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THE BREAD FROM LJUNGA IN CENTRAL SWEDEN
New analyses

This paper discusses new aspects of the bread from Ljunga, Skönberga par., Östergötland. It is suggested that the dating of the bread should be drawn back to the end of the Vendel Period, based on a redating of the comb fragments found with the bread. The morphology of the bread loaves from trial bakings indicates that the Ljunga bread was unleavened. Various chemical analyses were carried out. The composition of the amino acids still surviving in the bread, seems to confirm previous interpretations as to its content, based on light- and scanning electron-microscopic analyses. One must be very careful when drawing any conclusions, however, since many of the original amino acids in the bread could no longer be detected. Further, the composition of the ingredients in this bread provided it with a high nutritional value.

Introduction

This article should be seen as complementary to an earlier article (Hansson in press), wherein the earliest interpretation of the Ljunga bread as bark bread, is queried in the light of comparative evidence of bark-bread traditions from written records.

The role of plant foods in the diet of prehistoric populations has often been discussed, especially with regard to the proportions of meat to plants in the diet of European hunter–gatherers during the Palaeolithic and Mesolithic periods. In focus is also the importance of plant food in connection with the transition to an agrarian economy and consequently altered dietary patterns (Mason et al. 1994; Hillman et al. 1989a; 1989b; Lidén 1995). But just as much under debate, both in central and northern Europe as well as in Mediterranean areas, is plant food consisting mainly of cereals in the form of bread, during prehistoric and historic times (Arbman 1943; Währen 1956; 1963; 1967; 1989; Gräslund 1967; Hjelmqvist 1984; 1990; Petrequin et al. 1985; Robinson & Siemen 1988; Fechner 1991; Behre 1991; Hansson 1994; Marinval 1994; Viklund 1994).

Prehistoric bread varied considerably as to size, form, content and preparation technique, depending on geographical location, tradition, chronological period and social status, etc. During recent times, according to Swedish ethnological sources, special bread was baked for feasts and for specific occasions. This tradition seems very old, perhaps going back to ancient times. A similar tradition is recorded during classical antiquity for Mediterranean areas. Food and food habits form a part of a cultural heritage as the less prone to change "tough structure" of society (Martin & Coolidge 1978:13,15; Wing & Brown 1979:11f).

One must remember that bread is merely *one* of many ways to prepare food consisting mainly of plant substances. There are many other dishes, which may resemble bread, especially in its "archaeological" state. This is of vital importance when charred food remains are found on archaeological excavations. These remains might contain either plant foods alone or a mixture of plant foods and meat, and if they consist of only plant foods, these might sometimes be cereals combined with some other plant foods or cereals on their own. These different alternatives are all to be found in the written records (Olsson 1958; Keyland 1989), and have also been confirmed by microscopic analyses of prehistoric charred bread and other food remains found on archaeological excavations in Sweden (Hjelmqvist 1984; 1990; Hansson 1987:36; 1994:15; Hansson & Isaksson 1994:23; Hansson et al. 1993). Sometimes the composition of the ingredients can be considered a bit odd compared to our modern bread types, and sometimes, for various reasons, analysis cannot give an unambiguous answer (Hagberg 1959:184; Hansson 1994:16f; Hansson & Isaksson 1994:23f).

The charred prehistoric grave bread from Ljunga has previously been microscopically analysed and widely discussed. However, its content is so unusual that the present author has conducted further investigations as well as trial bakings, which will be here reported on and discussed in the light of an earlier study, wherein it was proposed that the cells from Scots pine (*Pinus silvestris*)

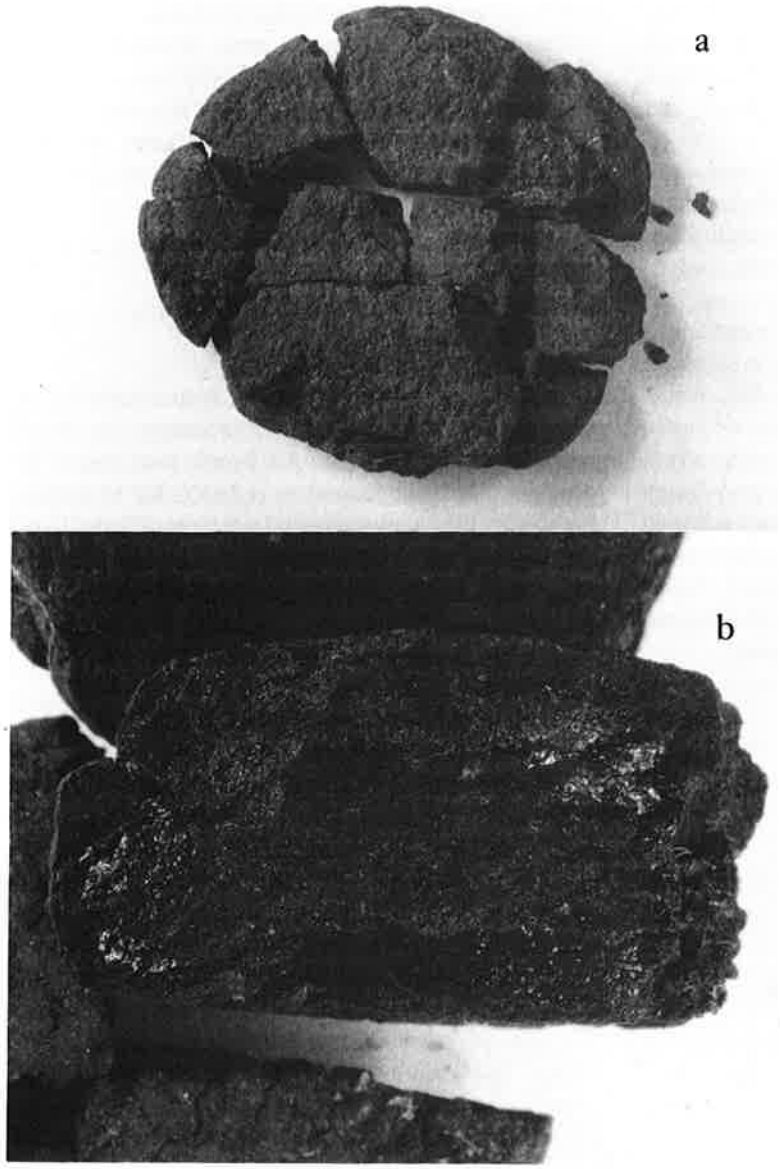

Fig. 1. The bread from Ljunga, (a) actual size, (b) fracture. Photo Bo A. Zachrisson.

should most probably be interpreted as contamination (Hansson in press). The aim is now to obtain information that is as complete as possible, both regarding bread content and preparation technique. The dating of the grave – and thus the bread – from Ljunga will also be discussed.

