sugar. The utensil used for spreading out the mixture was called a *skriv* (lit. “that which writes”) or *skrivkam* (lit. “writing-comb”), made from either birch-bark or wood, with a toothed edge (the resemblance to writing in drawing the comb over the bread, has given rise to the name “writing-bread”). The combed bread was placed back into the oven to allow the new surface to dry. This process could be repeated several times; the more often, the more splendid the result (fig. 5).

The most interesting aspect of this type of bread is that parallels exist from other parts of Sweden where a commonplace thin unleavened barley bread (leavened bread could also be used) was for special occasions brushed-over with a gruel-like paste. Keyland (1919, I:37, 179) refers to such bread from ethnological sources.

We do not know if this bread type occurred during prehistoric times. The thin decorative coating would most likely fall away during carbonization in a burial pyre or during a house fire. If the coating survived, it would be most difficult to differentiate it from normal splitting of the bread surface. In other words, such bread would fall under the category “normal daily bread”, since it was made from barley and furthermore unleavened.

Leavening

In the Mediterranean area, fermentation was used in the production of beer and wine at an early stage. This technique then began to be applied to bread which was now replacing porridge and grain-paste (Tannahill 1975:58f). Fermentation as a preservative even for animal products,

is however an ancient method used into present times in northern Europe and Arctic areas (Eidlitz 1971:130ff). An example is “leavened palt” (Sw. *surpalt*), a mixture of blood and cereals (Keyland 1919, I:163f, II:62, 65f). This has been compared to food-encrustations from pottery vessels found on archaeological excavations, which on chemical analysis were diagnosed as probable remains of fermented blood porridge (Arrhenius 1984; 1985; Arrhenius & Lidén 1989; Arrhenius & Slytå 1979; 1981). Meal-sausage (Sw. *mjölkorv*) and stuffed dump-lings are recorded from the Estonian islands and on the island of Hiiumaa these were often leavened; blood was frequently included as an ingredient. (Moora 1991:326).

Leavened bread is much more nutritious than unleavened bread. During fermentation the phytic acid in the cereals is broken down. This has great advantages since phytic acid has the ability to complex with proteins and particularly with the nutritionally important minerals calcium, magnesium, copper, iron (Fe^{2+} and Fe^{3+}) and others, which makes them biologically unavailable for absorption (Reddy et al. 1982:19, 20, 29).

The effect of phytate as a cause of zink deficiency in humans, finds support in reports from Egypt (Prasad et al. 1963:407; Sandstead et al. 1965:15) and Iran (Reinhold 1971:1204; 1973:187; Halsted et al. 1972:277; Reinhold et al. 1973:283) where it appears that zink deficiency occurred under conditions where unleavened flat bread was consumed in greater amounts than leavened bread (table 1).

There must have been a great risk for zink deficiency due to an unbalanced flat bread diet during prehistoric times in certain parts of the Mediterranean, where the mainstay of the diet consisted of unleavened bread. This would have been particularly the case with the lower classes of society. The upper classes always had more



Fig. 5. Skriv made from birch bark. After Olsson 1965, p. 35.

Bread	Phytate (mg/100g)	Treatment
Bazari	326	Leavened
Sangak	388	Leavened
Tanok	684	Unleavened

Table 1. Phytate concentrations of Iranian flat breads, leavened and unleavened. After Reddy et al. 1982, p. 37 (compiled from data in Reinhold 1975a, p.38; 1975b, p. 115).

access to animal products and had in general a more varied diet. Until the middle of the first millennium BC, the broad mass of the people in Italy and Greece still ate *puls* and *māza* (which could contain other ingredients than cereals). Later on, bread became more common: unleavened barley bread for the poor and slaves, leavened wheaten bread for the rich (Adrian 1951:79). In Egypt, bread, onions and beer formed the most usual daily diet of the poorer classes.

Zinc deficiency can lead to retarded growth, lowered immunity to infection and inefficient healing of sores. By eating sprouted cereals (Torelm & Bruce 1982:79) or cereals which were not quite mature and thus contained slightly less phytic acid (Reddy et al. 1982:7), or by eating leavened bread, the risks could be lowered. Sifted flour also contains less phytic acid since the acid mainly occurs in the germ and in the aleurone layer, one of the cell layers which surrounds the endosperm. Thus phytic acid is to be found in wholemeal flour but not in sifted flour (Torelm & Bruce 1982:80).

Another advantage of finely ground and sifted flour is that the inclusion of sand particles from the grinding-stone can be reduced. In grain-paste, porridge and coarse flat bread, sand particles are common. In three Late Bronze Age samples from the Swiss lakeside villages, Alpenquai near Zürich, analyses recovered a considerable amount of sand particles. It was common during prehistoric times for teeth to be considerably worn-down, and sand particles in the coarser flat breads could be one cause according to Bay (1938/1939:128). Renfrew & Bahn (1991:267f) have shown how a highly detailed examination of tooth condition can provide evidence on type of diet (and even identify other types of abrasion, pointing out that teeth often also served prehistoric man as a tool or third hand).

Bread that is to be yeast-leavened must be baked on wheat which includes gluten. Barley, rye, oats, millet och maize contain far too little gluten which in any case is of the wrong chemical composition to produce the same high, light and spongy bread as that baked from wheat-flour and brewers yeast or beer scum. Rye, on the other hand, is highly suitable for leavening by sour dough. In these fermentation processes different microorganisms are at work. The sourish taste in bread leavened by sour

dough is mediated by lactic-acid bacteria (Campbell 1950:171). In both cases, however, an oven is required.

The starch-rich endosperm in wheat contains gluten-forming proteins. The yeast fungi produce carbon dioxide under suitable conditions. When the two ingredients unite in a dough, a spongy mass is formed enclosing small gas bubbles which give elasticity to the bread. When the bread is baked, heat transforms the gluten-forming proteins in such a way that they become compact instead of elastic. Salt plays a role too: it is not added to bread purely for taste. Salt has a strengthening effect on the gluten and provides the baked bread with an even consistency (Wagner 1988:34). However, if these proteins have already been subjected to heat *before* the addition of the leavening substance, they will already have been transformed and have lost their elasticity and cannot function in the leavening process (Tannahill 1975:67). This means that emmer wheat (*Triticum dicoccum*) and einkorn (*Triticum monococcum*) can rarely be used in leavened bread, even though their gluten content is suitable for that purpose. Roasting was one of the methods used for threshing these types of corn, which are not free-threshing cereals (see below). This is one of the reasons why bread wheat (*Triticum aestivum*) became so important.

