

# Molecular and isotopic traces of cooking and consumption of fish at an Early Medieval manor site in eastern middle Sweden

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## Abstract

This paper is a presentation of a comparison between prehistoric food culture signals obtained through analyses of lipid food residues in pottery, i.e. pottery-use, from settlement remains on one hand and bone chemical analyses of human skeletal remains from an adjacent and contemporary cemetery on the other. The materials derive from the Early Medieval site Tuna in Alsike par., Uppland, Sweden. The results show a discrepancy between the two food signals and it is argued that pottery-use do not by necessity reflect everyday diet. But it is also argued that the integration of several food signals together with contextual archaeological data is a fruitful way to begin to understand the complexity of prehistoric cultures of food.

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## 1. Introduction

There are several ways to investigate prehistoric food habits. The obvious archaeological approach is to study artefacts and features connected to cooking and eating found among settlement remains and grave-goods. More detailed analyses may include osteological investigations of bones from food waste and plant macrofossils found in soil samples. Other information might be gathered through the analysis of food remains found adhering onto and adsorbed into ceramic vessels (Evershed et al., 2001; Gernaey et al., 2001). The only available way today to obtain direct evidence of diet is through the chemical analysis of human skeletal remains (Lidén, 1995).

In this paper we present a comparison between prehistoric food culture signals obtained through analyses of lipid residues in pottery and bone chemical analyses of human skeletal remains. The material comes from the Early Medieval manor

site of Tuna in Alsike parish, the province of Uppland in eastern middle Sweden. Pottery was sampled during recent settlement excavations at the site (Hjulström and Isaksson, 2004, 2005; Isaksson, 2003a; Isaksson and Hjulström, 2003), closely connected to an earlier investigated boat-grave cemetery (Arne, 1934) from which the human skeletal remains derive. Lipid residues in pottery are often assumed, explicitly or not, to reflect everyday diet. One reason for selecting this site was the opportunity to try and put this assumption to the test. To our knowledge this is the first time such a comparison has ever been attempted.

## 2. The site

The present-day village of Tuna is located on a low hill surrounded by level fields. In the Early Medieval period the site was situated on the northern shore of a shallow bay (Fig. 1). To the west this bay provided direct access to the extensive waterways of the Mälaren valley and central Uppland, connected to the Baltic Sea.

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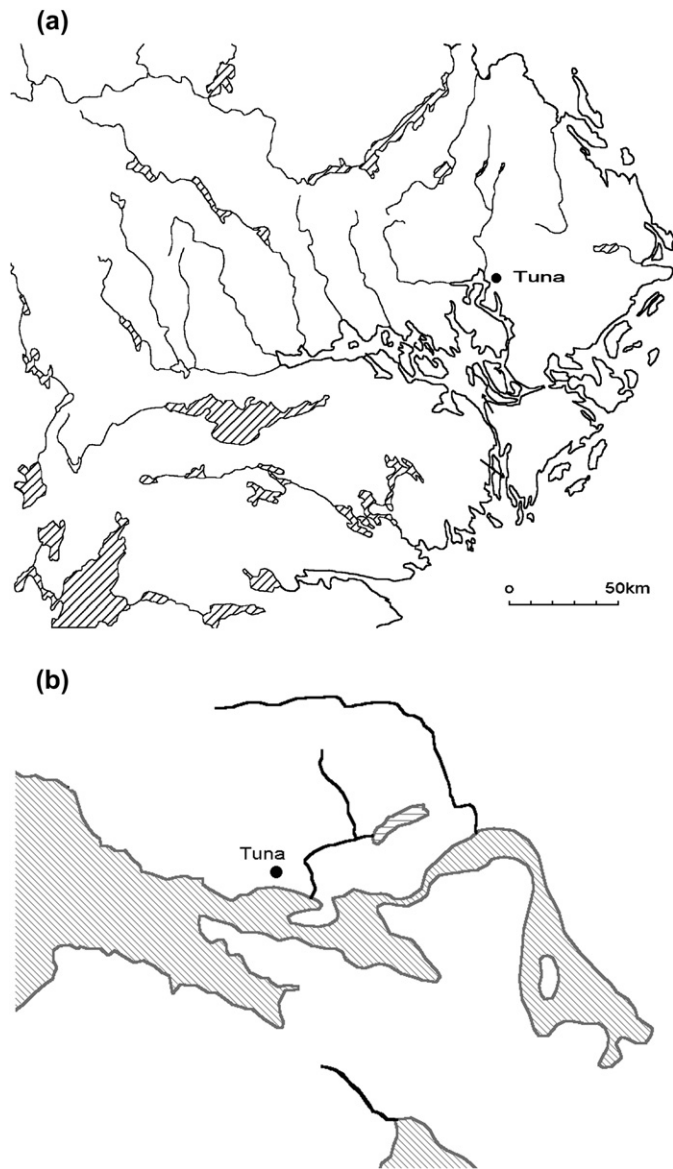


Fig. 1. (a) The location of Tuna in eastern middle Sweden. (b) The location of Tuna in the landscape around the end of the Viking Age. The shoreline is set to 5 m above present day sea-level.