Description of the Ljunga bread

The bread (SHM 14431:6) (fig. 1a) was found in 1911 during excavation of a male cremation grave, in a cemetery on Ljunga hill, Skönberga parish, Östergötland (fig. 2). The find was described by Bror Schnittger, who led the excavation, in the following way: "The bread, which consisted of a compact mass, burned by the pyre, forms a flat whorl-shaped disc, not unlike the bottom half of a rusk, c. 6 cm diam., and 1.7 cm thick" (Schnittger 1912:3, my transl.). During examination of the bread under low-magnifying microscope (×10), a compact structure could be observed, which also showed faint porosity in places (fig. 1b), quite unlike the structure which the author had earlier observed on most of the miniature bread loaves found in the Viking Age cremation graves at Birka. The upper side of the Ljunga bread is smooth; the furrows or cracks which can now be seen, seem to be secondary. This fact can be interpreted to signify that the bread is unleavened and that moreover the composition of the ingredients in the flour used, possibly differs somewhat to that for the prehistoric bread loaves from Birka. For example, the proportion of the peaflour noted in the earliest analysis of the Ljunga bread is unknown, and it is not quite clear if the inner bark from Scots pine also identified then formed a deliberate ingredient in the dough, or results from contamination, even if the latter suggestion just now seem to be the most reasonable (Hansson in press).

Baking trials

Comparative baking trials were carried out to investigate the baking technique used in making the Ljunga bread.

Trial bakings of *dryl* – an unleavened barley bread containing coarse-ground unsieved flour, still baked on The Faeroes according to long-standing traditional methods – have shown that unleavened bread develops a compact structure with a slight porosity when baked (Jessen 1956:182).

The present author carried out experimental bakings, to test if it really was possible to bake bread (bark bread) containing *only* the ingredients reported from the earliest microscopic analysis of the Ljunga bread, as believed for many decades, i.e. using flour made only from the inner bark of Scots pine (*Pinus silvestris*) and field peas (*Pisum sativum* var. *arvense*) (Rosendahl 1912a; 1912b).

Preparation of the inner bark mainly followed the instructions provided by Keyland (1989:128f). The bark was taken from the lower part of a thick trunk of Scots pine. The outer bark and the green layer were scraped away with a blunt knife, and the remaining millimetre-thin, but very saturated, layer was dried in a modern

oven at 75°C for one hour, to speed up the drying process (drying would probably have originally taken place on a bark-drying rack or by the fire). Following this, the inner bark was ground (using a meat mincer; during prehistoric times the bark would probably have been ground on a quern stone) and the resulting coarse inner-bark flour was soaked in water with frequent changes of water for four days.

One might imagine that during prehistoric times water was the most commonly used liquid when mixing bark-bread dough. But one cannot exclude the possibility that some other liquid was used. Therefore, different kinds of liquids were experimented with in the baking trials.

No records have been found regarding the leavening of bark bread; on the contrary, there is mention that bark bread was *not* leavened (von Linné 1953:60), which seems rather natural considering the absence of gluten (cf. Hansson 1994:10). However, decomposition (not deliberate leavening, since neither yeast nor sour dough were used) was considered likely to improve a dough consisting purely of inner-bark flour and peaflour, making it more easily digested and also easier to bake. Therefore, some of the trial loaves were kept at room temperature for a period of up to two days, to "ferment".

Ingredients

peaflour
bark flour
liquid: either water or honey solution or mead or sour milk
salt (according to the earliest analysis of the Ljunga bread (Rosendahl 1912a), salt formed one of the ingredients)

Measurements

2 dl peaflour = 100 g
2 dl soaked and drained inner-bark flour = 100 g
(2 dl dried inner-bark flour = 50 g)

Nine loaves of bark bread were prepared from different proportions of inner-bark flour and peaflour (at most 50% inner-bark flour) with the addition of varying liquids: water, water with honey, mead and sour milk. All were shaped to resemble the Ljunga bread (c. 6 cm diam. and c. 1.5 cm thick).

It proved no problem to knead, form and bake most of the loaves. However, it was difficult to make the dough stick together when using a high proportion of inner-bark flour, 50% or more. Pouring boiling water over the peaflour before kneading made the dough stickier in consistency and easier to hold together. This procedure is described by Carl von Linné (1953:49) in his records of folk customs from the province of Dalarna.

The best kneeding results were obtained from the loaves which contained less than 50% inner-bark flour and those loaves which were left to "ferment" at room temperature for two days. The two most successful loaves of bread (nos. 7 and 9) had the following ingredients:

- 50% inner-bark flour and 50% peaflour, liquid: 10% honey solution.
- 50% inner-bark flour and 50% peaflour, 1 ml salt, liquid: sour milk.

After two days "fermentation", both doughs had developed a faintly sourish and fresh aroma. The doughs had also risen somewhat. All loaves were baked in a standard electric kitchen oven at 250°C for 15 minutes. Prehistoric closed ovens would not have differed in performance to any marked extent.