Egypt is considered to have been the birth-place for the art of baking yeast-fermented bread (Brothwell & Brothwell 1969:95). By the beginning of the Dynastic Period in Egypt, wheat which parts readily from its chaff (free-threshing), so-called bread wheat, had been developed. This could be threshed without roasting or other special treatments to remove the chaff. For a long time, this free-threshing bread wheat was rare and was probably cultivated on a limited scale for use in bread-making for the upper levels in society. Previously emmer wheat (*Triticum dicoccum*), had been the most important grain type in Egypt where it continued to be used until Hellenistic times (Währen 1963:16; Pliny, *Natural History*, transl. Rackham 1971:230; Leek 1973:199; Harlan 1977:360).

The prerequisites for leavened bread must have been better in Egypt than in e.g. Mesopotamia (Tannahill 1975:66f), where wheat had become scarce on account of erroneous artificial irrigation which had impoverished the soil. Here one was driven to replace wheat with barley which is hardier (Wiedemann 1920:299). Bread wheat (*Triticum aestivum* s.l.), became common in Greece during the fourth millennium BC. The Greeks had regular trading contacts with Egypt even earlier, and were in need of imported grain. From Greece, bread wheat spread to the north and north east. Together with bread wheat, the art of baking fermented light spongy wheaten bread followed along.

There are many ways of initiating the yeasting process. Pliny the Elder observed that the Gauls and Iberians employed beer scum. They also had a lighter bread than other peoples. The Greeks and Italians who did not drink

Type of cereal-based food	Form of cereals	Treatment
1. Grain-paste	Roasted/unroasted cereals	Not processed (dried ¹)
2. Grain-paste	Sprouted cereals	Not processed (dried ¹)
3. Grain-paste	Immature cereals	Not processed (dried ¹)
4. Porridge	Roasted/unroasted cereals	Cooked
5. Porridge	Sprouted cereals	Cooked
6. Porridge	Immature cereals	Cooked
7. Unleavened flatbread	Roasted/unroasted cereals	Ground and baked
8. Leavened bread (sour dough)	Unroasted cereals	Ground and baked in oven
9. Leavened wheaten bread (yeast dough)	Unroasted cereals	Ground and baked in oven

¹ Dried grain-paste is sometimes called "unbaked bread" (Hillman 1985:17).

Table 2. The various kinds of bread or bread-like cereal-based dishes which existed during prehistoric times (according to Classical texts and Swedish ethnological sources).

beer but wine, used millet flour soaked in grape juice which was kneaded and left to ferment. This mixture could keep for a whole year (Pliny, *Natural History*, transl. Rackham 1971:253).

Other methods also existed. The most usual was to save a piece of dough (which could be dried) from the previous bake and include it in the following bake. This method is still used for sour-dough bread. Should the leaven get used up, Keyland provides a description of how previously in Sweden one could make a replacement: on Midsummer night or the night between the old and new Midsummer, before sunrise, preferably on a Thursday, while fasting and without speaking, a cloth was passed through the dewy grass and wrung out to obtain a liquid which was then added to flour to make a dough that was allowed to self-ferment, after which it could be used as a leaven. Once made, such a leaven would last a lifetime. Other methods of gathering a suitable liquid were to place a bowl of water in a field of cereals or use water which had "blossomed". (Keyland 1919, I:189)

The knowledge of how to leaven bread did not result in the abandonment of unleavened flat bread. Different ways of making bread existed side by side together with porridges and grain-pastes and gruels; all of which had their own natural place in the prehistoric diet.

Is it possible to classify different prehistoric charred, and possibly cereal-based, food remains?

Charred and mostly fragmented food remains are frequently found on archaeological excavations in Sweden. Sometimes they are called "bread", sometimes they are classified merely as "organic remains", especially when consisting only of small, more or less, spongy fragments with no discernable over- or underside. Even if it can be determined that these organic remains contain cereals – for instance by microscopic examination of botanical tissues – this is no guarantee that the find is bread. There is a complex group of cereal-based dishes which can resemble bread in the charred state. Hopefully, as already mentioned, faecal remains might be excluded on

Findplace	Context	Dating	Present Analyses	Earlier Analyses
Up, Adelsö par., Björkö, Birka, Bj 1148a	Cremation grave, in firelayer	Viking Age	Protein-, lipid-, fatty-acid analysis	Microscopic analysis
Sö, Bergshammar par., Västergården, Site 6. Dnr 6575/87	Cremation grave, on stone-packing	Viking Age/ Germanic Iron Age	Microscopic analysis. Protein-, lipid-, fatty-acid analysis	-
Up, Knivsta par., Vrå, Site 16, A1960, Layer 3	Pit, belonging to a pit-system	Bronze Age	Microscopic analysis. Protein-, lipid-, fatty-acid analysis	-
Vb, Bureå par., Harsjöbacken A2	Pit	Roman Iron Age	Microscopic analysis	Protein-, lipid-, fatty-acid analysis
Ög, Rappestad par., Folåsa, Site 32. Dnr 5147/77	Settlement	Middle Iron Age	SEM-analysis	-

Table 3. Overview of the five selected prehistoric charred organic remains.

the grounds of morphology or the presence of parasite ova of various species of intestinal worms.

The different kinds of bread or bread-like cereal-based dishes which existed during prehistoric times (according to Classical texts and Swedish ethnological sources) are listed in table 2. In all cases the grain-paste, porridge or bread might contain several other ingredients. However, in the case of the leavened light wheaten bread care must be taken. If too many different ingredients other than wheat-flour are added the bread might not rise. Intermediate forms of grain-paste, porridge and bread can also exist. (For further information about cereal-based food-stuffs especially in Turkey and the Near East, see Hillman 1984 and 1985.)

Analyses conducted on five prehistoric charred organic remains resembling bread

In order to test what certain types of analyses, in combination with morphological examination and observations on find-circumstances, can reveal about the nature of charred food remains, five finds from different prehistoric periods and different archaeological contexts, were carefully selected.