### 2.1. The cemetery

The site caught the attention of archaeologists for the first time in 1893 when the boat-grave cemetery was found (Stolpe, 1895). Between 1895 and 1896 ten graves were excavated. In 1928 an additional four were found (Arne, 1934). The number of buried individuals is seventeen (Arvidsson, 1999), fifteen of these are dated to Viking Age (AD 800–1050, Arne, 1934), twelve buried in boats. Two are dated to the 6th Century AD and are not buried in boats (Arrhenius, 1980). The relative richness in equipment and the military-like repetition of grave-goods combinations in the large boat-grave cemeteries around Lake Mälaren has influenced the interpretations of the people buried in boat-graves, e.g. being royalty, great land-owners, mounted warriors etc. (Ambrosiani, 1983; Engström,

1997; Hyenstrand, 1996; Steuer, 1989). At Tuna men, women and children are all represented, which is a difference from the other boat-grave cemeteries (Lidén et al., 2001).

Another difference is that the human skeletal remains at Tuna are well preserved, indicating variations in the treatment of the dead (Arrhenius, 1983; Lidén et al., 2001). Thanks to this preservation it has been possible to conduct bone chemical analyses on 12 of the individuals. Eleven of these are from boat-graves dated to the Viking Age and one is from a 6th Century burial.

These analyses of stable carbon and nitrogen isotopes of extracted bone collagen show that eight of the twelve individuals have  $\delta^{15}\text{N}$ - and  $\delta^{13}\text{C}$ -values indicative of fish as their main source of dietary proteins, in comparison with the  $\delta^{15}\text{N}$ - and  $\delta^{13}\text{C}$ -values of potential food sources (Arvidsson, 1999; Kalmö, 2003; Lidén et al., 1997). The relatively high mean  $\delta^{15}\text{N}$ -value ( $13.4 \pm 0.9$ ) and relatively low mean  $\delta^{13}\text{C}$ -value ( $-20.3 \pm 0.6$ ) for these eight individuals are consistent with a large consumption of fish from fresh or brackish water.

### 2.2. The settlement

In recent years a settlement contemporary with the boat-graves has been sought at the site. These investigations were part of the project *By House and Hearth* (Hjulström and Isaksson, 2005). The archaeology of the site offers a challenging complexity as remains from historical times superimposes the prehistoric ones and the farms of the village are still in use today. Ten trenches has been investigated inside the present-day village (Fig. 2).

In the trenches at Oppgårdén (3, 4) finds from Late Viking Age was found in the bottom layers and features, and in the trenches at Mellangårdén (5, 10) the earliest dateable finds are from Late Migration period (Hjulström and Isaksson, 2005). The dates of these finds are confirmed by radiocarbon dating of plant macrofossils (Table 1, Fig. 3) found in features of the site (Hansson, 2006). The settlement is thus contemporary with the cemetery, located some 80 m south of the settlement. It is from these trenches that the pottery was sampled.

### 3. Commensurable data?

There are a few questions regarding what the two materials, ceramic and human remains, actually represent. Solvent extractable lipid residues comes from the last or the last few uses of a pot, as proven by the co-existence of preserved aliphatic lipids and a thermally stable aromatic macromolecular phase within the same ceramic matrix (Craig et al., 2004). Thus, the extracted residues do not represent a mixture of the whole lifetime of use of the pot. The collagen in human skeletal remains represents primarily, but not exclusively, an average of the protein part of that individual's diet for several years prior to death (Eriksson, 2003).

As the village is still standing at the site today (Fig. 2) it has not been possible to perform a complete excavation of the Early Medieval settlement. This in itself makes the ceramic material a sample of the complete material of the site.