There were three main methods of baking bread in older times:

1. In a moisture containing closed oven for leavened bread (sour dough or other yeast), which can be fairly thick. The oven is heated and the bread re-

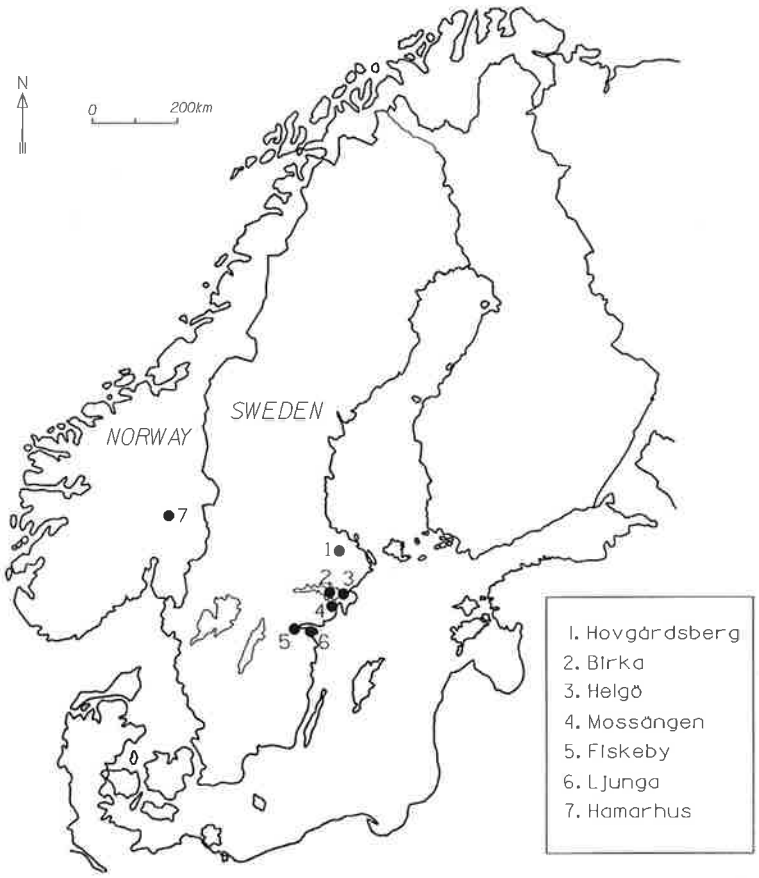

Fig. 2. Map showing the distribution of prehistoric and historic bread loaves in Scandinavia containing peaflour. Drawing Kjell Persson.

ceives heat from all directions, and thus does not need to be turned.

2. Baking on a slab, on embers, on a griddle, a baking-pan or the like. Used mainly for unleavened, rather thin bread, which is turned over to bake from both sides.
3. In/under the ashes. Used for thicker unleavened bread which requires longer baking time at lower temperature (Campbell 1945:46).

For my trials I chose a closed moisture-retaining oven in order to allow the bread to obtain a certain porosity, since the effects of standing at room temperature prior to baking were unknown, otherwise the difference between baking unleavened bread on a hot plate or in the oven should not be of any consequence. For leavened bread on the other hand such a difference would be crucial to success.

After baking, the surface of the unleavened loaves became smooth, while the fermented loaves showed furrows in their upper surface. Jessen's earlier observations of a certain porosity in his unleavened bread, was thus confirmed also for bread baked on a flour mixture of peas and inner bark. All loaves soon became relatively hard and difficult to chew, but tasted astonishingly good!

Naturally if flour from cereals had also been added, (later microscopic analyses showed that cereals also formed an ingredient in the Ljunga bread), the trial baking results would have been even better.

Analyses

The following analyses have been carried out on the Ljunga bread since it was discovered:

Year	Type of analysis	Researcher
1912	Light microscope	Rosendahl
1984, 1990	Light microscope	Hjelmqvist
1994	SEM	Hansson
1984	Amino-acid analysis	Olofsson, Arrhenius & Hansson
1984	Lipid analysis	Olofsson, Arrhenius & Hansson
1989	Trace element analysis	Brännland, Arrhenius & Hansson
1989	Protein analysis	Lidén, Arrhenius & Hansson

Microscopic analysis by Rosendahl

The earliest examination of the Ljunga bread was carried out in the beginning of this century by the botanist and chemist H. V. Rosendahl. Presence of aleurone grains (grains storing protein) and starch was at once established after chemical preparations of a bread fragment. At further chemical treatment, a considerable amount of cells from the corc cambium as well as a few tracheids

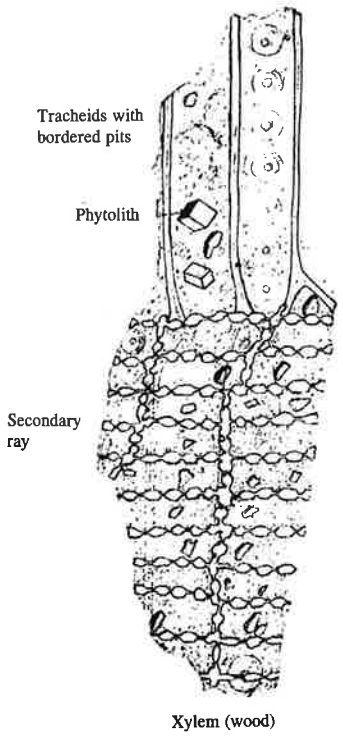

*Fig. 3. Wood from Scots pine (*Pinus silvestris*). After Rosendahl 1912a, p. 3, with modifications.*

from wood could be observed. These finds led Rosendahl to conclude that inner bark from Scots pine had been deliberately mixed into the Ljunga bread dough (Rosendahl 1912a:1ff; 1912b). The phenomenon interpreted by Rosendahl as salt crystals, mentioned and illustrated in connection with the wood tracheids with bordered pits (fig. 3), in my opinion might instead have been formed by phytoliths from the Scots pine (its morphology follows Rovner 1971:350). It is unlikely that salt crystals could remain in their original form in a dough subsequent to kneading, baking, and then the high temperature of the funeral pyre and not least, after all that, almost one thousand five hundred years in the soil.