One of these five is a certain find of bread and this specific find was chosen as its size resembles one of the charred organic remains which had been classified in a preliminary study by me as doubtful bread. Two of the selections had been termed "bread, query". Another find comes from a prehistoric pit most probably for seal train-oil production. The remaining find was preliminarily regarded by me as excrement. An overview of the five selected prehistoric charred organic remains is presented in table 3 and fig. 6.

Birka

This bread (fig. 7) came from cremation burial Bj 1148a, Birka, Björkö, Adelsö par., Uppland, found in a burial mound at an altitude of 0.75 m situated within area 1E of the Hemlanden cemetery (fig. 8). The specific location of the grave within this area is not known, and is not marked on the map of graves within the Hemlanden cemetery in Arbman's publication from 1943. At the centre of the grave, at a depth of 0.3 m, a faint fire-layer was discerned containing large pieces of oak charcoal. The only grave-goods were a fragment of a band-shaped frost-nail and pieces of bread. At a depth of 0.6 m another fire-layer was uncovered, containing grave-goods but no charred organic re-

mains (Arbman 1943:473). The burial was excavated by Hjalmar Stolpe late in the 19th century.

Professor Hakon Hjelmqvist in his examination of the botanical content of Birka's bread, found many fragments of cell walls of epidermis of husks (*palea* and *lemma*) of hulled barley (*Hordeum vulgare*). Five frag-



Fig. 6. Findplaces of the five charred organic remains discussed in this article. CAD-drawing: Gunilla Eriksson.

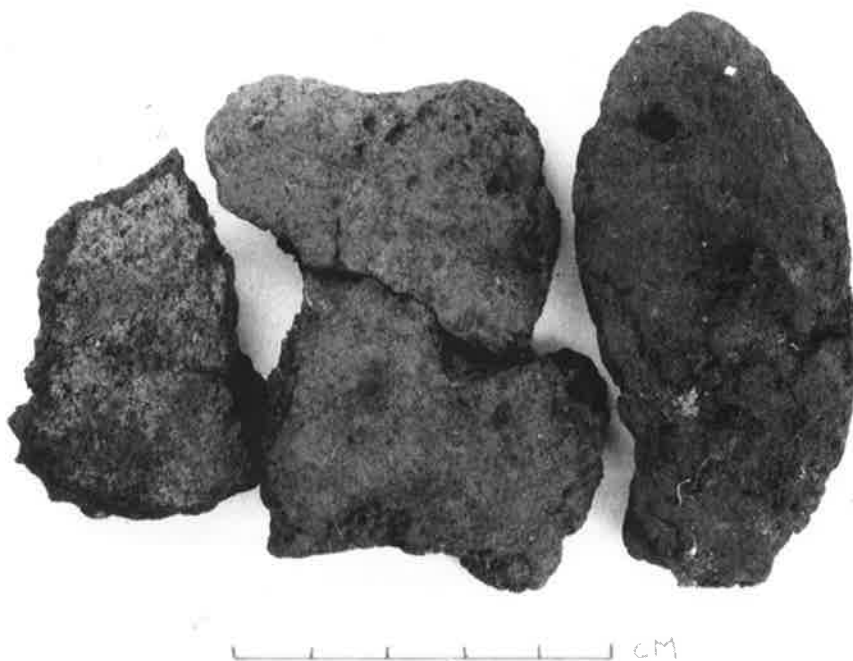


Fig. 7. Bread from cremation burial Bj 1148a, Birka, actual size. Photo: Sven Isaksson.

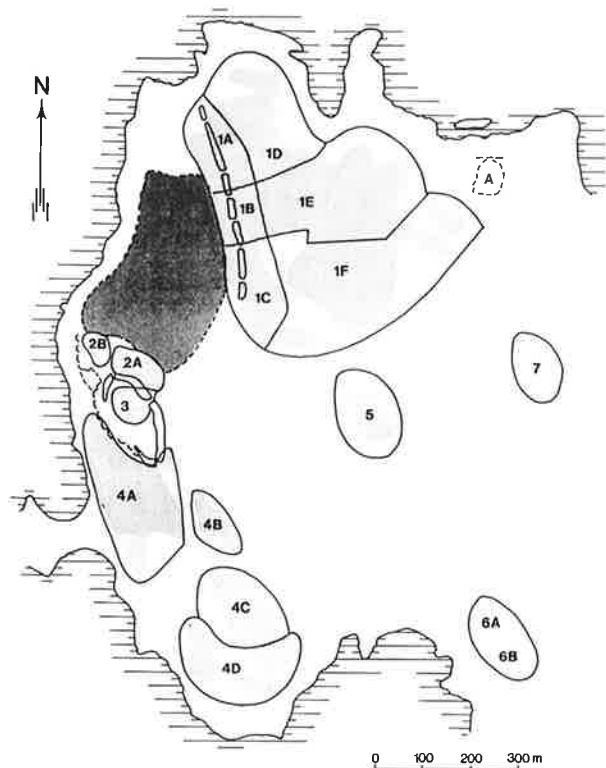


Fig. 8. Cemeteries on Björkö. 1 = Hemlanden, 2 = the cemetery north of Borg, 3 = the graves at Borg, 4 = the cemetery south of Borg, 5 = Grindsbacka, 6 = Kärrbacka, 7 = Ormnös.

ments showed cell walls from epidermis of husks (*palea* and *lemma*) of oats (*Avena sativa*). The bread most likely had been baked of barley meal with the addition of oat-flour (Hjelmqvist 1984:270).

Västergården

This bread-like cake (fig. 9) was found above the stone packing during excavations of a cremation grave with decorated ball-shaped burial-boulder, at Västergården (Site 6), Bergshammar par., Södermanland. The grave is dated by its find content to the Vendel/Viking transitional period. The prestigious grave-goods indicate that the individual (or individuals – this could be a double burial) were of considerably high status (pers. comm. Eva Fransson). Hans Christiansson (1948) has discussed an interpretation of the spherical boulders in ball-boulder burials as symbolic bread.

Vrå

Charred organic material (fig. 10) in many small fragments, from Vrå (1:50, 1:51), Knivsta par., Uppland (Site 16, structure A1960, layer 3, Find 20228). These remains were found in a pit belonging to a system of pits c. 20 m south of a 37 m long-house. Both house and pit-system are dated to 1300–1000 BC. The bottom layer of



Fig. 9. "Bread" from cremation burial in Västergården, actual size. Photo: Ann-Marie Hansson.