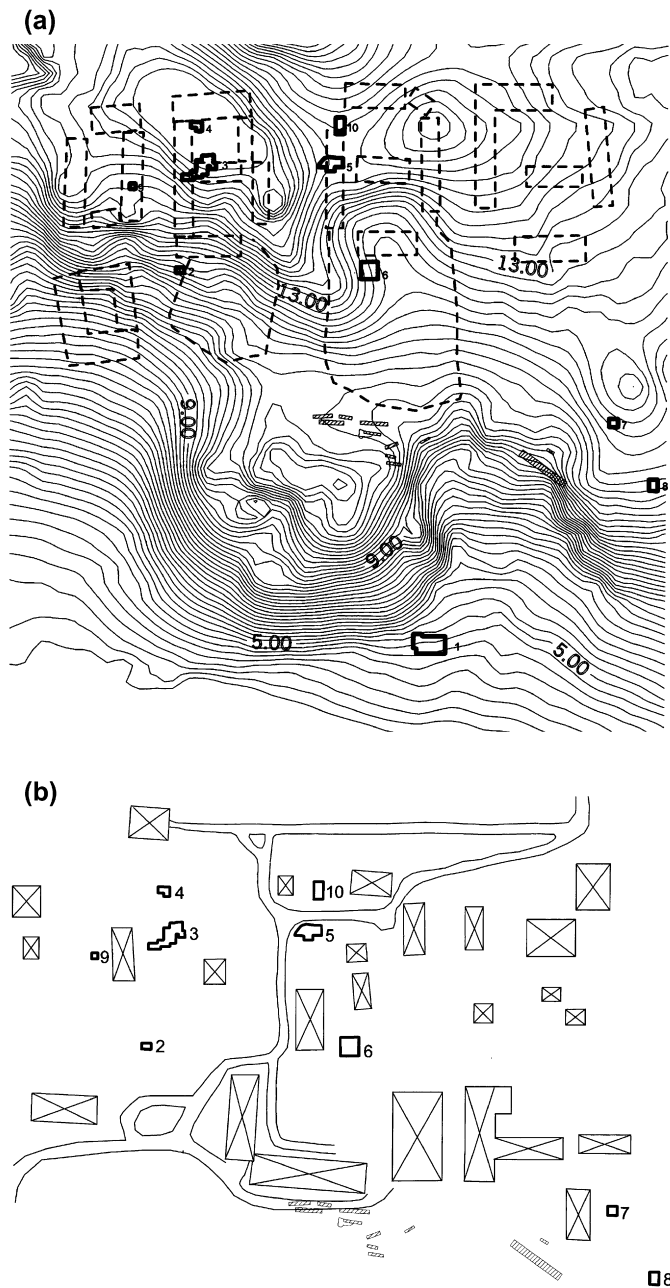


Fig. 2. Tuna in Alsike. (a) Present day topography at Tuna with buildings and fences (dotted lines) of the late 18th C. The four farms were called Västergården, Oppgårdén, Mellangården and Storgården (from left to right). (b) Present day Tuna. The numbered trenches are the ones excavated between 2002 and 2005. In trenches 3 and 4 (Oppgårdén) and in 5 and 10 (Mellangården) settlement remains contemporary with the boat-grave cemetery (hatched rectangles) have been found. In trench 1 a water deposited layer with finds from Early Medieval period was investigated. Drawings from Hjulström and Isaksson (2005).

The individuals buried in the boat-graves were not the only inhabitants of Tuna. The diet of these other people is of course unknown. There is a large chronological gap in the cemetery, with most of the excavated graves being dated to the Viking Age and only two graves from the end of the Migration period. Only one of the two oldest individuals has been analysed.

The two techniques analyse quite different food culture signals and the comparison of the data and the following

inference will by necessity be qualitative rather than quantitative. Pots are simply not people.

#### 4. Fish and fishing

Vertebrae from fish have been found in the cultural layers and features of the settlement (Hansson, 2006). No fish bones have been recorded in the boat-graves. In the Early Medieval period Lake Mälaren was a bay of the Baltic Sea. At a contemporary urban settlement and trade centre in this region (i.e. Birka) large quantities of fish-bone have been found, suggesting that fish was very common as food (e.g. Ericson and Svensson, 1995). The most frequent species are pikeperch, herring, pike and bream (Lõugas, 2001), fish caught in fresh and brackish water, taken as evidence for local fishing (Ericson et al., 1988). There is little evidence for marine fishery. During the Late Medieval period the demand for fish increased, stimulated by the Christian Church, with both political and economic effects in the near monopoly on fish-trade of the mighty Hanseatic League (Davidson, 1999).