Several small fragments from the seedcoat (testa) of field peas (fig. 4), comprising the upper layer of the testa consisting of palisade sclereids and the layer beneath, osteosclereids, were also found. No cells from cereals were recorded by Rosendahl.

There can be a small anatomic difference between our modern yellow pea (*Pisum sativum*) and field peas (*Pisum sativum* var. *arvense*). The osteosclereids in the testa from field peas are usually provided with longitudinal strips (Hjelmquist 1963:238). Such longitudinal strips are not reported in the bread from Ljunga. Maybe the cells were so degraded here, that they were difficult to discern.

In a find of peas from a Viking Age layer at Lund, Scania, only some of the peas were provided with these strips on their osteosclereids. Many of the peas were furthermore missing the whole seedcoat (Hjelmqvist 1963:238f).

Microscopic analyses by Hjelmqvist

Much later examination of the Ljunga bread by Hjelmqvist disclosed fragments of wheat (*Triticum* sp.) (Hjelmqvist 1984:271). Further analysis (Hjelmqvist 1990) produced cells from the fruit wall showing irregular rows of transversal cells. These had thin walls with rounded ends and intercellulars (fig. 5a). Since cells from palea or lemma (husks) were missing, this find was identified as probably naked barley (*Hordeum vulgare* var. *nudum*). The wheat sort, which also was determinable on the later occasion, had transversal cells with somewhat uneven side walls and straight or angled short ends (fig. 5b). The side walls were too thin to belong to bread wheat (*Triticum aestivum*), thus these were identified as emmer wheat. Cell size also contributed to the elimination of einkorn (*T. monococcum*). On the same occasion, the presence of inner bark from Scots pine was queried as probably due to contamination, rather than evidence of bark flour. (Hjelmqvist 1990:13)

Microscopic analysis by Hansson

It is not recorded from where on the loaf the earliest samples for microscopic analysis were taken, but it is likely that samples were taken where it was considered that the sampling cut would cause least damage to this ancient bread. There was probably no possibility, nor need, to study the bread structure in magnification during the sampling process. The results of analysis gained in this way will give a picture of the *average* content of a bread, but the Ljunga bread seems to be so unique with its compact structure and a content still difficult to interpret, especially concerning the role of inner bark, that it is desirable to obtain, if possible, a more complete picture. For this a different kind of sampling technique is required, involving the choosing of small samples from where one can discern certain details of interest on examining the whole bread under a low-magnifying microscope. Such a sampling technique does *not* reflect the *average* content of the bread but does instead perhaps shed light on ingredients with tough seedcoats, which can occur for instance very sparsely, such as spices or as contamination. At examination under low magnification (×10–60) of both the original surface and especially recent fractures, sporadic fragments of seedcoats and tissues from plants were discerned. In one case, the tissue resembled the underside of a slightly concave seedcoat. Even a small part of an endosperm (in the same seed?) could be discerned. The visible part showed a circular/oblong form, c. 1.0 mm diam. This suggested that the tissue might be larger. It was gently loosened with a scalpel and successfully transferred for further documentation and examination by scanning electron microscope (SEM)(fig. 6). Unfortunately the probable seed could not be identified, because of its fragmented state.

Another plant tissue (fig. 7), rather degraded, seemed to constitute transversal cells from a cereal. The cells are long and narrow, though how long is impossible to say as no limitation of the cells is visible. The rows of cells have glided apart. Normally these are situated quite close to each other, and a diagnostic feature then, is the intercellulars or angular lacunae (Colledge 1988:233) showing between the cell rows at barley but *not* at wheat. The cell walls found here, where they still existed, seemed to be uneven, which is the case with wheat. This unevenness might however be a secondary phenomenon. The short ends of the cells are also difficult to diagnose. They are not quite as evenly rounded as they are in barley, but neither are they predominantly angled nor straight as in wheat. Prof. Hakon Hjelmqvist has kindly helped me to identify these cells as barley (*Hordeum vulgare* var. *nudum*).

To make matters more difficult, this tissue could also be compared with somewhat unusual transversal cells, having apparent resemblance to other sorts of cells described in the literature, i.e. emmer wheat/spelt wheat (*Triticum dicoccum/spelta*), with long and narrow transversal cells possessing rounded, partly angled shortends (Hajnalová 1989:101, fig. 8:4) or spelt wheat (*T. spelta*) with transversal cells with partly rounded ends (Körber-Grohne & Piening 1980:207, fig. 17).

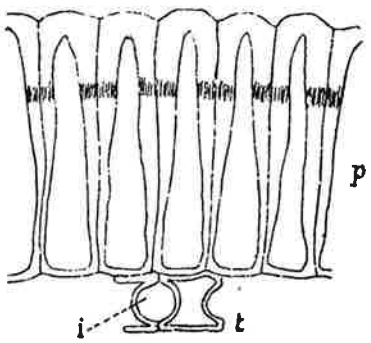

Fig. 4. Seedcoat from field pea (Pisum sativum *var.* arvense)*; p=palisade sclereids, t=osteoscleirids, i=intercellular. After Rosendahl 1912a, p. 2.*

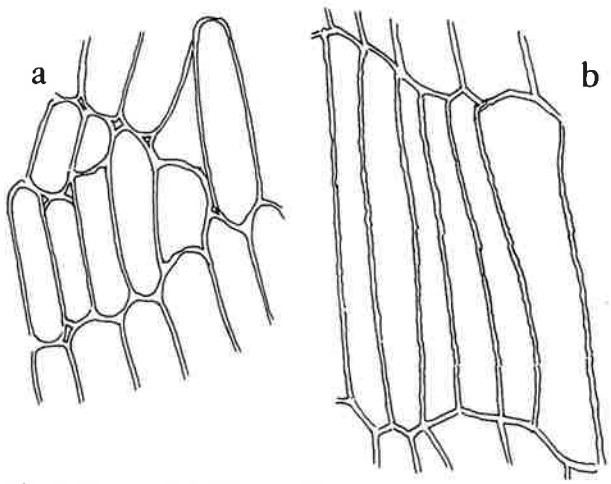

Fig. 5. Transversal cells (320×) in the Ljunga bread. (a) naked barley (Hordeum vulgare *var.* nudum) *(b) emmer wheat* (Triticum dicoccum)*. After Hjelmqvist 1990:14.*