Fig. 10. Charred organic remains from Vrå, actual size. Photo: Sven Isaksson.

the pit has been ^{14}C -dated to c. 1500–1000 BC. The pits were clay-lined and c. 0.6–0.7 m deep and had a secondary function as garbage pits producing pottery and mould fragments. The primary function of the pits is unknown (pers. comm. Thomas Eriksson, Uppsala).

No previous finds of bread are known from the Bronze Age in Sweden, but such are known from the Continent during this period (Fechner 1991:46). Could these charred organic remains have once been bread? Plant-macrofossil analysis has been conducted on this site, so it is known that cereals were grown there. It would be very interesting to have a product of one of these crops.

Harrsjöbacken

In connection with an archaeological excavation, carried out in 1991 by the Skellefteå Museum, organic remains (fig. 11) from structure A II, at Harrsjöbacken, Bureå par., Västerbotten, were found in a pit measuring 1.8 x 1.3 m wide and 0.8–0.9 m deep, and filled with fire-cracked stones. The pit was associated with a settlement situated on a sea promontary, and dated to the first centuries AD.

The black organic material from this pit came from between the stones. Isaksson (1992) has interpreted this to mean that the material probably melted as a result of the heat in the pit and subsequently spilled down and cooled between the stones. He describes the material as black with a glassy shine in fractures. Some pieces had melted around sand grains, a few also contained pieces of wood. In general, the material was morphologically homogeneous and structure-free

with a large number of blisters measuring 1 cm and less. The form of the blisters is suggestive of a development of gas while the material was in a viscous state.

Analyses of lipid content, protein content and fatty acids were conducted by Sven Isaksson (1992:63, 67).

Folåsa

During archaeological excavations of a Middle Iron Age settlement at Folåsa, Rappestad par., Östergötland (Site 32, Layer L II, SHM 5147/77), charred organic material was recovered in three fragments which fitted together to make one complete piece (fig. 12).

Conclusions

Birka

During complementary chemical analyses, no fats were found. Instead a low protein value, 0.701%, was measured (see Hansson & Isaksson in this vol.). In this case, it was already known that the charred material was bread, made from barley with the addition of oats (Hjelmqvist 1984:270). In the 28 analysed Birka burial-breads, where it was possible to identify the ingredients, barley is the commonest cereal (Hjelmqvist 1984). In all, c. 64 charred burial breads have been found at Birka (Hansson forthcoming). It was also common that bread was baked from several sorts of flour. Even flax seeds, peas and vetches have been used as ingredients in bread at Birka (Hjelmqvist 1984) and in bread from other places (Hansson 1987:36).

The bread loaf had an original diameter of c. 17–18 cm and was c. 1.3–1.7 cm thick. This is the only burial bread

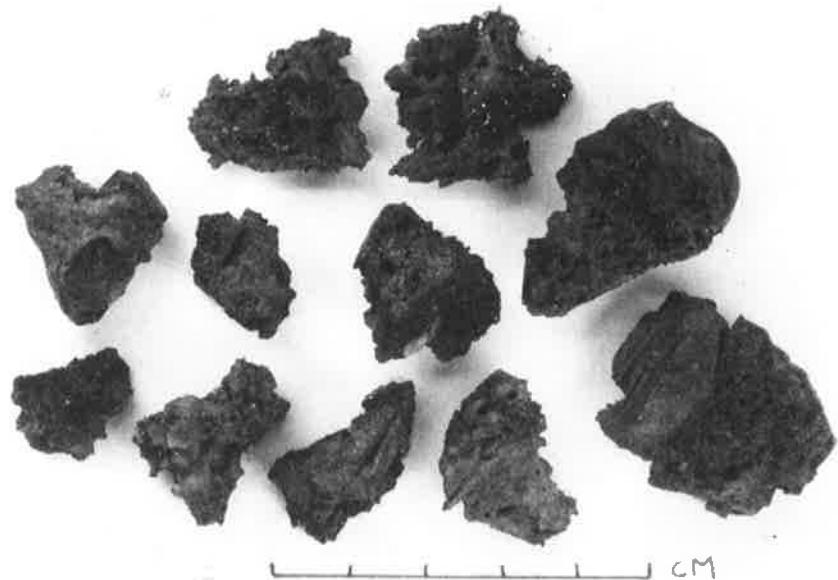


Fig. 11. Charred organic remains from Harrsjöbacken, actual size. Photo: Sven Isaksson.



Fig. 12. Charred organic remains from Follåsa, slightly larger than actual size. Photo: Ann-Marie Hansson.

from Birka with such a large diameter. Closest in size is a piece of bread from grave Bj 82b, which had a reconstructed diameter of c. 12 cm. (Bread is seldom symmetrical, so any assessment of diameter must be approximate.)

The bread from grave Bj 1148a could well have been baked in a type of turnable iron pan such as are known from archaeological excavations and usually dated to the Iron Age (Campbell 1950:123; Orrling 1981:35). One such pan was found at Torslundaåsen, Tierp par., Uppland, dating to the fifth century AD and measuring 8 cm at its greatest surviving radius (Campbell 1950:123). This measurement would have served relatively well for bread such as that from Bj 1148a, but no traces from baking in an iron pan can now be discerned on that bread. The upper side of the bread is greyish and the underside blackish and slightly concave. On the upper side small holes occur which resemble the pricking sometimes done to ventilate bread during leavening and/or baking (fig. 13). The bread had a rather crumbly and porous consistency. On the upper side where the surface was not destroyed, small pores could be discerned, measuring from 0.01 mm to 3 mm. Within the bread slightly larger gas bubbles could be traced. This bread-structure closely resembles that of the other charred burial breads from Birka.



Fig. 14. Cross-section through the charred organic remains from Västergården (x20). Photo: Ann-Marie Hansson.



Fig. 13. Prick-marks on the Birka bread. Photo: Ann-Marie Hansson.

Neither whole nor partial cereal grains were observable by binocular microscopic examination. No chaff or other organic remains were burned onto the underside of the bread, a common occurrence otherwise on burial bread from Birka.

Bread morphology, porosity, ingredients and not least position in the fire-layer, suggest an interpretation of this charred organic material as grave goods, which supports its earlier interpretation as bread.

