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Faculty of Humanities
School of History, Culture and Arts Studies
Archaeology
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Supervised by

Docent Henrik Asplund
University of Turku

Professor Richard Evershed
University of Bristol

Professor Bjørnar Olsen
UiT The Arctic University of Norway

Reviewed by

Professor Kerstin Lidén
Stockholm University

Associate Professor Ester Oras
University of Tartu

Opponent

Professor Kerstin Lidén
Stockholm University

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ABSTRACT

During the prehistoric period, groups in the northern areas used unglazed ceramic vessels to store and prepare their food. This action left both visible and invisible residues on the walls of the ceramic vessels used. The current multidisciplinary study focuses on the invisible organic residues absorbed in the walls of ceramic vessels and uses organic chemistry methodology to study the changes that occurred in prehistoric food procurement patterns.

To detect changes in the food culture, organic residues from archaeological pottery from Finland and North Norway are studied. To create reference values from Finland and the Baltic Sea, compound-specific stable carbon isotope values for the palmitic and stearic acids from modern mammalian tissue, ruminant milk, and fish are presented.

Hunting and gathering was undertaken during the Comb Ware period in South Finland. In this study, the first evidence of dairy farming was found from Corded Ware vessels. Agriculture was less common during the Kiukainen Ware period, as residues of dairy fats were found only from one Kiukainen Ware vessel. Based on the results obtained for this thesis, agriculture intensified again during the Early Metal Period, as nearly half of the studied Morby vessels were found to have been used for storing or processing dairy products. Even after agricultural practises arrived in Finland, hunting and gathering remained still an important part of the food procurement cycle.

During the Early Metal Period, groups using Risvik Pottery in North Norway were practising farming, but also utilising the marine environment as a food source. The hunter-gatherer groups in the coastal areas of the Norwegian Sea also based their diet mainly on fish and marine mammals. The groups inland in North Norway and Finland, however, had a more diverse food procurement pattern that consisted of terrestrial animals and fresh water fish.

Together with the previous knowledge, the findings presented in this thesis shed more light on the food procurement patterns of the prehistoric groups that were living in the North.

KEYWORDS: pottery, lipids, prehistory, gas chromatography, mass spectrometry, compound-specific stable carbon isotopes

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TIIVISTELMÄ

Ruoan valmistus ja säilytys lasittamattomassa keramiikka-astiassa jättää astian pintaan sekä näkyviä että näkymättömiä jälkiä. Tässä väitöskirjassa selvitetään orgaanisen kemian metodeja apuna käyttäen esihistoriallisten keramiikka-astioiden seinämiin imeytyneitä orgaanisia jäänteitä. Ruokakulttuurin muutosta selvitetään tutkimalla Etelä- ja Pohjois-Suomesta sekä Pohjois-Norjasta arkeologisilta kaivauksilta löytynyttä esihistoriallista keramiikkaa. Lisäksi tässä tutkimuksessa selvitetään Suomesta ja Itämerestä peräisin olevien nisäkkäiden, maidon ja kalojen palmitiini- ja steariinihappojen yhdistekohtaisten hiilen stabiilien isotooppien arvoja. Näitä arvoja voidaan tulevaisuudessa käyttää verrokkiaineistona tutkittaessa arkeologisen materiaalin isotooppiarvoja.

Kampakeraamisena aikana ravinto hankittiin metsästämällä ja keräilemällä. Tässä tutkimuksessa varhaisimmat todisteet maitotaloudesta Etelä-Suomessa löytyvät nuorakeraamisista astioista. Kiukaisten kulttuurin aikaan maatalous ei ollut yhtä yleistä kuin nuorakeraamisena aikana. On kuitenkin todennäköistä, että maataloutta harjoitettiin Etelä-Suomessa pienimuotoisesti myös Kiukaisten kulttuurin aikana. Tutkituista Morbyn kulttuurin astioista lähes joka toisesta löydettiin merkkejä maitotuotteiden käsittelystä tai säilytyksestä. Tämän perusteella voidaan todeta, että varhaismetallikauden aikana maatalous yleistyi Etelä-Suomessa uudelleen.

Pohjois-Norjassa varhaismetallikaudella Risvik-keramiikkaa käyttävät ryhmät harjoittivat maataloutta, mutta samanaikaisesti merenelävien osuus ruokavaliosta oli merkittävä. Myös Norjan rannikolla elävät metsästäjä-keräilijäyhteisöt hyödynsivät merenantimia suurissa määrin. Pohjois-Norjan ja Pohjois-Suomen sisämaassa asuvat ryhmät puolestaan käyttivät ravintonaan maanisäkkäitä ja makeanveden kalaa.

Väitöskirjassa esitetyt tulokset, yhdessä aiemman arkeologisen materiaalin tulkinnan kanssa, lisäävät ymmärrystämme pohjoisten alueiden esihistoriallisista ruonhankintatavoista.

ASIASANAT: keramiikka, lipidit, esihistoria, kaasukromatografia, massaspektrometria, hiilen yhdistekohtaiset stabiilit isotoopit

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July 2023

Mirva Pääkkönen

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List of Original Publications and Author Contributions

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Pääkkönen, M, Evershed, RP, Asplund H. Compound-specific stable carbon isotope values of fatty acids in modern aquatic and terrestrial animals from the Baltic Sea and Finland as an aid to interpretations of the origins of organic residues preserved in archaeological pottery. *Journal of Nordic Archaeological Science*, 2020; 19: 3–19.

II Pääkkönen, M, Bläuer A, Evershed RP, Asplund, H. Reconstructing food procurement and processing in Early Comb Ware period through organic residues in Early Comb and Jäkärlä Ware pottery. *Fennoscandia Archaeologica*, 2016; 33: 57–75.

III Pääkkönen, M, Holmqvist, E, Bläuer A, Evershed RP, Asplund, H. Diverse economic patterns in the North Baltic Sea region in the Late Neolithic and Early Metal periods. *European Journal of Archaeology*, 2020; 23: 4–21.

IV Pääkkönen M, Bläuer A, Olsen B, Evershed RP, Asplund H. Contrasting patterns of prehistoric human diet and subsistence in northernmost Europe. *Scientific Reports*, 2018; 8: 1–9.

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Author contributions to original publications:

I MP performed analytical work and data analysis. Writing by MP. Commentary by RPE and HA. Conceptualization by MP, RPE, and HA.

II MP performed analytical work and data analysis. Writing by MP and AB. Commentary by RPE and HA. Conceptualization by MP, AB, RPE, and HA.

III MP performed analytical work and data analysis. Writing by MP, EH, and AB. Commentary by RPE and HA. Conceptualization by MP, EH, AB, RPE, and HA.

IV MP performed analytical work and data analysis Writing by MP and AB. Commentary by BO, RPE and HA. Conceptualization by MP, AB, BO, RPE, and HA.

1 Introduction

In most parts of Europe, the Neolithic culture is connected to the arrival of agriculture. In Finnish archaeology, the term ‘Neolithic’ is a chronological term that describes the communities who still were hunter-gatherers, but also used ceramic vessels, whereas the same term elsewhere describes the economy, i.e. cultivation and farming. Sometimes in Finland, the term ‘sub-Neolithic’ is used to describe hunter-gatherer communities with pottery traditions (e.g., Carpelan 1970). In a recent doctoral thesis by Petro Pesonen, Neolithic was defined as ‘*the pottery producing period between Mesolithic and Bronze Age*’ (Pesonen 2021: 15). In this current thesis, a similar approach is taken, and the term ´Neolithic´ is chosen to represent all the Stone Age groups and communities that were using ceramic vessels. Thus, here, the use of the term ‘Neolithic’ takes no stand on whether animal husbandry and cultivation were practised or if the groups were practising hunting and gathering.