In the culture of food of the Early Medieval period meat had a special position. The references to animal products in Old Norse family sagas greatly exceed the references to foods from vegetables. This does not, however, reflect the everyday diet. The special cultural position of meat was more social and ideological than dietary (Isaksson, 2000, 2003a). The mentioning of fish in the same Old Norse texts is intermediate between animal and vegetable products (Isaksson, 2003b). These references concerns fishing trips, good fishing spots and the importance of fish for basic subsistence, noted as a staple food, especially dried fish. It is described how it is stored but nothing is said about how it was cooked or eaten. The only fishing tools mentioned is various types of nets.

There are no obvious tools for fishing in the grave-goods of the cemetery at Tuna, save for the boats, or in the settlement material. Fishing equipment is however rather uncommon both in settlements and graves of the Early Medieval period (Lõugas, 2001; Roesdahl and Wilson, 1992). Fish may also have been caught in fixed fish-trap constructions, which are known from the Late Medieval period. These are very suitable for sheltered coves and shallow shores (Wessnert, 2002),

Table 1

Radiocarbon dates of plant macrofossils found in soil-samples from various contexts at Tuna

Lab number	Context	<sup>14</sup> C Age BP	Calibrated AD, 68.2% probability
Ua-33218	Trench 3, Feature 25, Posthole	1165 ± 35	780–900, 920–950
Ua-33219	Trench 4, Feature 51, Posthole	930 ± 35	1030–1160
Ua-33222	Trench 5, Feature 111, Posthole	1420 ± 40	600–660
Ua-33223	Trench 10, Feature 156, Sunken-floor house	658 ± 40	1270–1310, 1350–1390

Calibrated with OxCal v3.9 (Bronk Ramsey, 1995, 2001) using atmospheric data (Stuiver et al., 1998).

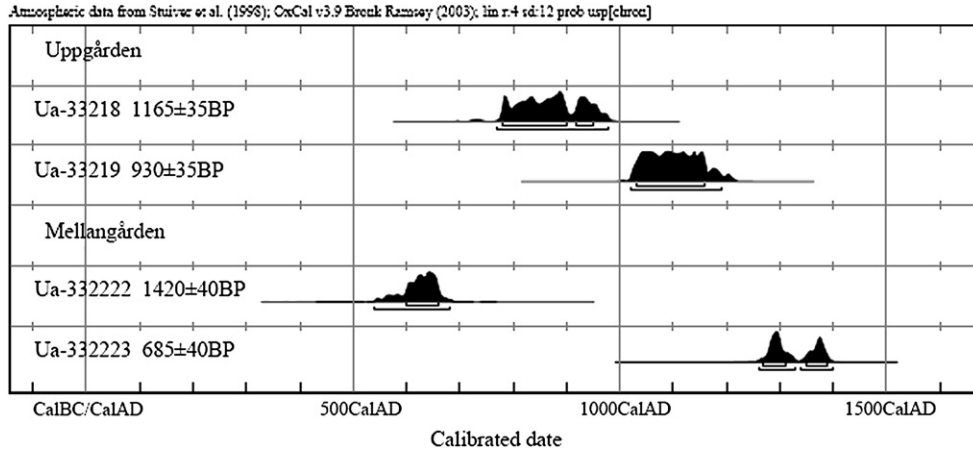


Fig. 3. Radiocarbon dates of plant macrofossils found in soil-samples from features at Oppgård and Mellangård at Tuna. Calibrated with OxCal v3.9 (Bronk Ramsey, 1995, 2001) using atmospheric data (Stuiver et al., 1998).

waters common around Tuna in Early Medieval times. In trench 1 (Fig. 2) we investigated a water-deposited layer (Isaksson and Hjulström, 2003), datable to Early Medieval period, and beneath this layer two small postholes were found. These postholes may be the remains of any kind of waterside construction, including fixed fish-traps.