Västergården

This bread-like cake had an original diameter of 15–17 cm and a thickness of c. 2 cm at the outer edge. The central part lacks any upper side and full thickness cannot be measured. The cake survived in many pieces and the upper side could be clearly distinguished from the underside. In many places, remains of fine rootlets occurred. Characteristic for this bread is that it broke horizontally in such a way that the upper and lower sides separated. Apparently the large gas bubbles (fig. 14) within the loaf had caused it to split. Consistency was very hard. The gas bubbles had in some cases an elongated form as if the material had been somewhat viscous. In the fractures it could be seen that the material was not carbonized throughout and where less charred was of a brownish shade. The imprint from an enclosing container seemed to be in evidence (fig. 15). At one place on the underside there were small wavelike marks, probably the impression from an underlying surface. No charred botanical fragments could be discerned.

The chemical analyses carried out here produced no lipids, but the protein content was high, 2.33% (see Hansson & Isaksson in this vol.). Microscopic analysis revealed botanical tissues, which were interpreted as transverse and longitudinal cells from wheat (*Triticum*), most likely bread wheat on account of the absence of fragments of husks (*palea* and *lemma*). Phytoliths from the grass family (Poaceae), to which family the cereals belong, were also present. Even cells from fragmentary seeds of fat-hen (*Chenopodium album*) were recovered.

Seed fragments of fat-hen have earlier been found in bread from a cremation grave at Fiskeby, Östra Eneby

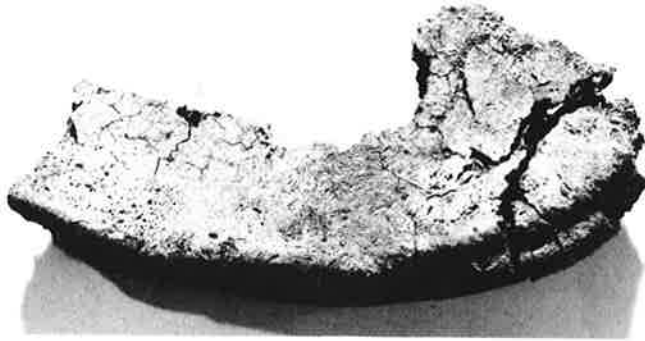


Fig. 15. Impression from possible surrounding mould on the sides of the "bread" from Västergården. Photo: Ann-Marie Hansson.

par., Östergötland, dated to the Vendel- or Viking Periods (Hjelmqvist 1990:13). Fat-hen was one of the most common weeds of cultivation on manured fields during prehistoric times, and often followed along with the cereal grains during threshing. There are many examples of fat-hen having been eaten. Seeds of fat-hen have been recovered from the stomach and intestines of Danish bog bodies, including those from Grauballe (Helbaek 1958:84), Tollund (Helbaek 1950:326) and Borremosse (Brandt 1951:348). Even the bog body from Lindow in England, mentioned above, produced seeds of fat-hen (Holden 1986:118). Whether these followed along as threshing residue or comprised a final ritual meal has been the subject of dispute (Jonsson 1991:35ff). Helbaek (1960:17) has noted that with regard to the stomach contents of the Danish bog bodies, "there is a striking agreement between the species here encountered and those most commonly found mixed with the carbonized grain which is frequently excavated in Danish Iron Age houses...". But there also exists a find of gathered seeds of fat-hen alone (with the occasional seed of other species) from a Danish Early Iron Age house at Fjand, in western Jutland (Helbaek 1960:17). Also in Poland the use of fat-hen is archaeologically recorded (Dembinska 1975:57).

Further evidence for the use of fat-hen seeds for food comes from two findings from the archaeological excavations of early medieval Dublin, Ireland. A faecal mass containing seeds of fat-hen (*Chenopodium album*), was found among the 11th century houses on the Fishamble Street site. A shallow grave also of 11th century date, dug into boulder clay on the High Street site, contained the skeleton of a c. 12-year old girl with, in her pelvic region, a soft black mass (possibly faecal in origin) crammed with crushed seeds which included fat-hen (*Chenopodium album*) *Polygonum* and chickweed (*Stellaria media*) (Mitchell et al. 1987:23).

In the carbonized organic remains from Västergården there were also traces of at least two species of mould fungi, probably belonging to Ascomycota and Saccaromycetaceae. Cells from the latter occurred in abundance and can have been primary while those of the

former can be secondary, as part of an interrupted degrading process. Yeast cells have earlier been found in a drinking-horn (Grüss 1932:180). Also found were a membrane-like milky semi-transparent substance and an amorphous mass possibly indicative of an animal ingredient. Hjelmqvist (1990:17) discovered a similar phenomenon in bread from grave 1 at Västbyn, Frösö par., Jämtland, which he observed could have been *palt*, a dish which is usually made on cereals and blood (Hjelmqvist 1990:17). Sour *palt* which involved fermenting the blood bread was also used in earlier times. The high protein content of the Västergården "bread" could be further indication of blood being an ingredient. Fermentation also concentrates the protein content, and thus raises the protein value (Arrhenius 1985:340; Arrhenius & Slytå 1981:87).

The form of the gas blisters and presence of yeast fungi and especially the spores of Ascomycota, implies that the organic remains from Västergården had undergone some form of degradation. Cell structures break down more effectively through fermentation than by cooking (Arrhenius 1987:116), and in this charred organic material from Västergården it was difficult to find tissues that were not degraded.

The fat-hen (*Chenopodium album*) seeds could be threshing residue which followed along with the wheat used in this "bread". However, since so little botanical material was identifiable, it is possible that even other cereal sorts were included as ingredients.

Noteworthy is the placement of these remains, on top of the stone packing in the grave, which is very unusual.

Vrå

On one of the pieces of charred organic material, upper- and undersides were clearly discernable. However it is not possible to say whether these were the original upper- and undersides or were formed later from deposition in the pit. The largest piece measured c. 2 cm in diameter and was c. 1 cm thick. Porosity showed a slight horizontal orientation suggestive of a layered structure. The smaller pieces seemed more charred and more compact, but all pieces were fairly crumbly. Some botanical material could be discerned.

No cell structures could be observed during microscopic analyses despite that examination by binocular microscope revealed botanical tissues. Phytoliths were however found, most likely belonging to the grass family (Poaceae), which includes the cereals. Chemical analyses revealed 3.3% fat and 0.257% protein (see Hansson & Isaksson in this volume).