It is likely, that before the tradition of making ceramic pots appeared in Finland, vessels made of organic material, such as birch bark, wood, and animal hides were in use. However, there is no surviving archaeological record of the use of such containers (Huurre 1998: 111). Pottery arrived in Finland and North Norway around 5600–5200 cal BC and provided new ways to store and prepare food (Skandfer 2005, 2009: 355–356; Pesonen et al. 2012: 661; Piezonka 2012). More detailed discussion of the arrival of pottery to the study region can be found e.g., in Nordqvist & Mökkönen (2017), Pesonen (2021), and Jørgensen et al. (2023). In this thesis, organic residues, absorbed in the walls of archaeological pottery, are studied from both the Neolithic and the Early Metal Periods. The study area is located in South Finland (Neolithic and Early Metal Period) and North Finland and North Norway (Early Metal Period; see Fig. 1).

1.1 Background of Organic Residue Studies

Lipids are best described via their physical properties rather than their structural composition. They are insoluble in water, but soluble in low-polarity solvents. Both animal and plant tissues contain lipids, i.e., fats, oils, waxes, hormones, and resins. In the current thesis, the focus is on triacylglycerols, which are esters of glycerol and fatty acids. However, in the archaeological context triacylglycerols have typically decayed over the millennia, forming monoacylglycerol, diacylglycerols, or glycerol and free fatty acids. Here ‘organic residue’ is used as a synonym for the lipids found in archaeological potsherds.

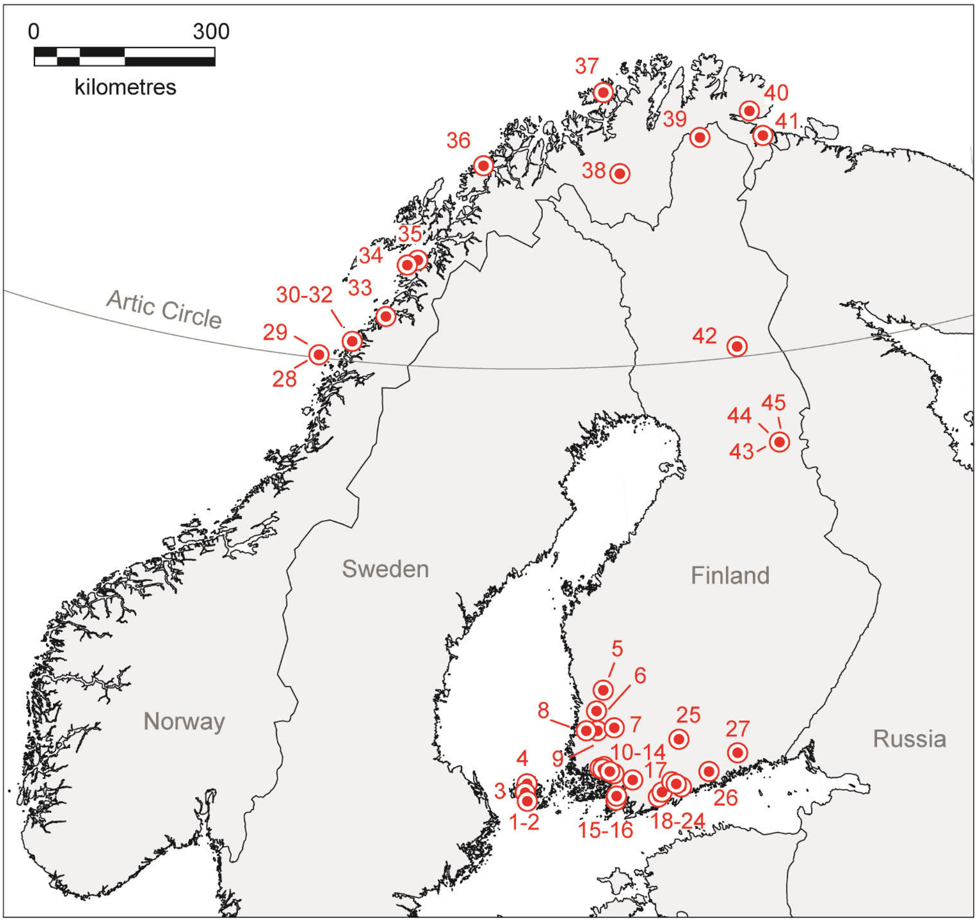

Figure 1. Map of the locations of the finding sites for the studied sherds. Legend for the numbering of the sites are in Tables 2 and 3.

Organic residue analysis is a widely used method in archaeological research. The remains of fats in archaeological vessels have been studied since the 1970’s when the oil content of Mediterranean amphorae was studied using gas chromatography (GC; Condamin et al. 1976). The method has become increasingly popular since the early 1990´s (e.g. Evershed et al. 1990, 1991; Charters et al. 1993). In recent years, several organic residue studies have been conducted in the Baltic Sea area and North

Norway (e.g. Craig et al. 2011; Cramp et al. 2014a; Oras et al. 2017; Papakosta 2020; Dolbunova et al. 2022; Visocka 2022; Jørgensen et al. 2023).

In organic residue analysis, extracted lipid samples are typically first screened with GC in order to gain information on whether ancient fat residues have survived in the ceramic sherd. If a sample is deemed to be suitable for further analysis, it is usually analysed using gas chromatography-mass spectrometry (GC-MS), and the compound-specific stable isotopes of certain fatty acids are measured using a gas chromatography-combustion-isotope ratio mass spectrometer (GC-C-IRMS).

Organic residue analysis is an important tool in Northern areas when tracing the changes in food culture, as the preservation of archaeological bone material is typically poor due to the acidic soils (Kibblewhite et al. 2015). Mainly burnt and highly fragmented bone material is found in Finnish prehistoric sites. Even though the fragmentation rates of the surviving bone material are high, the zooarchaeological assemblages do broadly reflect the regional economies (Ukkonen 2001: 13; Tourunen 2011; Bläuer & Kantanen 2013). Because the bone assemblages are sparse, organic residue analysis can be used to broaden the aspect on how different commodities were used for food.

Due to differing cooking habits, some of the changes in food culture are not visible if only the absorbed residues of archaeological pottery are studied. For example, if smoking or drying of certain foods had been carried out, no signs of these procedures are likely to be visible in the potsherds using organic residue analysis methods. Also, the cooking temperatures might affect the visibility of certain biological marker compounds (biomarkers) used to identify the origins of ancient fats. For example, ω-(*o*-alkylphenyl)alkanoic acids (APAAs), the indicators of cooking aquatic organisms in ceramic vessels, are only formed if the aquatic material is heated to relatively high temperatures, i.e., 200 °C (Matikainen et al. 2003: 568; Hansel et al. 2004; Evershed et al. 2008; Bondetti et al. 2021). Thus, if fish or seal was prepared in lower temperatures, then these biomarkers would not be present in the analysed samples. Biomarkers related to processing of aquatic organisms are discussed in more detail in the next chapter.

All organic matter in the archaeological contexts has degraded in varying degrees (Isaksson 2000: 34). Some lipid-lean foods leave only minor traces of lipids in the walls of ceramic vessels, while other food materials might leave traces that survive the multiple uses of the vessel. It has been reported that five boilings of meat yields *c*. 150 times higher concentration of lipids compared to ten boilings of vegetable leaves (Evershed 2008a: 30). In addition, there might be varying time-depths in a certain lipid residue; however, if the same ceramic vessel has been used several times, then different instance of use of that vessel would leave different lipid residues (Evershed 2008: 35; Isaksson 2009: 134).

The majority of the studied vessels come from archaeological sites located near the Baltic Sea or the Norwegian Sea. The studied inland sites are also located near waterways. Thus, it is likely that both terrestrial and aquatic resources were exploited for food in most of the studied sites. This versatile resource exploitation will be identified as a mixing of terrestrial and aquatic fats in the vessels. If such mixing is not found, that either indicates that the certain vessels were used solely for processing one type of food or that the culture based its food economy strictly on a single resource.

What people ate during the prehistoric period depended not only on the available resources, but also on the cultural traditions (Eriksson & Lidén 2013: 288). When tracing the diet of an individual or a certain group of people, stable isotopes of bones or teeth should be analysed (e.g., Drucker & Bocherens 2004; Larsson 2009: 52; Schwarcz & Schoeninger 2012). However, organic residue analysis can provide information on the economy and culinary practises of a society (Isaksson 2010). Thus, in this thesis, even though the focus is on what kinds of commodities were processed in the ceramic pots, no absolute conclusions on the diet of the studied groups are made.