Fish is a food prepared and consumed in a variety of ways, other than cooking in a pot. It is eaten raw, pickled, fermented,

fried and roasted. A traditional way of preserving fish in Sweden in historical time was drying. Smaller dried fishes were eaten raw or roasted directly on the embers, while the larger ones were usually cooked (Keyland, 1919). In late 18th C. Iceland dried fish was also popular, eaten raw with a spread of sour butter, like on a piece of bread (von Troil, 1933). We know from the bone chemical analyses that the people buried in the boat-graves at Tuna had a substantial part of their

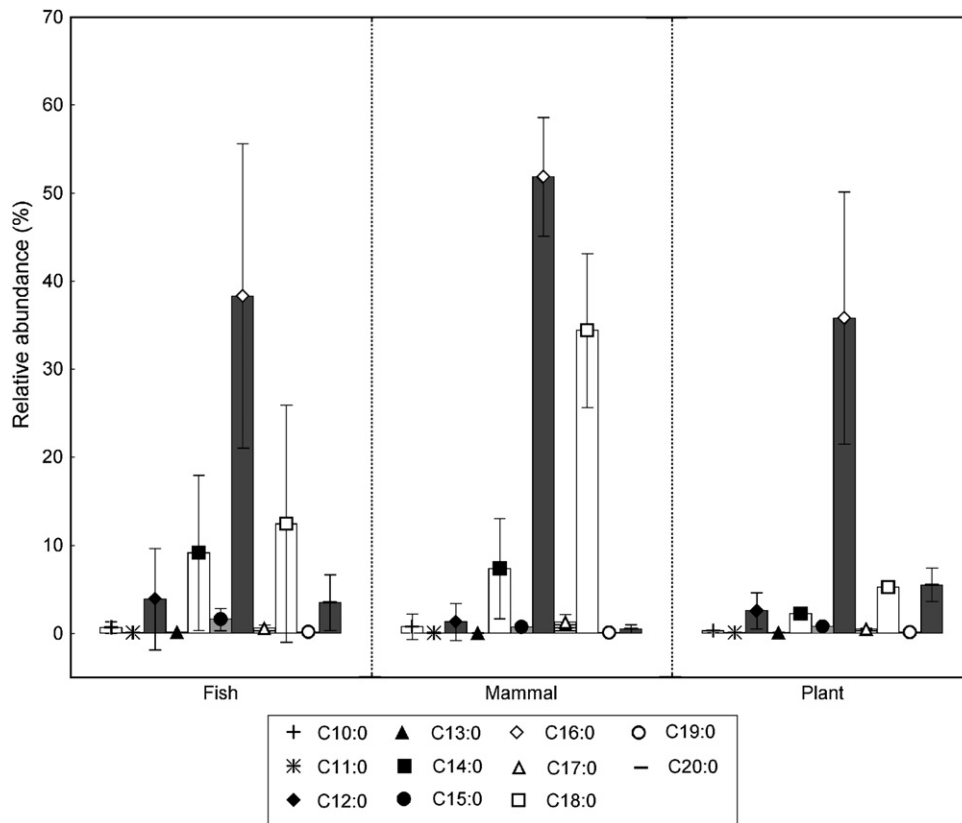


Fig. 4. The distribution of n-alkanoic acids in experimentally decomposed lipids of various origins. Multivariate analyses of variance show that the distributions are statistically significant different between lipid residues from fish and mammals (Wilks'  $\Lambda = 0.054$ , Rao's  $R = 12.63$ ,  $df = 8$ ,  $p = 0.00068$ ), and between lipid residues from mammals and plants (Wilks'  $\Lambda = 0.013$ , Rao's  $R = 35.62$ ,  $df = 5$ ,  $p = 0.00050$ ). The difference between fish and plants was not statistically significant.

protein from fish, which is in accord with the Old Norse texts. But from these sources we get no suggestions on how fish was cooked or eaten. The historical sources seem to indicate that fish may have been prepared and consumed in ways that would be hard to trace in the archaeological record, i.e. raw, dried, roasted, etc.

## 5. Experimental

### 5.1. Identifying fish lipid residues

Identifying fish lipid residues in ancient pottery is not a trivial thing (Brown and Heron, 2005). All the samples analysed for this paper turned out to be mixtures of various foods, which complicates matters. This result was expectable as the most common dish of the Early Medieval cuisine was the stew (Isaksson, 2003a), by definition a mixture.

Through decomposition experiments we have shown that it is possible to distinguish between lipid residues of fish (perch, pikeperch, herring) from those of terrestrial animals (cow, sheep, wild boar) based solely on the distribution of saturated *n*-alkanoic acids (Olsson, 2004). It proved, however, impossible to separate fish from plant lipid residues mainly because the *n*-alkanoic acid distribution of both is dominated strongly by the C16:0 acid (Fig. 4).