This sample is unlikely to be bread as coarse plant material can be discerned in the fractures (i.e. it has not undergone grinding essential to the definition of bread, see definition above). Some form of grain-paste or porridge however is not ruled out. Since this find comes from a pit of uncertain function which was later used as a refuse pit,

a faecal origin is worth considering. Faecal material, however, should not contain fat, at least not in this high concentration.

If the fat, which is most likely to be of animal origin, is primary to this sample, then it might be best to interpret this find as a porridge or grain-paste. It is well to recall Pliny's description (see above) of the storing of grain-paste in a jar under a layer of flour and bran. In the Vrå material some strands of straw can be discerned. The clay-lined pit could have been a storage-pit (note that pottery sherds occurred in its fill). This is one interpretation of several, but in my opinion the most likely.

Harrsjöbacken

In this case, analyses of lipid content, protein content and fatty acids had already been conducted. The charred organic remains were interpreted as possible residue from seal train-oil production (Isaksson 1992:63, 67). New samples for fatty-acid analysis indicated that it contained entrail lipids, but the sample was low in protein. These different analyses show that the organic material from this pit is of heterogeneous character. Complementary microscopic examination found no botanical tissues. The form of the gas blisters indicate together with the hardness of the material that it cannot be bread. Morphology and find circumstances are further support for this interpretation.

Folåsa

The complete piece was surrounded by a layer of ash and clay. In shape the piece was round-oval and pointed at one end in a way which recalled the closing of an end bowel muscle, i.e. an indication that this probably was faecal material. The coprolites which have been collected from British excavations usually measure 15–20 mm in diameter (Jones 1983:225). The charred organic material from Folåsa is c. 20 mm in diameter and has cavities after seeds where the endosperm has disappeared, but the testa still remains (fig. 16).

Examination by binocular microscope revealed seed



Fig. 16. Fracture in the charred organic remains from Folåsa. Photo: Ann-Marie Hansson.

coats in the fractures, some of which were charred, others varied in colour from brown to reddish-brown. The content seemed somewhat layered.

Only a minor examination using scanning electron microscope (SEM) was conducted on this charred organic material in order to test the method in such circumstances. Crushed seeds of fat-hen (*Chenopodium album*) and flax (*Linum usitatissimum*) were identified.

The find was originally suspected by me to be a human stool from its morphology. The crushed seeds which were found in it do not indicate otherwise. Already in the days of Pliny we hear of the blending of seeds of flax into grain-paste. In Swedish contexts, flax seeds have been found in some of the Viking Age bread from Birka. In Eketorp ring-fort on Öland (in house T), belonging to the Migration Period, a charred seed-cake was recovered which analyses proved to contain c. 90% seeds of gold-of-pleasure (*Camelina sativa*), and c. 10% seeds of flax (*Linum usitatissimum*). Flax seeds contain c. 40% fat, which makes it an important addition to any diet (Hansson et al. 1993 and references cited therein).

	Designation prior to analyses	Morphology	Main content	Structure	Porosity	Designation after analyses
Birka	Bread	Bread-like, pickled	Barley, oats, no fat, low in protein. Rather finely ground	Crumbly	Somewhat porous	Bread, probably leavened with sour dough
Västergården	Bread	Bread-like with imprint from possible container	Wheat, fat-hen, fungi, no fat, high in protein. Content degraded	Hard	Traces of elongated blisters	Possible <i>pait</i> , leavened
Vrå	Bread?	Pieces with no clear upper- or underside	High fat content, low in protein. Coarsely ground or not ground at all ¹	Crumbly	Somewhat porous	Possible grain-paste
Harrsjöbacken	Residue of seal train oil cooking	Pieces with no upper- or underside	No botanical remains, high fat content, low in protein.	Very hard	Traces of elongated blisters	Residue of seal train oil cooking?
Folåsa	Bread?	Cross-section roundoval, stool-like	Flax, fat-hen. Botanical material somewhat fragmented ²	Hard, brittle	Cavities from charred seeds	Coprolite

Table 4. Classification of charred organic material after microscopic and chemical analyses.

¹ No botanical remains found

² No chemical analysis carried out

Summary

These different charred organic remains closely resembled one another in general structure but with the help of chemical and microscopic analyses it has been possible to gain information as to the biological origin of their content. The archaeological contexts and dates of each sample were of course also of importance for establishing identifications. Further factors of great relevance are original form if surviving, porosity, gas-blisters/bubble morphology (size and shape) and nature of the material (whether firm, brittle or crumbly). An essential additional aid to interpretation has here been the comparative study of cereal-based food records in Swedish ethnological literature and Classical texts.

The degree to which this charred organic material is affected by the temperature and duration of the heating process during carbonization has not been discussed here, and likewise the effect of the individual circumstances and environment of each deposition on the survival of the evidence has not been examined. These are processes worthy of study in their own right. However, despite the unknown effects of these highly important factors, the analysis methods undertaken here have brought us a stage closer to a classification of charred organic remains from archaeological sites (table 4), and thereby have provided a clearer picture of the Swedish prehistoric cereal diet.

Acknowledgements

I am indebted to Sigun Danfors, Statens Livsmedelsverk, Uppsala, for information on phytic acid. For kind assistance with museum material I wish to thank Elsie Lindström, Museum of National Antiquities, Stockholm. A warm thanks also to Gertrud Grenander Nyberg for checking the ethnological details and to Uaininn O'Meadhra, Stockholm, for translating this article from Swedish.