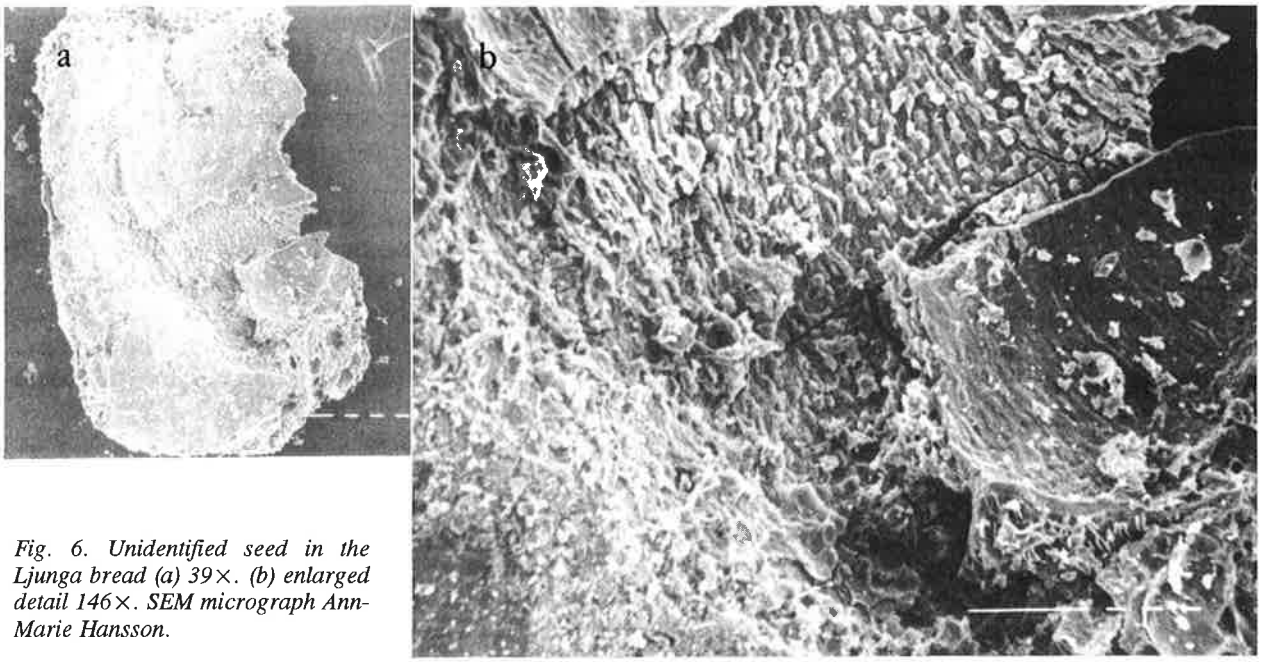

Fig. 6. Unidentified seed in the Ljunga bread (a) 39×. (b) enlarged detail 146×. SEM micrograph Ann-Marie Hansson.

To summarize, botanical content of the bread from Ljunga according to microscopic analyses comprises:

- Naked barley (*Hordeum vulgare* var. *nudum*)
- Emmer wheat (*Triticum dicoccum*)
- Pea (*Pisum sativum* var. *arvense*)
- Scots pine (*Pinus silvestris*)
- Unidentified seed (weed?)

Chemical analyses

The Archaeological Research Laboratory has, under the guidance of Prof. Birgit Arrhenius, for some years now carried out a general interdisciplinary study "Diet and Nutrition in Ancient Times", stemming from analyses of cultural deposits. More recently this work has expanded to include analyses of organic remains on pottery sherds. In that project work, different kinds of methods have been used. For instance, amino-acid, protein, fatty-acid, and trace-element analyses have revealed much information on organic content (see e.g. Arrhenius 1985; 1987; Arrhenius & Lidén 1989; Arrhenius & Slytå 1981; Slytå & Arrhenius 1979). But even other types of food remains, such as charred bread, have been submitted to analyses, for example concerning protein and fatty-acid content (Hansson 1994; Hansson & Isaksson 1994).

In charred prehistoric food remains, several amino acids and lipids often survive, which can depend on the fact that during a charring process, the charcoal itself will react as an isolator. This is very important, as amino acids decompose at c. 200°C (Slytå & Arrhenius 1979:20). In the food residues on pottery sherds no cellular structures were found, and all showed a characteristic surface pattern containing minor depressions. These features have been interpreted as the result of probable fermentation (Arrhenius 1985:340ff).

For bread, a different preparation technique is used than for the porridge-like content of these pots, resulting in the occurrence of cellular structures in the bread, and an absence of surface depressions of the kind characteristic for food remains on pottery sherds. Yet the outer carbonized layer must also here have acted as an isolator.

It was decided to use protein, amino-acid, lipid, and trace-element analyses on the Ljunga bread to compare such results with the microscopically observed data for any correspondence. Charred bread constitutes food-remains of a biological origin, and therefore is rather sensitive to outer impact of different kinds: physical, chemical and microbiological. As a result, we must expect that many of the original amino acids will have been destroyed or reduced in an archaeologocal find (Slytå & Arrhenius 1979:7).

At the request of the present author, in collaboration with Prof. Birgit Arrhenius, protein analysis was carried out on the Ljunga bread by Kerstin Lidén, amino-acid- and lipid analyses by Gerd Olofsson, and trace-element analysis by Lovisa Brännland – all at various times connected to the Archaeological Research Laboratory, Stockholm University. When choosing samples for these analyses, the glued parts of the Ljunga bread were avoided for reasons of contamination.

The results were control checked against the charred bread from the present author's baking trials (bread no. 2 containing 75% peaflour, 25% Scots pine inner-bark flour and water). Protein content was also compared to ordinary Swedish wheaten crisp bread as well as with the identified ingredients in the Ljunga bread, ingredient by ingredient.