1.1.1 Biomarkers Applied in This Study

Several different biomarkers have been reported in the literature. As mentioned earlier, all of the studied archaeological sites were located near or in close vicinity to a waterway. Most of the cultures studied here are expected to have used aquatic organisms as part of their food procurement cycle to at least some degree. Thus, in this chapter the biomarkers that indicate the processing of aquatic organisms are discussed.

Fats and oils from fish and seal are reported to contain high abundances of monounsaturated and polyunsaturated long chain fatty acids, such as $C_{16:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, eicosapentaenoic acid ($C_{20:5}$ n-3), and docosahexaenoic acid ($C_{22:6}$ n-3; Ackman 1967; Puustinen et al. 1985; Käkelä et al. 1993; Keinänen et. al. 2017). Unsaturated fatty acids rarely survive in the archaeological context (Evershed et al. 1999). Thus, different compounds have to be used when identifying aquatic fats from surviving organic residues.

In addition to the aquatic biomarkers discussed in this thesis, there are also biomarkers that derive from processing of plants. These biomarkers include hydroxyl fatty acids, dicarboxylic acids, wax esters, long-chain *n*-alkanes, and *n*-alkanols, (see e.g., Cramp et al. 2011; Roffet-Salque et al. 2017). There are also compounds that can be used to detect boiling or roasting (Roffet-Salque et al. 2017). Long-chain ketones, with odd carbon number distributions of $C_{29:0}$ to $C_{35:0}$, are reported to form the pyrolysis of animal fats of acyl lipids and ketonic decarboxylation reactions.

Formation of these long chain ketones occur during the cooking process when the temperature exceeds 300 °C, and thus can indicate heating of food commodities (Evershed et al. 1995; Raven et al. 1997).

It should be noted that the absence of a particular biomarker is not an indicator that certain commodities were not processed in the ceramic vessels, or that they were not included in the human diet. The biomarkers might have decayed over the millennia when the potsherd was buried in the soil, or they might be under the detection limit of the analytical instrumentation.

1.1.1.1 *ω*-(*o*-Alkylphenyl)alkanoic Acids

APAAs (Fig. 2) have been reported as evidence of the processing of aquatic fats in high temperatures (Copley et al. 2004; Hansel et al. 2004; Craig et al. 2007). APAAs have been reported to form in degradation experiments where unsaturated fatty acids mixed in a pottery matrix were heated *in vacuo* at 270 °C for 17 hours (Evershed et al. 2008: 110). They are also known to form when heating methyl linolenoate at 260–270 °C (Matikainen et al. 2003: 567–568). Recently, Bondetti et al. (2021) demonstrated that APAAs will form in much lower temperatures and shorter heating times than previously reported. Heating of pure fatty acids at 200 °C for five hours have been found to result APAAs. It has been reported that APAAs also form when heating rapeseed oil mixed with pottery matrix for one hour at 270 °C. APAA formation has been demonstrated to occur both in laboratory and in simulated cooking over an open fire (Bondetti et al. 2021). In addition to marine organisms, plants contain high concentrations of unsaturated fatty acid C_{18}. The unsaturated long chain fatty acids, C_{20} and C_{22}, on the other hand, are found in low concentrations in plants (Malainey et al. 1999: 88–89; Clapham et al. 2005). Thus, APAAs with carbon lengths C_{20} and C_{22} are not formed when heating plant material (Hansel et al. 2004). However, APAAs with a chain length of C_{20} have been reported to form when heating terrestrial animal tissues (elk, red deer, beaver, and pork; Bondetti et al. 2021). Recently it has been suggested that if the ratio of C_{20}/C_{18} APAAs is above 0.06, then the organic residues originate from aquatic rather than from terrestrial sources (Bondetti et al. 2021). However, as Bondetti et al. (2021) point out, this particular method needs further investigation. Thus, the abundance ratio of C_{20}/C_{18} APAAs was not examined in this thesis.

To summarise, if APAAS with carbon chain lengths of C_{18}, C_{20}, and trace abundances of C_{22} are present in the archaeological sherd, then they can be considered as a sign of the processing of aquatic animal fats in vessel. In addition, at least one of the three isoprenoid fatty acids (IFAs, discussed later) should be present in the sample to verify the origin of fat residues as being aquatic (Hansel et al. 2004; Evershed et al. 2008).

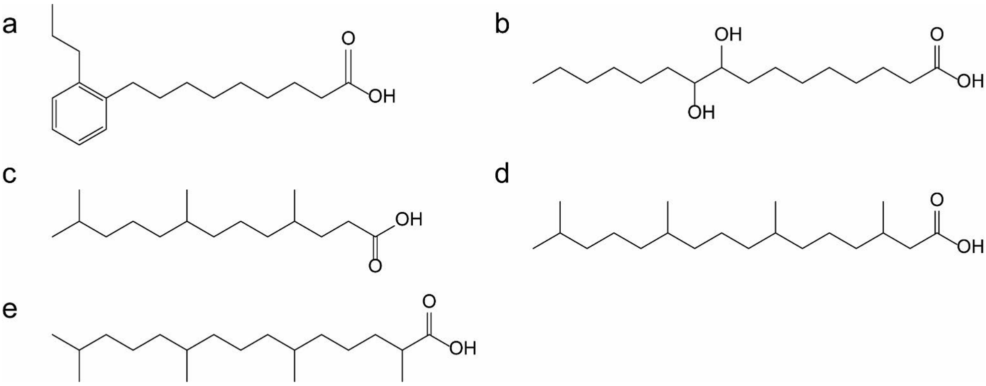

Figure 2. Structures of biomarkers related to the processing of aquatic organisms. (a) Example of ω-*o*-alkylphenyl)alkanoic acid: 9-(2-propylphenyl)nonanoic acid. (b) Example of vicinal dihydroxy acid: 9,10-dihydroxypalmitic acid. (c) Isoprenoid fatty acids TMTD, (d) phytanic acid, and (e) pristanic acid.

APAAs can be detected from examining of the lipid extracts of archaeological samples, processed to form fatty acid methyl esters (FAMEs), by using GC-MS with the selected ion monitoring (SIM) mode for ions with a mass-to-charge ratio (*m/z*) 105, 262, 290, 318, and 346 (see Fig. 14b). However, if APAAs are found in high abundance, they are also visible in the full scan analysis.

1.1.1.2 Dihydroxy Acids

Unsaturated fatty acids are poorly preserved in archaeological pottery (Evershed et al. 1999). Vicinal dihydroxy acids (DHYAs; Fig. 2) are formed when polyunsaturated fatty acids are auto-oxidized to form hydroperoxides (Hansel & Evershed 2009; Cramp & Evershed 2014). As mentioned earlier, unsaturated fatty acids are found in high abundances in fish and seal blubber (e.g. Ackman 1967; Fredheim et al. 1995). Thus, DHYAs with a carbon chain length of C_{16} to C_{22} are typically found in archaeological pottery if fats from an aquatic origin were processed in those vessels (Hansel et al. 2011). It does need to be noted, however, that DHYAs, as APAAs, might also derive from processing plants in the vessels (Copley et al. 2005; Hansel et al. 2011).

Free lipids are typically found from the potsherd after traditional solvent extraction with a chloroform/methanol mixture. However, lipids with a polar functional group, such as a hydroxyl group, form stronger intermolecular bonds with the polar surface of the ceramic matrix (Correa-Ascencio & Evershed 2014). When using solvent extraction, alkaline treatment of the sample is required to release the DHYAs that are bound to the ceramic matrix of the vessel wall, before they can be extracted and analysed (Regert et al. 1998). It has been suggested that when using solvent extraction, the accumulated inorganic salts on the ceramic matrix can interfere with the release of the lipid residues. In direct methanol acid extraction, treatment with a mixture of strong acid might dissolve the inorganic salt deposits and thus release the lipids. When performing direct methanolic acid extraction, however, no additional alkaline treatment is needed in order to extract a polar fraction of the sample (Correa-Ascencio & Evershed 2014).