Theoretically fish and plant lipid residues should be separable by the presence or absence of cholesterol (fish) and phytosterols (plant), or their corresponding decomposition products in the lipid residues. The experiments also showed that lean fish (pikeperch, perch) leave negligible lipid residues already after only thirty days of experimental decomposition. Lean white fish, whose flesh is not oily, is the most suitable for drying because lipids in fish are highly unsaturated and goes rancid easily. For example the late medieval stockfish, a general name for any dried white fish, was made from cod, pollack, whiting, hake, etc. (Davidson, 1999). Hansel et al. (2004) has suggested that marine lipid residues may be identified by an *n*-alkanoic acid distribution dominated by C16:0, together with the detection of the isoprenoid alkanolic acids 4,8,12-trimethyltetradecanoic acid (4,8,12-TMTD) and 3,7,11,15-tetramethylhexadecanoic acid (3,7,11,15-TMHD), and the detection of C16, C18 and C20  $\omega$ -(*o*-alkylphenyl)alkanoic acids. The  $\omega$ -(*o*-alkylphenyl)alkanoic acids are formed during heating of triunsaturated alkanolic acids (C16:3, C18:3, C20:3). The two acyclic isoprenoids are quite common in the geolipid record and are generally considered non-specific of any biological source (Brassell et al., 1983). As vegetable oils are rich in C18 triunsaturated alkanolic acids, and many also contain the C16 homologues, this leaves us with the C20  $\omega$ -(*o*-alkylphenyl)alkanoic acids as potential indicators of marine lipid residues. However, not all fish produce the C20:3 alkanolic acid in substantial amounts, such as the lean fish in our decomposition experiment. Also, the C20:3 alkanolic acids are found in other food sources, such as terrestrial mammal liver (Estévez et al., 2004).

The analysis of stable carbon isotopes of individual alkanolic acids by gas chromatography combustion isotope ratio mass spectrometry (GC-C-IRMS) may have aided the analysis

but does not seem to enable the separation between marine and porcine lipids, or to separate between freshwater fish and terrestrial animals (Craig et al., 2007). We chose therefore to focus on lipid biomarkers.

To identify possible fish residues we defined the following two criteria: (1) an *n*-alkanoic acid distribution dominated clearly by the C16:0 acid (peak-area ratio of C18:0/C16:0 <0.48, as observed from experimental data (Isaksson, 2000; Olsson, 2004)) together with the presence of cholesterol; and/or (2) the presence of the two acyclic isoprenoid alkanolic acids and the complete set of C16, C18 and C20  $\omega$ -(*o*-alkylphenyl)alkanoic acids. The peak-area ratio was calculated through the integration of the total ion-chromatogram. Low-abundance components were detected through the extraction of ion-chromatograms for several characteristic ion-fragments of each compound.

### 5.2. Samples

Potential pottery samples for analysis were selected already at the site, directly when found. These potsherds were never handled with bare hands and were wrapped in aluminium foil before being placed in a plastic bag, to minimise any post-excavational contamination. The samples were put in a freezer the same day in wait of analysis. The actual sample selection was performed in the laboratory. Very few of the potsherds showed any trace of visible surface residues and we were obliged to focus on adsorbed lipid residues in order to get a satisfactory sample.

Rather than analysing as many potsherds as possible we performed a sample selection in order to analyse as many as necessary to address our questions, i.e. a sub-sample representative of the pots used in the excavated areas of the settlement. Instead of taking a sample from all sherds in every context we made a selection of secure contexts and made a stratified sampling from each of these. The population from which the sample was taken is certainly very far from the total population, but with this contextual sample strategy it is at least possible to have an idea of what the sample represent. In doing so we tried to identify individual vessels through the morphology of the potsherds. The samples were also selected to get the largest possible spatial distribution within each context. As lipid residue content generally tend to decrease from rim to base of a ceramic vessel (Charters et al., 1993), priority was given to sherds from rim and upper body during the sample selection. This sampling strategy resulted in 29 sherds to analyse, nine from trench 3 and ten each from trench 5 and 10.

### 5.3. Extraction and derivatisation

Following documentation of the potsherds ceramic was ground off from the inside using a low-speed pottery grinder. The first half a millimetre was discarded to avoid any contamination from soil. The powdered ceramic was transferred quantitatively (0.5–1.5 g depending on the size of the sherds) into an extraction vessel and an internal standard was added (hexatriacontane, C36). Three ml of a mixture of chloroform and

methanol (2:1, v:v) was added and the lipid residues were extracted through sonication ( $2 \times 15$  min). The samples were allowed to settle for 12 h and were then centrifuged (3000 rpm, 30 min). The clear extracts were transferred to vials and the solvent evaporated under a gentle stream of nitrogen.