In table 1, the composition of the amino acids is expressed both as mg per 100 mg protein, and as mg per 100 g food. Protein values are provided in table 2 to facilitate comparison between the amino acids expressed in different ways.

Lipids were detected in the Ljunga bread; the results have been reported elsewhere (Arrhenius 1984). To properly interpret the results of the trace-element analysis, additional prehistoric bread loaves need to be analysed in a similar manner.

Dating of the grave from Ljunga

It is important that this unusual bread be correctly dated, especially as it has often been referred to as Viking Age (Rosendahl 1912a; 1912b; Campbell 1950:115; Olsson 1958:20; Hjelmqvist 1963:239; Gräslund 1967:258). This dating is also followed by the Museum of National Antiquities in Stockholm (SHM) where the bread is now stored.

According to Schnittger, however, the grave goods date the grave to the Viking Age or *possibly somewhat older*. These grave goods comprise the bread loaf itself, burned bones (unspecified but including the deceased), two iron frost-nails, an iron arrowhead, an iron knife-blade, fragments of iron, a slate whetstone, a red glass bead and fragments of a decorated comb. These grave goods were considered standard for a man's grave of the period (Schnittger 1912:3ff).

The comb fragments (fig. 8), might possibly provide a somewhat closer dating. They belong without doubt to two combs made of different material and with different decorative elements.

Schnittger compared one comb fragment with that illustrated in *Svenska fornsaker*, fig. 526 (Montelius 1872:152, 200), a comb of elk antler, found in the Black Earth of Birka (Björkö, Adelsö par., Uppland), which in its turn very closely corresponds to Ambrosiani's comb type B1:2 (Ambrosiani 1981:64), though the correspondence is not total. Here we find the same type of grid pattern of double lines that occurs on eight of the comb fragments from the Ljunga grave. The close grid pattern on one of the Ljunga-grave comb fragment does not exist on Ambrosiani's B1:2 combs and neither do the three decorative lines parallel to the edges of the connecting plate on two of the comb fragments.

The B1:2 combs from the graves from Birka are mainly dated to Late Birka Period, but they also occur sparsely during Early Birka Period. Thirteen graves containing B1:2 combs can be dated to Late Birka Period and three graves with these combs belong to Early Birka Period (Ambrosiani 1981:76). Dating has here been made in accordance with the traditional method of combination dating.

Grid patterns of both single and double lines are found on a comb type from Elisenhof (Tempel 1979:155). The dating of this type of comb is considered to be eighth century (Tempel 1979:167). Its distribution, seems to be fairly local (Tempel 1979:169). However, in Bergby, Vendel par., Uppland (SHM 19416, grave 42), fragments of a comb have been found with this decoration. The grave is dated to the eighth century (Nerman 1958: 152, 224, Pl. 330).

Also in one of the graves at the cemetery of Ormknös, Björkö, Adelsö par., Uppland, comb fragments with similar decoration pattern have been found. This grave has been dated to the late Vendel Period (Arrhenius 1978:49). Two of the fragments from the Ljunga grave have three lines parallel to the edges of the connecting plate. This type of ornament is common during the Vendel Period (Ambrosiani 1981:131), in the Mälar Valley (Lamm 1973:Pl. 8, 9, 11–15, 17), on Gotland (Nerman 1969:Pl. 122, 192), in Grobin (Nerman 1958: Pl. 22, 24, 29, 36, 47, 50, 53, 54), and on the west coast of Norway (Petersen 1951:489; Sjøvold 1974:237ff). Comb fragments with this decoration are common during the seventh century and most of the eighth century

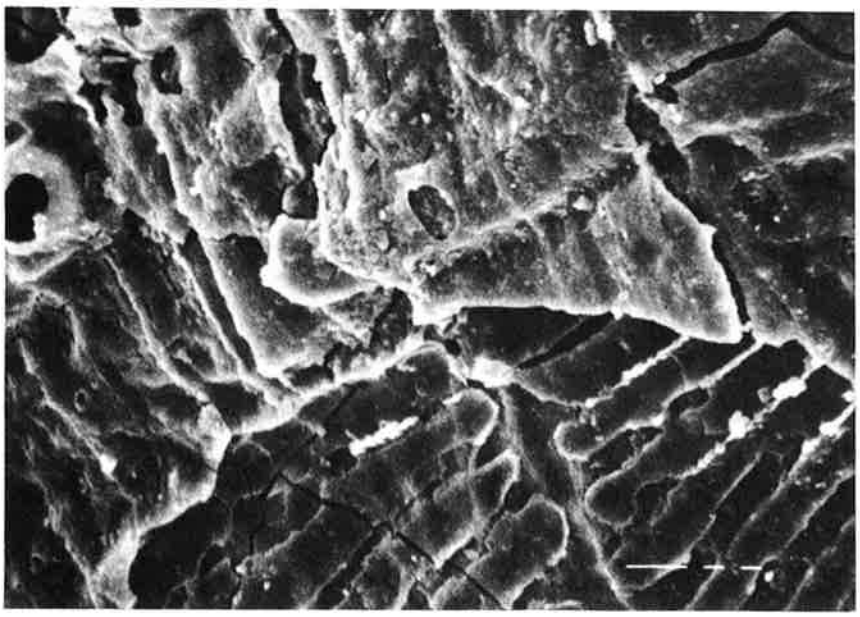

Fig. 7. Cf. transversal cells of barley (Hordeum vulgare) *in the Ljunga bread (×720). SEM micrograph Ann-Marie Hansson.*

Table 1. Amino-acid composition of the Ljunga bread, of test breads and ingredients according to high-pressure thin-layer chromatography (HPTLC) analyses performed at the Archaeological Research Laboratory (mg/100 mg protein), and compiled from Statens livsmedelsverk *1988 (mg/100g food).*