DHYAs can be detected from the lipid extracts of archaeological samples that are processed to form methyl esters, by using GC-MS with the SIM mode for the ions *m/z* 159, 187, 215, 231, 243, 259, 287, and 315 (Table 1 and Fig. 3).

Table 1. Characteristic ions arising from fragments *a* and *b* of trimethylsilylated fatty acid methyl esters of DHYAs. See also Fig. 3. Data obtained from Hansel et al. (2011)

***m/z* fragment a**	***m/z* fragment b**	**Dihydroxy acid**
215	231	7,8-dihydroxypalmitic acid
187	259	9,10-dihydroxypalmitic acid
159	287	11,12-dihydroxypalmitic acid
215	259	9,10-dihydroxystearic acid
187	287	11,12-dihydroxystearic acid
159	315	13,14-dihydroxystearic acid
243	259	9,10-dihydroxyarachidic acid
215	287	11,12-dihydroxyarachidic acid
187	315	13,14-dihydroxyarachidic acid
243	287	11,12-dihydroxybehenic acid
215	315	13,14-dihydroxybehenic acid

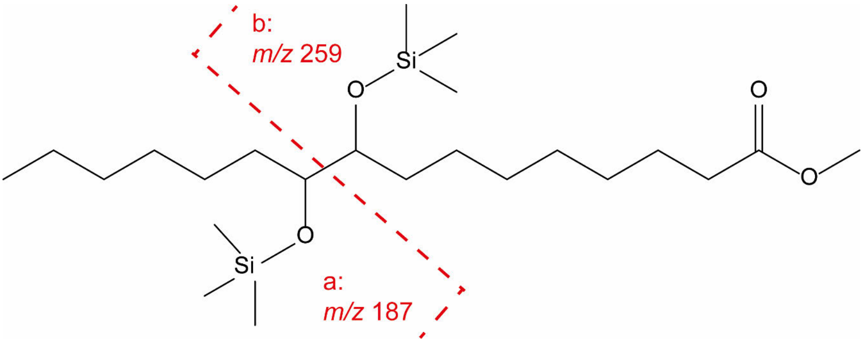

Figure 3. Fragmentation of characteristic ions, *m/z* 187 and *m/z* 259, of trimethylsilylated fatty acid methyl ester of 9,10-dihydroxypalmitic acid. See also Table 1.

1.1.1.3 Isoprenoid Fatty Acids

The IFAs, 4,8,12-trimethyltridecanoic acid (TMTD), phytanic acid, and pristanic acid (Fig. 2), are considered to be aquatic biomarkers, as they are found in marine organisms (Ackman & Hooper 1968). IFAs have been previously reported in pottery recovered from several archaeological sites connected with the processing of aquatic products (e.g. Copley et al. 2004; Hansel et al. 2004; Oras et al. 2017).

In addition to aquatic organism, phytanic acid is found in terrestrial fats, mainly in ruminant carcass and dairy fats. Phytanic acid has different diastereomers (3S,7R,11R,15-phytanic acid and 3R,7R,11R,15-phytanic acid). Due to differences in biosynthesis of phytanic acid from phytol, ratio of these diastereomers differ between aquatic and terrestrial environments, 3S,7R,11R,15-phytanic acid being associated with aquatic organisms. Sufficient separation for the two isomers requires using the SIM mode and polar GC-column (Lucquin et al. 2016; Whelton et al. 2021). IFAs can be identified based on their GC-MS fragmentation patterns.

1.1.2 A Stable Carbon Isotope Proxy

GC-C-IRMS can be used to determine the stable carbon isotope ($\delta^{13}C$) values of palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids obtained from organic residue analysis of archaeological pottery. The compound-specific determination of $\delta^{13}C$ values allows the identification of ruminant adipose tissue, non-ruminant adipose tissue, dairy fats, and fats of aquatic origin (Dudd & Evershed 1998; Copley et al. 2003; Cramp & Evershed 2014).

Differences of the $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ of the ruminant adipose and dairy fats are due to differential routing of dietary carbon. This action enables the identification of dairy fats from ruminant carcass fats by calculating $\Delta^{13}C$ ($=\delta^{13}C_{18:0}-\delta^{13}C_{16:0}$) values and using them to identify the source of the ancient fat residues (Dudd & Evershed 1998; Dunne et al. 2012). Freshwater organisms, on the other hand, can be identified because of their more depleted $\delta^{13}C$ values than those of terrestrial animals. In addition, the fats of marine organisms are more enriched in stable carbon isotope values compared to fats of terrestrial animals (Cramp & Evershed 2014: 325–326).

1.2 Background of the Studied Archaeological Periods

Archaeological cultures often consists of artefact types and other cultural heritage material that originate from several different locations (Lang 2020: 122). Many archaeological cultures have been named after stylistic features of the pottery they used (Damm 2012). Good examples of this are Comb Ware culture and Corded Ware culture, both also studied in this thesis. Often pottery is the main, and in some cases the only, feature that is used to define an archaeological culture (Lang 2020: 147) However, the archaeological artefact types are very heterogeneous. Material culture is created by humans who have varying cultural practises. Thus, the archaeological record can be divergent (Nordqvist & Häkälä 2014: 20). In pottery, for example, the temper or style of decoration may vary within one pottery style depending on what was locally available (Damm 2012: 45).

The way how pottery was produced, the used clay and temper, and how pots are decorated can give information on the social networks between different prehistoric groups. Two groups using pots with similar characteristics may have had closer contacts with each other compared to their interactions with groups using different types of pottery (Lang 2020: 146–147). In this thesis, it is acknowledged that pottery styles do not necessarily represent archaeological cultures. However, in Finnish archaeological literature, cultures and ceramic periods are often treated as one (for critical discussion see e.g. Mökkönen 2011). In this thesis, due to simplicity, ceramic-based naming of the archaeological cultures is used.

Both in Finland and in Norway, ceramic tradition preceded agriculture. The earliest pottery types from two different ceramic traditions, Säräisniemi 1 Ware (Sär 1, also known as Early Neolithic Comb Ware, 5190–4455 cal BC) and Early Comb Ware (also known as Sperrings Ware), appeared nearly simultaneously in the study area. Early Comb Ware pottery can be divided into two phases: older Early Comb Ware (KaI:1, Sperrings 1 Ware, 5155–4335 cal BC) and younger Early Comb Ware (KaI:2, Sperrings 2 Ware, 4510–4225 cal BC; Fig. 4.). Sär 1 Ware appeared around 5400 BC in easternmost Finnmark, Northwest Russia, and North Finland (Skandfer 2005, 2009; Pesonen 2021: 16). In Finland, Sär 1 Ware has mainly been recovered from the Lake Oulujärvi region, Kainuu, and Lapland (Torvinen 2000). The main period of Sär 1 Ware in the northern areas has been dated between 5400–4500 BC and might extend until 4100 BC. In Finnmark, and possibly in North Finland, the pottery tradition ceased after Sär 1 Ware around 4500–4100 BC. Pottery came into use again around 2000–1500 BC when asbestos-tempered pottery emerged in the northern areas (Skandfer 2005: 5–6, 2009: 347, 357–358, 368). In South Finland, the tradition of using ceramic vessels continued without any breaks. More detailed information on the chronology of different archaeological pottery types in Finland can be found in Nordqvist (2018: 58) and Pesonen (2021: 16).