The lipid residues were treated with bis(trimethylsilyl)trifluoroacetamide containing 10% (v) chlorotrimethylsilane at 70 °C for 15 min to produce trimethylsilyl derivatives, which were then dried under nitrogen. The derivatised extracts were re-dissolved in *n*-hexane and analysed by GCMS. All glassware was washed in concentrated nitric acid before use and only *Pro Analyti*-grade solvents were used.

#### 5.4. Gas chromatography-mass spectrometry

The analysis was performed on a HP 6890 Gas Chromatograph equipped with a SGE BPX5 capillary column (15 m  $\times$  220  $\mu$ m  $\times$  0.25  $\mu$ m). The injection was done by pulsed splitless (pulse pressure 17.6 Psi) technique at 325 °C through a *Merlin Microseal™ High Pressure Septum*. The oven was temperature programmed with an initial isothermal of 2 min at 50 °C, followed by an increase of the temperature with 10 °C per minute to 350 °C, followed by a final isothermal at this temperature of 15 min. Helium was used as carrier gas and held at a constant flow of 2.0 ml per minutes throughout the analysis.

The gas chromatograph was connected to a HP 5973 Mass Selective Detector via an interface with a constant temperature of 350 °C. The fragmentation of separated compounds was done by electronic ionisation (EI) at 70 eV. The temperature at the ion-source was 230 °C. The mass filter was set to scan between *m/z* 50 and 700, providing 2.29 scans per second. The temperature of the mass filter was 150 °C. The data was processed using the HP Chemstation™ software.

## 6. Results and discussion

### 6.1. Possible fish residues

Of the twenty nine analysed potsherds five fell within the above-defined criteria for possible fish lipid residues, as presented in Table 2. All five came from the trenches at Oppgården. Three of the five fit the first criteria and two show the full range

of acyclic isoprenoid alkanolic acids and  $\omega$ -(*o*-alkylphenyl)-alkanoic acids. The signal from the C18  $\omega$ -(*o*-alkylphenyl)-alkanoic acids is much stronger than those from the C16 and C20 homologues in both samples, which might indicate that the original dish also included oil-rich vegetable seeds, such as linseed or hempseed (Isaksson et al., 2005). This is to some extent supported by the detection of  $\beta$ -sitosterol.

None of the samples are pure fish lipid residues. All three samples that fit the first criteria also contain traces of plant lipids;  $\beta$ -sitosterol, plant wax residues in the form of long-chain alkanolic acids, alkanols and alkanes, or C18  $\omega$ -(*o*-alkylphenyl)alkanoic acids. An alternative interpretation of these lipid traces could be plant lipids with minute traces of animal lipids. This seems unlikely, however, as cholesterol is a minor component in animal adipose lipids in comparison to alkanolic acids. Had there been mammal lipids present the C18:0/C16:0-ratio would have been expected to be higher, as is the case with the two last samples. The lipid trace of these two samples contain the C20  $\omega$ -(*o*-alkylphenyl)alkanoic acids but has an *n*-alkanoic acid distribution indicative of terrestrial animal lipids (C18:0/C16:0 >0.48), and could be interpreted as lipid residues from, for example, a liver stew. This would however not explain the presence of the two isoprenoid alkanolic acids. Also, both these samples contain substantial traces of intact triacylglycerols with a wide distribution indicative of milk lipids (Dudd et al., 1999) and an inclusion of milk fat would effect the C18:0/C16:0-ratio towards the terrestrial animal level.

Five out of twenty nine pots with traces of possible fish lipid residues gives a ratio of 0.17, and eight out of twelve individuals with a diet dominated by fish gives a ratio of 0.67. The compositions of the food residues from the ceramic seem ill matched with the bone chemical results.

### 6.2. The cooking and consumption of fish

We know that the people buried in the boat-graves at Tuna had a substantial part of their diet from fish. The results of the lipid residue analysis do not seem to concur with these bone chemical data. As our decomposition experiments have shown lean fish may leave little lipid residues to find why the difference in detectability between the two food signals may be too big for a rational comparison. But there may also be other

Table 2  
Lipid residues with possible traces of fish lipids

Sample	Neutral lipid data					Isoprenoid alkanolic acids			$\omega$ -( <i>o</i> -alkyl-phenyl)-alkanoic acids		
	C18:0/C16:0	Cholesterol	Phytosterol	Plant wax residue	C29–35 mid-chain ketones	4, 8, 12-TMTD	3, 7, 11, 15-TMHD	C16	C18	C20	
A25	0.462	×	nd	×	nd	nd	×	nd	×	nd	
F270	0.348	×	×	nd	nd	nd	nd	nd	nd	nd	
F358b	0.313	×	×	×	×	nd	×	nd	×	nd	
F466	1.20	nd	×	×	nd	×	×	×	×	×	
F470	2.36	×	×	×	×	×	×	×	×	×	