	(mg/100 mg protein)					*(mg/100g food)*			
Amino acids[1]	Test bread no. 1*	Test bread no. 3**	The Ljunga bread	Inner bark of Scots pine	Field pea, charred	Sour milk 3% fat	Dried peas	Wheat, whole meal	Barley
Leu	0.014	0.012	–	–	0.176	320	1480	700	740
Met	(+)	–	–	(+)	–	105	210	320	160
Val	0.014	0.012	–	(+)	0.087	330	1000	530	570
His	(+)	(+)	–	–	–	53	480	250	240
Ala	0.041	0.039	0.035	0.014	0.262	110	900	430	400
Asp	(+)	0.012	–	0.014	(+)	300	2380	570	540
Glu	0.041	0.037	0.035	0.014	0.263	660	3490	2800	2400
Gly	–	–	–	(+)	–	82	860	450	360
Pro	0.041	0.012	0.035	0.014	0.263	320	830	980	1200
Ser	0.014	0.012	0.017	(+)	(+)	185	930	520	480
Arg	–	(+)	–	–	–	120	660	520	440
Thr	0.014	(+)	–	–	–	145	860	330	330
Lys	(+)	–	0.017	–	0.09	300	520	340	350

[1]See abbreviation list for the amino acids at the end of the article.
*bread no. 1, content: 50% inner bark from Scots pine, 50% peaflour and water.
**bread no. 3, content: 50% inner bark from Scots pine, 50% peaflour and sour milk.

and are extremely unusual during the Viking Age (Petré 1984:70ff). Petré's examination concerns the island of Lovö, situated in Lake Mälaren, central Sweden.

One of the comb fragments has groups of dot and circle decoration on the connecting plate, which also can be dated to the Vendel Period (Petré 1984:70ff; Nerman 1969:Pl. 122, 192).

Thus a most likely dating for the Ljunga grave, based on the comb fragments from the two different combs, is the end of the Vendel Period. The remaining grave goods do not contradict this dating.

Discussion

Prehistoric bread and even bread from later periods did not always contain cereals, as previously mentioned. The reason for using some other flour than that from ground cereals might be an emergency situation (*Svenska Linnésällskapet* 1964; Eidlitz 1969), or tradition (Nordhagen 1954). In the case of peas it might depend on a need for a higher protein value than cereals alone can give (Hansson 1987:16). During historic times peaflour as an ingredient in bread occurs mainly in marginal agricultural areas, and such bread was sometimes used when working hard physically and as travelling fare; Sw. *"man bir (står sig) bättre på det"* (it keeps you going), as one used to say in the province of Jämtland (Campbell 1945:29).

The peaflour content in the bread from Ljunga was long the only evidence of the cultivation and usage of peas in Sweden during ancient times (Rosendahl 1912a:2f; Campbell 1950:116). Later it became obvious that peaflour as an ingredient in ancient bread was not quite so uncommon. Of all the bread found on Swedish archaeological excavations only 80 have been analysed, and of these, 13 have proved to contain peaflour (table 3, fig. 2).

Right from the start there has been a continuous evolution of cultivated plants. In the cultivated members of Fabaceae, the seeds have increased in size (Zohary & Hopf 1994:95). The older pea sort, the field pea (*Pisum sativum* var. *arvense*), has a slightly angular pea, containing a considerable amount of tannic acid, which causes it to taste rather bitter (Osvald 1959:159). The seedcoat is also dark grey-green, marbled or patchy (Renfrew 1973:111). At some point in time a recessive mutation occurred and the seedcoat lost its colour, so that in certain peas the seedcoat became uncoloured, "white" (the pea in fact appears yellow); this sort is now called "garden pea" (*Pisum sativum* var. *sativum*).

We do not know which pea sort was used in the bread from Ljunga, but it is not impossible that it could be the new "white" sort. As early as the twelfth century, there exist written records of "white" peas in central Europe. In Scandinavia in the year 1378 there is evidence for this new pea sort: King Hakon Magnusson of Norway, in a letter concerning trade, mentions a barrel of "white" peas (Becker-Dillingen 1929:39).

It might be significant that "white" peas are here mentioned in a royal connection, as this new pea sort could have had a certain status. But still during the Middle Ages, the old sort, the field pea, "the potato of the Middle Ages" had great importance, at least in Germany, according to information from tithes records (Wimmer 1905:244; Hjelmqvist 1963:239). Peas (with

Table 2. Protein, Cu and Zn content of the bread from Ljunga and comparable bread loaves and botanical substances

Analysed organic material	Protein (% by weight)	Cu (mg/100g)	Zn (mg/100g)
Bread from Ljunga	0.6%	0.04	0.02
Test bread no. 2, charred	4.4%	0.00	0.02
Wheaten crisp bread[1] (not charred)	10%	-	-
Dried peas[1]	21.5%	0.69	3.8
Inner bark, Scots pine, spring DS[2]	3.6-3.9%	0.35	8.9
Inner bark, Scots pine, autumn DS[2]	3.6-3.9% (6.2%[3])	0.24	7.9
Sour milk, 3% fat (not DS)[1]	5%	0.01	0.1
Wheat, whole meal[1]	10%	0.47	3.6
Barley[1]	9.2%	0.4	1.7

[1]*Statens Livsmedelsverk* 1988
[2]*Maanpuolustuksen tieteellinen neuvottelukunta* 1979
[3]Källman 1991, p. 398
DS=dry substance

their high protein value) were also used as fasting food and were therefore especially appreciated within the monasteries.

Other ingredients in the bread from Ljunga are naked barley and emmer wheat. Neither of these cereals are very common during the Late Iron Age, according to analysis of imprints of plant remains in Sweden (naked barley 15%, emmer wheat 1%) (Hjelmqvist 1979:53). In bread, however, the frequency of emmer wheat seems to be higher (Viklund 1994:33). Weeds are sometimes also found in bread, and the unidentified seed in the Ljunga bread might be a seed of weed. The distribution of weed seeds in bread confirms what the macrofossil analyses of plant remains have pointed out, i.e. that the cleaning of cereals was not especially thorough during the Iron Age. Seeds of weeds are often found together with cereals (Engelmark & Viklund 1990:36).