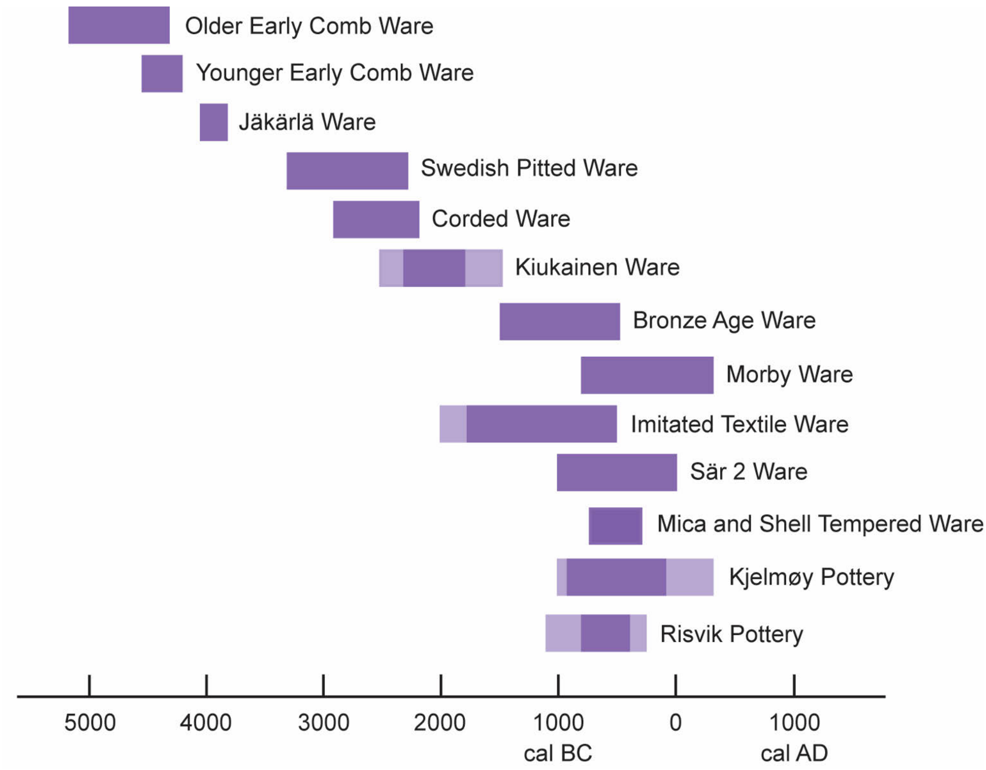

Figure 4. Timeframes for pottery styles from Finland and North Norway studied in this thesis. Datings taken from Hansen & Olsen (2014), Arntzen (2015), Halinen (2015), Lavento (2015), and Pesonen (2021).

1.2.1 South Finland during the Neolithic and Early Metal Period

Traditionally, the Comb Ware culture economy is considered to have been based on fishing, hunting, and gathering, as direct evidence of agriculture is missing (Zvelebil 1981). The zooarchaeological material found from the Comb Ware culture sites supports this view. Typical animal bone material from the Comb Ware sites indicates that different seals (grey seal, harp seal, and ringed seal, *Halichoerus grypus*, *Phoca groenlandica*, and *Phoca hispida* respectively) were the most common game animals in the coastal sites. However, seal bones have also been found in great quantities at inland sites. In addition, large herbivores, such as Eurasian elk (*Alces alces*) and wild forest reindeer (*Rangifer tarandus fennicus*), have been hunted alongside small game animals, such as the European beaver (*Castor fiber*) and mountain hare (*Lepus timidus*). Bones of various fur-bearing omnivores and carnivores have also been discovered at the Comb Ware dwelling sites (Ukkonen 1993: 257). When reindeer (*Rangifer tarandus*) and wild forest reindeer are discussed in this thesis, no assumption is made as to whether those reindeer originally came from domesticated or wild animal stock.

Jäkärlä Ware, a variant of Comb Ware, is typically found only in South-West Finland (Edgren 1966: 15, 1993: 46; Asplund 1995: 69). The Jäkärlä Ware has been dated to 4030–3830 cal BC (Pesonen & Oinonen 2019: 261). Groups with Jäkärlä Ware are believed to have had differing cultural practises compared to the Early Comb Ware groups. Some of the stone tools found from sites with Jäkärlä Ware do differ from those recovered from other contemporaneous dwelling sites (Halinen 2015: 111; Pesonen & Oinonen 2019: 247). Jäkärlä Ware is considered to partially simultaneous with Typical Comb Ware (3800–3545 cal BC; Pesonen 2021: 90). Despite that slightly overlapping dating of these cultures, it appears that there are no ceramic vessels that are hybrids of the Jäkärlä Ware and Typical Comb Ware (Edgren 1966: 149; Asplund 1997a: 84). In addition, no indication of any connections between these two groups have been found in the archaeological record (Halinen 2015: 111).

In recent years, several publications have discussed the arrival of cereal cultivation to Finland. Cultivation in Finland has been suggested to begin during the Early Neolithic period (ca. 5300–4000 BC) or as late as Early Iron Age (ca. 500 AD; Alenius et al. 2013; Lahtinen & Rowley-Conwy 2013). However, arrival of agriculture is often linked to the Corded Ware Culture (2900–2200 cal BC). During the final stages of the Stone Age, the Corded Ware vessel tradition spread to South and South-West Finland. The arrival of Corded Ware in Finland is linked to the larger Corded Ware/Battle Axe Culture phenomenon in Europe (Halinen 2015: 56). Groups with Corded Ware have been reported to practise animal husbandry, and residues of dairy fats have been found in Finnish Corded Ware vessels (Cramp et al. 2014a). In addition to dairy fats, other indications of domesticated animals have been found from the Corded Ware period, as remains of goat hair has been recovered from a burial site (Ahola et al. 2018).

Even though there are indications of domesticated animals, the remains of cultivated plants are yet to be found from the Corded Ware sites in mainland Finland (Vanhanen et al. 2019). It has been suggested, however, that the Late Mesolithic groups adopted farming from their Eastern cultural contacts (Pesonen & Leskinen 2009: 299). The Corded Ware culture in Finland had strong contacts with other Corded Ware groups in the Baltic Sea area (Holmqvist et al. 2018). These strong contacts could have created the need and the necessary knowledge to carry out early agrarian practises in South Finland.

Kiukainen Ware (2500/2300–1800/1500 cal BC) and Swedish Pitted Ware (3300–2300 cal BC) are also part of the Late Neolithic cultural landscape in South Finland. In Finland, Swedish Pitted Ware vessels are mainly found on the Åland Islands (Halinen 2015: 56–57; Vanhanen 2019: 60). In general, terrestrial animals are not believed to have been a major part of the diet of groups using Swedish Pitted Ware (Eriksson et al. 2008; Fornander et al. 2008: 293). An indication of this circumstance can be found in the remaining bone material, and based on the zooarchaeological data, the Swedish Pitted Ware groups on the Åland Islands based their diet and subsistence heavily on marine resources (Storå 2000: 73). Still, cereal grains have been found on the Swedish Pitted Ware sites both from Sweden and the Åland Islands, thus indicating that the groups with Swedish Pitted Ware were practising cultivation on a small scale (Vanhanen et al. 2019).

There are also some indications of animal husbandry and cereal cultivation occurring during the Kiukainen period. A bone of either sheep or goat (*Ovis aries*/*Capra hircus*) from a Kiukainen settlement site at Pietarsaari has been radiocarbon-dated to this period (2200–1950 cal BC; Bläuer & Kantanen 2013: 1649). Two cattle (*Bos taurus*) bones, a sheep bone, and a pig (*Sus scrofa*) bone recovered from the Åland Islands have been radiocarbon-dated to the Late Neolithic, contemporaneous to the Kiukainen Culture (Storå 2000). Cereal grains have been found at the Turku Niuskala site. Grains are found in large number and from several excavation areas, up to 76 grain remains have been found from the Turku Niuskala site (Lempiäinen-Avci et al. Manuscript). One of these grains has been reported to date to the very end of the Neolithic period or the Early Bronze Age (1900–1000 cal BC; Pihlman & Seppä-Heikka 1985; Vuorela & Lempiäinen 1988; Asplund et al. 1989; Asplund 2008: 292). However, more recent radiocarbon datings indicate that *Hordeum* was cultivated already in the Late Neolithic period (Lempiäinen-Avci et al. Manuscript). In addition, cereal pollen evidence indicates that cereal cultivation was carried out during this period (Vuorela 1999: 146–147; Asplund 2008: 190).

In the coastal Bronze Age (1500–500 cal BC) agriculture becomes more common. Bones of cattle, sheep, and horse (*Equus caballus*) have been radiocarbon dated to that period. Of these, horse and cattle are the oldest radiocarbon-dated bones from these species in Finland (Bläuer & Kantanen 2013). In addition, cereal grains have been found at several Bronze Age settlement sites (Turku Niuskala, Laihia Alatalo, Laihia Palomäki, Eura Luistari, and Eura Kauttua; Pihlman & Seppä-Heikka 1985; Vuorela & Lempiäinen 1988; Asplund et al. 1989; Asplund 2008: 292; Holmblad 2010: 135; Uotila 2014; Vanhanen & Koivisto 2015; Lempiäinen et al. 2020).