References

- Adrian, W. 1951. *So wurde Brot aus Halm und Glut*. Bielefeld.
- Arbman, H. 1943. *Birka I: Die Gräber*. Untersuchung und Studien. Stockholm.
- Arrhenius, B. 1984. Analysrapport gällande organiskt material på keramikskärvor funna i Löddesborg, Löddeköpinge sn, Skåne. In Jennbert, K.: *Den produktiva gåvan*. Acta Arch. Lundensia. Series in 4°, No. 16.
- Arrhenius, B. 1985. Chemical analyses of organic remains in archaeological context. *ISKOS* 5.
- Arrhenius, B. 1987. Prehistoric diet and archaeology in the laboratory. *Swedish Archaeology 1981-1985*. Svenska Arkeologiska Samfundet. Stockholm.
- Arrhenius, B. & Lidén, K. 1989. Fisksoppa eller vegetabilisk gröt? Diskussion kring matresterna från Tybrind Vig. *Laborativ Arkeologi* 3. Stockholm.
- Arrhenius, B. & Slytå, K. 1979. Kemisk analys av organiskt material i lerkärl från Hallunda. *Årsredogörelse 1976-1979. Del 3. Rapport från Stockholms Universitets Arkeologiska Forskningslaboratorium nr 3, 1979*. Stockholm.
- Arrhenius, B. & Slytå, K. 1981. Fermenterade blodgrötar. *Rapport från Stockholms Universitets Arkeologiska Forskningslaboratorium nr 1, 1981*.
- Bay, R. 1938/1939. Prähistorisches Brot und seine Bedeutung für die Abkautung der Zähne. *Schweizerische Gesellschaft für Anthropologie und Ethnologie, Bulletin*.
- Berg, G. 1960. Några äldre brödtyper i Sverige. Folkliv og kulturlevn. *Studier tilegnet Kai Uldall 14 september 1960*. Odense.
- Brandt, I. 1951. Planterester i et Moselig fra Borremose. *Aarbøger for Nordisk Oldkyndighed og Historie* 1950. Copenhagen.
- Bringeus, N.-A. 1987. *Livets Högtider*. Borås.
- Brothwell, D. 1986. *The Bog Man and the Archaeology of People*. British Museum Publications. London.
- Brothwell, D. R. & P. 1969. *Food in Antiquity: A Survey of the Diet of Early Peoples*. Ancient Peoples and Places, Gen. ed. Glyn Daniel. London.
- Brown, A. 1974. Bone strontium as a dietary indicator in human skeletal populations. *Contributions to Geology* 13, no. 2.
- Brown, A. & Keyzer, H. 1978. Sample preparation for strontium analysis of ancient skeletal remains. *Contributions to Geology* 16, no. 2.
- Campbell, Å. 1950. *Det svenska brödet. En jämförande etnologisk-historisk undersökning*. Stockholm.
- Christiansson, H. 1948. Gravklot och gravoffer. *Tor* 1948. Uppsala.
- Collinder, B. (transl.) 1972. *Den poetiska Eddan. Sången om Rig*. Uddevalla.
- Davies, R. W. 1978. Brot im römischen Bereich. *Reallexikon der germanischen Altertumskunde* 3. Berlin.
- Dembinska, M. 1975. Food products consumption and dishes in the light of Polish historical sources from the 10th to the 18th century. *Ethnologische Nahrungsforschung* (Ethnological Food Research). Helsinki.
- Dickson, C. 1989. The Roman army diet in Britain and Germany. *Archäobotanik. Dissertationes Botanicae* 133. Berlin-Stuttgart.
- Eidlitz, K. 1971. *Föda och nödföda*. Kristianstad.
- Fechner, K. 1991. *La Culture du Pain. Aspects d'une recherche multidisciplinaire*. Bruxelles.
- Grüss, J. 1932. Zwei altgermanische Trinkhörner mit Bier- und Metresten. *Prähistorische Zeitung* 22.
- Halsted, J. H., Ronaghy, H. A., Abadi, P., Haghshenass, M., Amirhakimi, R. M., Barakat, R. M. & Reinhold, J. G. 1972. Zinc deficiency in man: The Shiraz experiment. *Am. J. Med.* 53.
- Hansson, A.-M. 1987. Forntida bönor och ärter. *Labo-*