Pure fish lipid residues should have a C18:0/C16:0-ratio <0.48. × = detected, nd = not detected. The C29–35 mid-chain ketones are indicative of lipids being heated in the ceramic, i.e. cooking pots (Evershed et al., 1995).

reasons for the difference connected to the culture of food in the Early Medieval period.

We know nothing of the life history or the life span of the vessels, or of any connection between life span and use. It is therefore not possible to rule out that the meat pots were used occasionally and the fish pots more regularly. If drying was the most common way to preserve fish and if lean fish was preferred for this process it may explain the disagreement between the results from the two techniques. However, it cannot be ruled out that they preferably ate fish in other ways than cooked in a stew, e.g. raw, dried, pickled, cured, fermented, roasted etc. The difference is then a result of the culinary arts of the Early Medieval period.

The difference may also be the result of meal order and customs, including ideas on where and when meals were eaten (Hjulström and Isaksson, 2005). We would expect there to have been several meal companionships, e.g. based on duties, rank, gender, age etc., and it is quite possible that several of these meal companionships consumed most food outside the settlement.

As it has not been possible to excavate the whole site the population from which we took our pottery sample is very far from the total population. The difference between the bone chemical analyses and the lipid residue analyses may therefore be a result of a spatial organisation of subsistence, if fish were primarily handled in an unexcavated part of the settlement. Such spatial divisions have been identified before concerning both storage and preparation of different food products at Early Medieval settlements (Isaksson, 1998, 2003a; Isaksson et al., 2004, 2005). A  $\chi^2$ -test of the difference between of the results from the analyses of potsherds from Oppgården and those from Mellangården show that there is a statistically significant difference in the frequency of possible fish lipid residues ( $\chi^2 = 12.85$ ,  $df = 1$ ,  $p = 0.0003$ ). Of the two parts of the settlement Oppgården seems to start later than Mellangården. A chronological change may therefore be possible. If the two materials are overlapping in time or even contemporary the difference is rather a reflection of the spatial organisation of food at the site. In the material from Mellangården there are lipid residues from terrestrial animals in eighteen out of nineteen potsherds but at Oppgården there are only six out of nine. A  $\chi^2$ -test show that this difference is just statistically significant ( $\chi^2 = 3.93$ ,  $df = 1$ ,  $p = 0.047$ ). If the two areas are part of the same household this may reflect the same spatial division, with the buildings at Mellangården mainly being concerned with the handling of meat and the buildings at Oppgården mainly with fish.

If the two areas represent two different households the result may reflect a difference in social status, i.e. gastronomy — the expression of social hierarchy through food, cooking and eating (Hjulström and Isaksson, 2005). Meat was part of the Early Medieval gastronomy (Isaksson, 2000) and the greater access to animal products at Mellangården may be a signal of a higher social position. In one of the sampled contexts in trench 10 at Mellangården we found a fragment of glass from an imported Frankish drinking-vessel, which must be considered a luxury object connected to eating. If this whole

deposition is the residue from feasting activities and as meat was part of the gastronomy this may have influenced the results, i.e. an overrepresentation of meat pots in the sample. If so these animal lipid residues may be seen as to indicate the location of a feast-hall at Tuna.

## 7. Conclusion

At least at this site we can conclude that pottery-use do not reflect everyday diet and certainly not the sample we have analysed. Food signals from lipid residues only provide circumstantial evidence of diet. Food signals from bone chemical analyses will provide direct evidence of diets, but will on their own provide little evidence of other food cultural aspects. If not the result of a difference in detectability between the two food signals, fish was preferably prepared and consumed in other ways than cooked in a pot, e.g. eaten raw, dried, pickled, cured, fermented or roasted, at the Early Medieval manor site Tuna.

We do not believe that this site is more complicated than any other. It is rather this integrated approach, including the application of several analytical techniques, contextual considerations both for the selection of sampling strategies and analyses, and for the interpretations of data, that complicate things. We hope this paper has shown that this complexity is to be traced to the prehistoric culture of food and that the integrated approach is a fruitful way to begin to try and understand prehistoric food cultures.

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