Early Metal Period pottery, Morby Ware (800 cal BC–300 cal AD), has mainly been recovered from the southern part of Finland (Uusimaa, Varsinais-Suomi, Satakunta, and South Ostrobothnia; Raninen & Wessman 2015: 223). During the Morby Ware period, agricultural practises are believed to have been more common than during the previous cultural periods. Previous investigations of organic residues revealed dairy fat in one Morby vessel from Espoo Bolarskog I (Cramp et al. 2014a: 6). In addition, evidence of managing fields with fire and cultivation using ard-ploughing and manuring have been discovered in South-West Finland during the same period as Morby Ware was in use (Vanhanen & Koivisto 2015).

1.2.2 Early Metal Period in North Norway and North Finland

At around 2000 BC hunter-gatherer groups in the North Scandinavia and Kola Peninsula started preparing pottery vessels made by mixing asbestos fibres with clay (Hansen & Olsen 2022: 54). During the Stone Age, groups in the interior of North Fennoscandia had a mobile hunter-gatherer lifestyle (Halinen 2005). However, groups settling in the coastal areas of North Norway and the Kola Peninsula were practising a nearly sedentary lifestyle at the end of the Stone Age (Olsen 1994: 60–76; Hodgetts 2010; Sjögren & Damm 2019).

During the Early Metal Period (1800–1 BC), the Fennoscandian cultural landscape differentiated (Sjögren & Arntzen 2013; Arntzen 2015; Bergman & Hörnberg 2015; Sjögren & Damm 2019). Communities along the Gulf of Bothnia and the west coast of North Norway became orientated more toward an agricultural way of life and sought cultural contacts from South Scandinavia. Around 1000 BC the asbestos-tempered pottery in North Scandinavia differentiated into two distinct styles: Risvik (1100–270 BC, main period 800–400 BC) and Kjelmøy (1000 BC–300 AD, main period 900–100 BC) pottery. Sites with Risvik pottery are found to be distributed on the northwest parts of the Norwegian coast, whereas the sites with Kjelmøy pottery are mainly located in the interior and northeastern Fennoscandia (Jørgensen & Olsen 1988; Andreassen 2002: 19; Hansen & Olsen 2022: 54). Risvik pottery is connected with the coastal communities and is found only in Norway. Groups in the interior and northeastern areas of Norway and Finland still continued practising hunting and gathering. In contrast to the coastal dwellers, these groups also became more involved with the Eastern and Central Russian metal-producing exchange network. Kjelmøy pottery is connected with these hunter-gatherer communities (Hansen & Olsen 2014:40, 2022: 56; Lavento 2015: 205). Mica and shell -tempered pottery, found in Northeast Norway, has stylistic and chronological similarities with Kjelmøy pottery (Jørgensen & Olsen 1987: 17).

Studied vessels from Finland represent various types of a more heterogeneous group of Säräisniemi 2 (Sär 2, 1000–1 BC) pottery. In the Finnish archaeological tradition, Kjelmøy pottery is considered to be one of the sub-groups of Sär 2 pottery. Other sub-groups are Sirnihta, Luukonsaari, and Anttila pottery. Contrary to other Sär 2 pottery groups, Anttila pottery is non-asbestos-tempered (Lavento & Hornytzkyj 1996: 48). Imitated Textile Ware (IT, 2000/1800–500 BC) also belongs to the Early Metal Period tradition of tempering pottery with asbestos, and is known found in most parts of North Fennoscandia (Gjessing 1942: 275; Carpelan 1970: 29; Jørgensen & Olsen 1987: 16; Lavento 2001; Arntzen 2015).

1.3 Objectives and Scopes

This thesis focuses on the changes in the food culture in South Finland that occurred from the Neolithic to the Early Metal Period. Additionally, food culture is studied in North Finland and North Norway during the Early Metal Period. The aim of this thesis is to study animal-based subsistence of prehistoric groups living in the northern areas by studying ancient lipid residues found in the archaeological pottery in tandem with comparing those results to zooarchaeological material. The goal of this thesis is to detect possible changes in the food culture and compare the food procurement patterns of different cultures and different time periods in Finland and North Norway.

The focus is on the lipids absorbed in the walls of unglazed archaeological pottery. Even though deposits of carbonised food crust were found from some of the sherds, composition of food crusts are not studied in this thesis. The focus is on food procurement patterns of prehistoric groups, so only compounds related to food production or food processing are included. Thus, even though residues of pine tar resins were found in some of the studied archaeological potsherds, these are not shown or discussed in this thesis.

The results of the organic residue analysis of pottery from South Finland have previously been published by other researchers, including Cramp et al. (2014a) and Papakosta & Pesonen (2019). However, the number of studied sherds has been relatively low, 70 and 22, respectively. Recently Jørgensen et al. (2023) published new organic residue analysis results from North Norwegian pottery. However, article **IV** is the first publication where organic residues from North Finland and North Norway have been studied.

One of the main goals of this thesis was to collect and create information of modern reference fats obtained from Finland and the Baltic Sea. The Baltic Sea played an important part in providing food even during historical periods (e.g. Mannermaa 2016). Thus, it is important to have local reference values from the study area. Stable carbon isotope values of modern fats are used as a reference when identifying the origin of the archaeological fat residues. It was also essential to obtain modern local reference material, as local ecological conditions might have caused animals to seek specialised diets. Recently, a study covering the modern reference material of 42 fish and terrestrial mammals from Estonia and the Baltic Sea was published (Courel et al. 2020). However, prior to this study, this kind of reference material from Finland or the Baltic Sea region on a larger scale had never been studied.

1.4 Dissertation Structure

The scientific approach taken in this thesis is multidisciplinary, using archaeological material and methods of organic chemistry. The main theme throughout is to note and describe the results obtained from organic residues of archaeological pottery. The studied modern reference animal material and archaeological ceramic material is presented first. Then the methods will be discussed. Next, discussion of the results of the four articles, on which this thesis is based, will be presented. The articles are not presented in chronological order, but rather in the order that shows how each article creates a foundation for the next. The results from modern reference fats will be presented first. Then, results from the study of organic residue analysis of archaeological pottery are discussed. Results obtained from the archaeological pottery will be presented in chronological and regional order, so that the results from the Comb Ware from South Finland are presented first, and the results from the Early Metal Period from Norway and North Finland are discussed last. This order will create the possibility of clearly understanding the changes in the food culture in the study region during the Neolithic and Early Metal Periods.

Article **I** focuses on the fatty acids of modern reference animal fats, obtained either from muscle tissue, blubber, or from milk, and their carbon isotope composition. The compound-specific stable carbon isotope values presented in Article **I** will be used as the basis of the identification of archaeological animal fat residues in the following articles. Articles **II–IV** focus on the absorbed organic residues found in archaeological pottery. Article **II** focuses on the organic residues of Comb Ware vessels recovered from South Finland. This article aims to identify what the groups that were inhabiting the coastal areas of the Baltic Sea during the Stone Age used as their food source. Article **III** focuses on the Late Stone Age and Early Metal Period ceramics to detect either differences or similarities in the food consumption habits between these cultural periods in South Finland. Article **IV** focuses on the organic residues of Early Metal Period ceramics from the North Norwegian coastal areas and ceramics from inland settlement sites from both North Norway and North Finland. Article **IV** explores the possible differences or similarities between coastal dwellers and the groups that were inhabiting inland settlement sites.

2 Materials and Methods

The material consists of modern ecological reference tissue samples from animals (Article **I**) and archaeological pottery (Articles **II**, **III**, **IV**). In this chapter material and used methods will be described.