- rativ arkeologi 2. Stockholm.
- Hansson, A.-M., Lidén, K. & Isaksson, S. 1993. The charred seed-cake from Eketorp. *Sources and Resources. Studies in Honour of Birgit Arrhenius*. PACT 38. Rixensart.
- Harlan, J.R. 1977. The origins of cereal agriculture in the Old World. In Reed, C. A. (ed.): *Origins of Agriculture*. Paris.
- Heer, O. 1866. (Pflanzen der Pfahlbauten) Treatise on the plants of the Lake Dwellings. In Keller, F., transl. J. E. Lee: *The Lake Dwellings of Switzerland and Other Parts of Europe*. London.
- Helbaek, H. 1950. Tollundmandens sidste maltid. *Aarbøger for Nordisk Oldkyndighed og Historie*. Copenhagen.
- Helbaek, H. 1958. Grauballemandens sidste måltid. *Kuml* 2. Aarhus.
- Helbaek, H. 1960. Comment on *Chenopodium album* as a food plant in prehistory. *Geobotanisches Institut Rübel, Zürich. Bericht* 31.
- Hillman, G. C. 1984. Traditional husbandry and processing of archaic cereals in modern times: Part I, the glume-wheats. *Bulletin on Sumerian Agriculture* 1.
- Hillman, G. C. 1985. Traditional husbandry and processing of archaic cereals in recent times: The operations, products and equipment that might feature in Sumerian texts. Part II: The free-threshing cereals. *Bulletin on Sumerian Agriculture* 2. Cambridge.
- Hillman, G. 1986. Plant foods in ancient diet: the archaeological role of palaeofaeces in general and Lindow Man's gut contents in particular. In Stead, I. M., Bourke, J. B. & Brothwell, D. R. (eds.): *Lindow Man, the Body in the Bog*. London.
- Hillman, G. C., Robins, G. V., Oduwell, B., Sales, K. D. & McNeil, D. A. C. 1985. The use of electron spin resonance. Spectroscopy to determine the thermal histories of cereal grains. *Journal of Archaeological Science* 12.
- Hjelmqvist, H. 1984. Botanische Analyse einiger Brote. In Arwidsson, G. (ed.): *Birka II:1. Systematische Analysen der Gräberfunde*. Stockholm.
- Hjelmqvist, H. 1990. Über die Zusammensetzung einiger prähistorischer Brote. *Fornvännen* 85.
- Holden, T.G. 1986. Preliminary report on the detailed analyses of the macroscopic remains from the gut of Lindow man. In Stead, I. M., Bourke, J. B. & Brothwell, D. R. (eds.): *Lindow Man, the Body in the Bog*. London.
- Isaksson, S. 1992. Sältranstillverkning i Harrsjöbacken. *Kontaktstencil* 36. Arktisk Arkeologi. Turku. Unpublished.
- Jones, A. K. G. 1983. A coprolite from 6–8 Pavement. In Hall, A. R., Kenward, H. K., Williams, D. & Greig, J. R. A. (eds.): *Environment and Living Conditions at Two Anglo-Scandinavian Sites*. The Archaeology of York. Vol 14: The Past Environment of York.
- Jonsson, J. 1991. *Varför förekommer ogräsfrön i magtarmkanalerna hos bronsålderns och järnålderns mosslik?* Unpublished M.A. thesis (*D-uppsats*), Department of Archaeology, University of Umeå.
- Keller, F. 1866. *The Lake Dwellings of Switzerland and Other Parts of Europe*. Transl. J. E. Lee. London.
- Keyland, N. 1989. *Svensk Allmogekost*, I–II. Stockholm.
- Körber-Grohne, U. 1991. Identification methods. In van Zeist, W., Wasilikowa, K. & Behre, K.-E (eds.): *Progress In Old World Palaeoethnobotany*. A retrospective view on the occasion of 20 years of the International Work Group for Palaeoethnobotany. Rotterdam.
- Leek, F. 1973. Further studies concerning ancient Egyptian bread. *The Journal of Egyptian Archaeology*.
- Lerche, G. 1981. Khubz Tannur: Freshly consumed flat bread in the Near East. In Fenton, A. & Owen, T. M. (eds.): *Food in Perspective. Proceedings of the Third International Conference on Ethnological Food Research*. Edinburgh.
- Maurizio, A. 1916. *Die Getreide-Nahrung im Wandel der Zeiten*. Zürich.
- Mitchell, G. F., Dickson, C. A. & Dickson, J. H. 1987. The plant remains. In Mitchell, G. F.: *Archaeology & Environment in early Dublin*. (Medieval Dublin Excavations 1962-81 Ser C, vol 1) Dublin.
- Moora, A. 1968. Über die volkstümliche Nahrung in der ostestnischen Grenzzone. Congressus Secundus Internationalis Fenno-ugristarum. Helsingiae Habitus 23–28, VIII, 1965. Pars II. *Acta Ethnologica*. Helsinki.
- Moora, A. 1991. *Eesti talurahva vanem toit. II osa. Joo-gid, leib ja leivakõrvane*. Tallinn "valgus".
- Moritz, L.A. 1958. *Grain-mills and Flour in Classical Antiquity*. Oxford.
- Olsson, A. 1958. *Om allmogens kosthåll. Studier med utgångspunkt från västnordiska matvanor*. Lund.
- Olsson, A. 1965. "Helgdagsbröd på ett synnerligt sätt". *RIG*. Lund.
- Orrling, C. 1981. Bröd. *Vikingatidens ABC*. Statens Historiska Museum. Stockholm.
- Prasad, A. S., Miale, A. Jr., Farid, Z., Sandstead, H. H., Schultert, A. R., & Darby, W. J. 1963. Biochemical studies on dwarfism, hypogonadism and anemia. *Arch. Intern. Med.* 111.
- Rackham, H. (transl.) 1971. Plinius Secundus, Gaius. *Natural History with an English translation in ten volumes*. Volume V. London.
- Reddy, N. R., Sathe, S. K. & Salunkhe, D. K. 1982. Phytates in legumes and cereals. *Advances in Food Research* 28. London.
- Reinhold, J. G. 1971. High phytate content of Iranian bread: A possible cause of zinc deficiency. *Am. J. Clin. Nutr.* 24.
- Reinhold, J. G. 1973. Phytate concentrations of leavened and unleavened bread. *Ecol. Food Nutr.* 1.
- Reinhold, J. G. 1975a. Phytate destruction by yeast fermentation in whole wheat meals. *J. Am. Diet. Assoc.* 66.

- Reinhold, J. G. 1975b. Zinc and mineral deficiencies in man: the phytate hypothesis. In Chavez, A., Bourges, H. & Basta, S (eds.): *Review of Basic knowledge*. Karger/Basel.
- Reinhold, J. G., Nasr, K., Lahimgarzadeh, A. & Hedayati, H. 1973. Effects of purified phytate and phytate rich bread upon metabolism of zinc, calcium, phosphorous, and nitrogen in man. *Lancet* 1.
- Renfrew, C. & Bahn, P. 1991. *Archaeology: Theories, Methods and Practice*. London.
- Runia, L. T. 1987. Strontium and calcium distribution in plants: effect on palaeodietary studies. *Journal of Archaeological Science* 14.
- Samuel, D. 1993. Ancient Egyptian cereal processing, beyond the artistic record. *Cambridge Archaeological Journal* 3, n. 2. Cambridge.
- Sandstead, H. H., Shukry, A. S., Prasad, A. S., Gabr, M. K., El Hifney, A., Mokhtar, N. & Darby, W. J. 1965. Kwashiorkar in Egypt. I. Clinical and biochemical studies, with special reference to plasma, zinc, and serum lactic dehydrogenase. *Amer. Journ. Clin. Nutr.* 17.
- Schoeninger, M. J. 1979. Diet and status at Chalcatzingo: some empirical and technical aspects of strontium analysis. *Amer. Journ. Phys. Anthropol.* 51.
- von See, K. 1981. *Edda, Saga Skaldedichtung, Aufsätze zur skandinavischen Literatur des Mittelalters*. Heidelberg.
- Szpunar, C. B., Lambert, J. B. & Buikstra, J. E. 1978. Analysis of excavated bone by atomic absorption. *Am. Journal of Phys. Anthropology* 48.
- Tannahill, R. 1975. *Food in History*. Bungay.
- Thomson, D. F. 1949. *Economic Structure and the Ceremonial Exchange Cycle in Arnhem Land*. Melbourne.
- Torelm, I. & Bruce, Å. 1982. Fytinsyra i livsmedel. *Vår föda* 3/82.
- Wägner, R. 1988. *Läsebok för bröddälskare*. Stockholm.
- Währen, M. 1963. *Brot und Gebäck im Leben und Glauben der Alten Ägypter*. Bern.
- Währen, M. 1978. Brot. *Reallexikon der germanischen Altertumskunde* 3. Berlin.
- Währen, M. 1989. Brot und Gebäck von der Jungsteinzeit bis zur Römerzeit. Eine Skizze zum Forschungsstand mit besonderer Berücksichtigung der westschweizerischen Seeufersiedlungen. *Helvetia Archaeologica* 79, 20. Basel.
- Wiedemann, A. 1920. *Das alte Ägypten*. Heidelberg.