The protein in the bread from Ljunga measured 0.6%. By comparison it can be mentioned that one of the bread loaves (Bj 1148a) from Birka, Adelsö par., Uppland, contained 0.7% protein. The values are very close in these two loaves. There is another "bread", from Västergården, Bergshammar par., Södermanland (SHM 6575/87), which has a higher protein content, 2.3% (Hansson & Isaksson 1994:26), but this bread was not so heavily charred, and the results of analyses furthermore suggested that blood constituted one of the ingredients. Probably it was also fermented.

There seems to be a significant difference between organic remains on pottery sherds, where the protein value can vary between 1 and 20% (Arrhenius 1985:341), and the protein value found in charred bread. The higher protein value for organic remains on pottery seems to depend on the fact that these remains probably were fermented, as both trace elements and protein become highly concentrated during the fermentation process (Arrhenius 1985:340).

The Ljunga bread is the first Scandinavian prehistoric bread that has undergone amino-acid analysis. Of the five amino acids detected in the bread, only lysine is essential. Thus, since we only have traces of the original amino-acid pattern remaining, it is difficult to draw any conclusions concerning the original amino-acid content in detail.

Dried peas have a higher protein value than cereals (cf. table 2). Therefore it is not remarkable that the amino-acid pattern for peas fits into the pattern obtained from the analysis of amino acids in the Ljunga bread. Even if most of the amino acids which have a high value in peas also reach a high value in barley and wheat, this is never as high as in peas. As a whole, therefore, the amino acids which still remained in the bread and could be detected by our analysis, seem to confirm, or at least not contradict, the vegetable content of the bread as identified by microscopic analyses. Those amino acids which have high values in meat are low or missing here. If meat of some kind had constituted an ingredient in the Ljunga bread, arginine and measurable values of aspartic acid should have been found, as meat contains almost twice as high values of these amino acids as cereals and peas. Lysine and glutamic acid have similar qualities and the ratio has been used to discriminate between meat and plant food (Arrhenius 1985:341). The lysine value is, however, rather high, considering its sensitivity to heat and this is hard to explain.

Fig. 8. Comb fragments (actual size) from the Ljunga grave. Photo: Bo A. Zachrisson.

Table 3. Prehistoric and historic Scandinavian bread containing peaflour. Literature references to the bread content (Cf. Hansson 1987:36f; Viklund 1994:33).

Bread loaves	Period	Locality	References
6	Roman Iron Age	Helgö, Ekerö par., Uppland	Hjelmqvist 1982:238; 1984:271; Hansson 1987:37
1	Late Iron Age	Mossängen, Västerljung par., Södermanland	Hjelmqvist 1990:17
1	Vendel Period	Hovgårdsberg, Vendel par., Uppland	Hjelmqvist 1990:11
1	Vendel Period	Ljunga, Skönberga par., Östergötland	Rosendahl 1912a, 1912b; Hjelmqvist 1990:13; Hansson in press
3	Viking Age	Birka, Adelsö par., Uppland	Hjelmqvist 1984
1	Viking Age	Fiskeby, Östra Eneby par., Östergötland	Hjelmqvist 1990:13
3	16th century	Hamarhus, Norway	Jessen 1956
Σ16			

With regard to trace elements, we still know too little of their composition in bread. Further analyses on bread in the future should hopefully produce more data.

The Ljunga bread seems be have been highly nutritious. If one desires bread with a high protein value, it is very wise to mix flour from peas (seeds of the Fabaceae family) and cereals (seeds of the Poaceae family) into the dough. Peas are rather low in the amino acid methionine which is higher in cereals; cereals are low in the amino acid lysine which is higher in peas. Therefore, by mixing peas, naked barley and emmer wheat in the bread, a higher protein value is obtained than from only cereals or only peas. If, furthermore, the inner bark from Scots pine is deliberately mixed in, which might be open to discussion, there is also a chance for a small addition of vitamin C. The lipids (fat) detected in our analyses could provide additional energy. No husks at all were found when analysing the bread. Emmer wheat is a *non* free-threshing cereal, and this may mean that extra care was taken to extract the husks before grinding the kernels to flour, or that the flour was thoroughly sieved. Already during classical antiquity in Gaul, sieves made of horsehair were used to obtain a finer flour (Davies 1978:548). If the husks from emmer wheat were removed, there may also be a possibility that the naked barley instead could be hulled barley with its husks removed. Hjelmqvist (1984:272) has earlier discussed this identification problem.

These rather uncommon cereals together with peas (perhaps the new white sort), and a little fat of some kind, as ingredients point to a bread not only with high nutritional value, but also a bread of high quality (Hjelmqvist 1990:13) and a certain status, which would be most suitable for a wealthy deceased man to bring along on his last journey, to the world beyond.

Conclusions

The dating of the bread, it is suggested, should be drawn back somewhat, to the end of the Vendel Period according to a redating of the comb fragments found with the bread.

The baking technique has been assessed off trial bakings. It is certain that the bread was not leavened and maybe hot water was poured onto the ingredients (if there was much peaflour) to make the dough sticky and hold together. Probably special care has been taken when threshing the emmer wheat, as no husks were found in the analyses.

According to the microscopic analyses (light microscope and scanning electron microscope) the following ingredients could be identified: naked barley (*Hordeum vulgare* var. *nudum*), emmer wheat (*Triticum dicoccum*), pea (*Pisum sativum* var. *arvense*), inner bark from Scots pine (*Pinus silvestris*) and one unidentified seed (weed?). The chemical analyses confirm as a whole the results of the microscopic analyses. The nutritional value of the bread was high.

Abbreviations

Customary abbreviation of the amino acids:

Leucine	Leu
Methionine	Met
Valine	Val
Histidine	His
Alanine	Ala
Aspartic acid	Asp
Glutamic acid	Glu
Glycine	Gly
Proline	Pro
Serine	Ser
Arginine	Arg
Threonine	Thr
Lysine	Lys

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