2.1 Sampling of Potsherds and Modern Ecological Reference Tissues and Milk

Altogether, 243 potsherds from different ceramic vessels from several cultural phases were studied. The sherds are listed in Appendix 1. The studied pottery types were selected as representative of periods with different food procurement patterns. Comb Ware and Jäkärlä Ware were chosen as traditionally these pottery types are connected to hunter-gatherer groups. Corded Ware, Kiukainen Ware, Bronze Age Ware, and Morby Ware were selected as representative of periods of potential change in food procurement patterns towards agriculture. The pottery from North Norway and North Finland was chosen to represent different subsistence patterns, i.e. early animal husbandry and hunter-gatherer lifestyle, in the northern areas.

The archaeological pottery was acquired from the archaeological collections of the University of Turku, the Satakunta Museum, the Finnish Heritage Agency, the Arctic University Museum of Norway, and the Åland Museum. Archaeological potsherds were collected so that, if possible, rim sherds were chosen for the study, as the top parts of archaeological vessels yield higher lipid concentrations than the lower part of these vessels (Charters et al. 1993). However, museums and collections had differing conditions when providing permits for a destructive analysis, wherein a small piece of a sherd was ground into powder. Thus, not all the studied sherds were form the rim of a vessel. In some cases, body sherds were chosen for analysis because rim sherds were considered to be more important to be preserved as intact, as they typically carry more information on the vessel type, than do vessel body sherds. Based on the decision of collection holders, in some cases, permission for destructive analysis was not granted for rim sherds. However, if permission to analyse rim sherds was granted, those rim sherds, or sherds that could be clearly connected to the rim of the vessel were preferred. This process was followed to prevent sampling of the same vessel multiple times, as rim sherds, based on their size and stylistic features, were easier to identify as belonging to specific vessels.

There were several sources where the modern ecological tissue and milk samples were acquired. Fish samples were mainly acquired with help from the Natural Resources Institute Finland and the Archipelago Research Institute (University of Turku). Fish were also collected from recreational fishers or purchased from fishmongers. Samples of wild mammals were gathered from the collections of the Natural Resources Institute Finland, the Zoological Museum of the University of Oulu, and from hunters and a taxidermist. Samples of organic pork and beef were purchased from local supermarkets in Turku during summer 2014. Milk samples were acquired from organic animal farmers.

2.1.1 Modern Ecological Reference Material

The analyses shown in Article **I** are based on modern animal fats that were collected from Finland and from the Baltic Sea. A total of 108 modern muscle tissues and milk samples were studied. Samples were collected, so that fish and game species, which would have been the species most likely used for food in prehistoric times, were collected for the study. Additionally, fatty acids from some animals, such as wolf (*Canis lupus*) or Eurasian lynx (*Lynx lynx*), which were less likely to have been consumed as food, were also studied. All modern animal tissue and milk samples were stored in a freezer (-20 °C) and freeze dried before extraction of the fatty acids.

There are three different pathways of photosynthesis for terrestrial plants: C_3, C_4, and crassulacean acid metabolism. Latter occurs mainly in epiphytes and succulents that grow in very arid regions (Ehleringer & Cerling 2002: 186). C_4 plants are rare in North Europe. Thus, the native vegetation in the study area consists mainly of C_3 plants (Still et al. 2003; Pyankov et al. 2010). Sampling of the modern ecological reference material was aimed toward animals which were have been grown on a pure C_3 diet. If the animals had been fed with C_4 plants, such as maize, that diet could have an effect on the $\delta^{13}C$ values of their fats (Roffet-Salque et al. 2016). To avoid sampling animals fed with modern silage, a sampling of modern reference tissues of domesticated animals was conducted during the summer when those animals were likely freely grazing in their pastures.

The $\delta^{13}C$ values presented in Article **I** were not corrected for post-Industrial Revolution fossil fuel burning, which is constantly affecting atmospheric carbon dioxide causing it to increasingly deplete in ^{13}C. Even though the $\delta^{13}C$ vales are not corrected in Article **I**, in order to match the modern values with the archaeological values, in Articles **II–IV** the values obtained from terrestrial animals and freshwater fish are corrected for the contribution of post-industrial carbon by adding 1.3 ‰ (Friedli et al. 1986). The isotopic value of oceanic carbon is also affected by the decrease in the $^{13}C/^{12}C$-ratio of the atmosphere via the gas exchange at the air-sea interface. Riverine runoff from freshwater bodies to the Baltic Sea has also had an effect on the $\delta^{13}C$ values of the Baltic. Thus, the freshwater reservoir effect can alter the $\delta^{13}C$ values of fish and seals living in the Baltic Sea (e.g. Lougheed et al. 2013; Philippsen 2013). This circumstance creates difficulties when assessing which correction factor to use for the modern fats obtained from the Baltic Sea. Due to the complexity of the carbon cycle of the water bodies (see e.g., Gustafsson et al. 2015), the modern values of brackish reference tissues are not corrected here for either post-Industrial Revolution depletion of $\delta^{13}C$ values or the reservoir effect. When using a $\Delta^{13}C$ proxy, the $\delta^{13}C$ values of the fatty acids $C_{16:0}$ and $C_{18:0}$ are equally affected by the environmental effects, thereby eliminating the need to use any correction factors.

2.1.2 Archaeological Pottery from South Finland and the Åland Islands

In Articles **II** and **III**, the focus is on Early, Middle, and Late Neolithic pottery collected from South Finland and from the Åland Islands (Fig. 1 and Fig. 5). Article **II** focuses on vessels from Southwest Finland dating back to the Early Neolithic Comb Ware and Jäkärlä Ware periods. In Article **II,** a total of 64 potsherds were screened for their fatty acid content and of these, 28 were chosen for further analysis using GC-MS and GC-C-IRMS. Pottery dating to the Early Comb Ware period was collected from the Kokemäki Kraviojankangas and the Pomarkku Myllytörmä/Patakoski sites while the Jäkärlä Ware came from the Turku Jäkärlä site.

In Article **III,** 121 vessels from South Finland and the Åland Islands were studied. Of these 121 vessels, 85 were studied further using biomarker and GC-C-IRMS analysis. Sites studied in Article **III** date back to the Corded Ware period, the Kiukainen Ware period, the Bronze Age, or to the Early Metal Period of Morby Ware. Vessels dating to the Corded Ware Period came from sites in mainland Finland and were gathered from 13 sites. Vessels from the Kiukainen Period were collected from two sites, Kiukainen Uotinmäki and Turku Kotirinne. Only one sherd was studied from the Swedish Pitted Ware gathered from the Saltvik Härdalen 21.11 site. In addition, one of the studied sherds, from the Saltvik Härdalen 21.11 site, had characteristics of both the Kiukainen Ware and the Swedish Pitted Ware. Only two vessels were studied from the Bronze Age, and they came from Eura Kauttua. Vessels from the Morby period came from 13 sites from both the Åland Islands and mainland Finland (Fig. 1, Table 2).

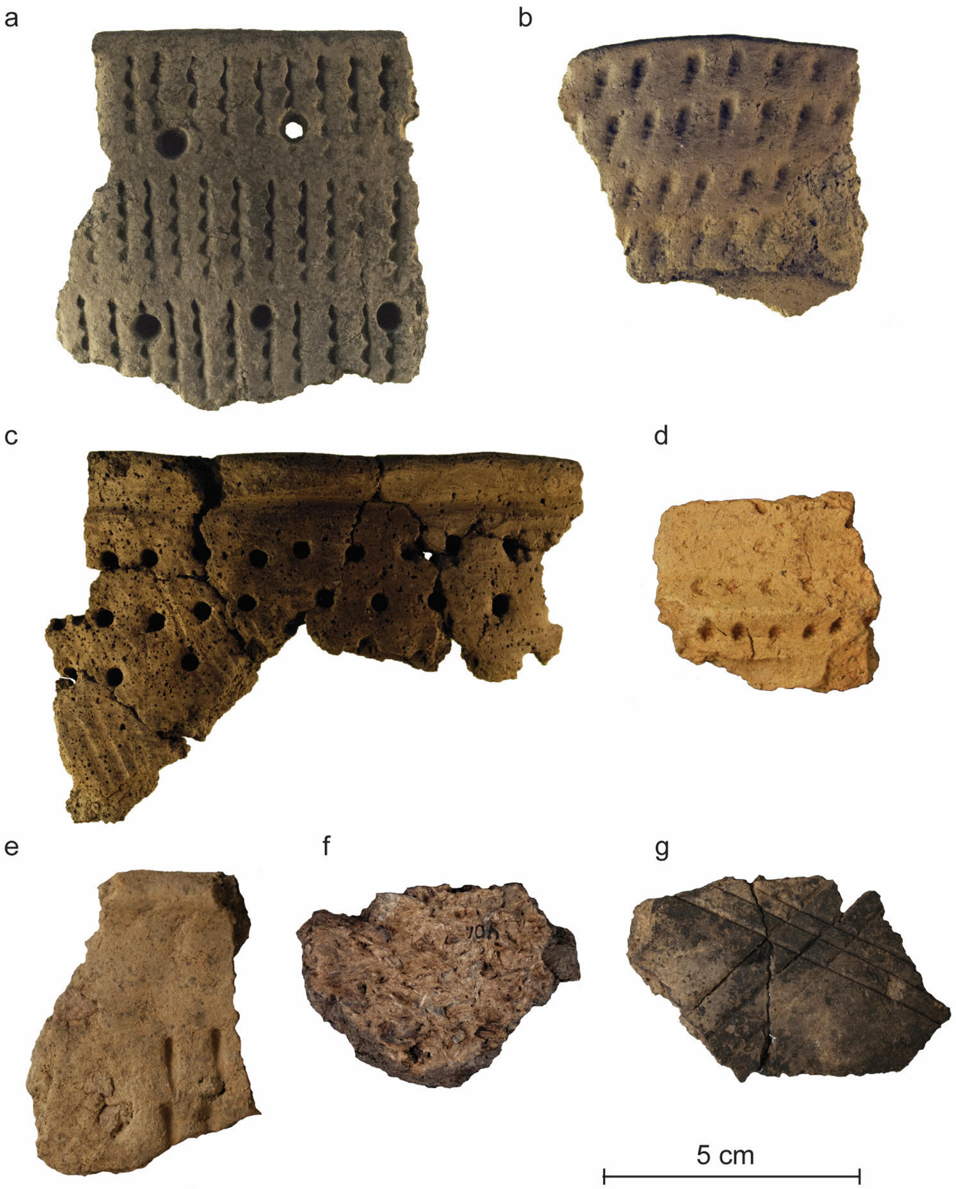

Figure 5. Examples of selected sherds from Finland, the Åland Islands, and North Norway. a) Early Comb Ware sherd (CC3;TYA 116:980; University of Turku), b) Jäkärlä Ware sherd (JAK7; TYA 313:28; University of Turku), c) Kiukainen Ware sherd (LN3; TYA 245:50, 66, 67, 76; University of Turku), d) Corded Ware sherd (CW8; TYA 615:22; University of Turku), d) Morby Ware sherd (LN71; ÅM 652:201; Ålands Museum), f) Risvik Pottery sherd (SÄR25; Ts 4066; the Arctic University Museum of Norway), and g) Kjelmøy Pottery sherd (SÄR1; C21105/291c; the Arctic University Museum of Norway).

Table 2. The number of analysed sherds and the number of sherds with identifiable organic residues gathered from localities in South Finland.

	Number of analysed sherds	Number of sherds with identified lipids	Location on Fig.1
COMB WARE			
Kokemäki Kraviojankangas	32	13	7
Pomarkku Honkakoski	1	0	5
Pomarkku Myllytörmä/Patakoski	13	10	5
JÄKÄRLÄ WARE			
Turku Jäkärlä	18	5	10
CORDED WARE			
Espoo Näkinkylä	2	2	21
Helsinki Malminkartano	1	1	23
Hämeenlinna Hauho Perkiö	3	1	25
Inkoo Ragnvalds Tähtelä	1	0	18
Kirkkonummi Tengo Nyåker	5	5	20
Lapinjärvi Malmbacken Norrby	3	3	27
Piikkiö Isohepojoki Lausmäki	1	0	10
Porvoo Böle Munkby	3	2	26
Salo Märy Halikko	2	0	17
Siuntio Dalamalm	1	0	19
Turku Jäkärlä	5	4	11
Vantaa Jönsas-pohjoinen/itä Kaarela	1	1	24
Västanfjärd Galtarby II	2	2	16
KIUKAINEN WARE			
Kiukainen Uotinmäki	18	14	9
Saltvik Härdalen 21.11	1	1	4
Turku Kotirinne	37	24	12
SWEDISH PITTED WARE			
Saltvik Härdalen 21.11	1	1	4
BRONZE AGE WARE			
Eura Kauttua	2	2	9
MORBY WARE			
Espoo Bolarskog I	9	6	22

	Number of analysed sherds	Number of sherds with identified lipids	Location on Fig.1
Finström Godby	2	1	3
Jomala Dalkarlby	1	1	2
Jomala Överby	1	1	1
Jomala Överby 37.4	10	9	1
Kemiönsaari Kåddböle	1	1	15
Lieto Pahka Pahamäki	1	0	14
Nousiainen Koivumäki	1	0	10
Piikkiö Moisio Moision Alitalo	1	1	13
Rauma Vermuntila Kaiku Kajantalo	1	0	8
Rauma Vermuntila Kallio	2	0	8
Turku Räntämäki Orhinkarsina	1	1	13
Ulvila Suolisto Peltomäki	1	1	6

2.1.3 Archaeological Pottery from North Norway and North Finland

To study the transition from hunter-gatherer community to agrarian community in northern areas, pottery from North Norway and North Finland was also chosen to be part of this study (Article **IV**, Fig. 5). Sherds came from four different ceramic types connected to hunter-gatherer communities. The studied vessels were tempered by either asbestos, mica, talc, soapstone, or shell. A total of 16 Kjelmøy sherds came from sites located in both coastal venues and inland North Norway. Risvik Pottery sherds, connected to early agrarian communities in North Norway were also studied (Table 3). In addition, mica and shell -tempered Ware and IT Ware vessels were studied. The studied Sär 2 Ware sherds came from sites located in inland Finland. All of the studied sites were located in the vicinity of a body of water, either at the ocean coast or along lakes and rivers (Fig. 1).

Table 3. The number of analysed sherds and the number of sherds with identifiable organic residues from localities in North Norway and North Finland.

	Number of analysed sherds	Number of sherds with identified lipids	Location on Fig.1
IMITATED TEXTILE WARE			
Sørøysund Sandbukt Sørøy	3	3	37
Træna Kirkhellaren	1	0	28
KJELMØY POTTERY			
Kautokeino Virdnejávri 106	6	5	38
Nesseby Mortensnes	1	1	40
Sørvaranger Mestersanden	9	9	41
MICA AND SHELL TEMPERED WARE			
Sørvaranger Mestersanden	6	6	41
RISVIK POTTERY			
Bodø Skålbunes	1	1	33
Hamarøy Uteid	1	1	35
Meløy Nedre Valla	1	1	30
Meløy Solheim Mesøy	1	1	31
Meløy Texmoen	1	1	32
Steigen Bø	1	1	34
Træna Kirkhellaren	6	3	28
Træna Røsnesvalen	1	1	29
Tromsø Sandvika	1	0	36
SÄR 2 WARE FROM FINLAND			
Kemijärvi Neitilä 4	2	1	42
Suomussalmi Kalmosärkkä N	9	7	43
Suomussalmi Kalmosärkkä S	2	2	44
Suomussalmi Kellolaisten Tuli	4	1	45
Utsjoki Guatniljärvi	1	1	39

2.2 Methods

Lipids were extracted from archaeological potsherds or from modern reference animal tissue and milk samples. After extraction, the samples were screened using GC. Archaeological samples containing a suitable amount of lipid residues were further analysed using GC-MS and GC-C-IRMS. All modern reference tissue and milk samples were analysed using GC-MS and GC-C-IRMS. All laboratory work was carried out at the Organic Geochemistry Unit at the University of Bristol between the years 2013–2015. In this chapter a summary of used methods is described. More detailed information on the methods can be found in the published Articles **I**–**IV**.

2.2.1 Extraction Techniques

Two different extraction techniques were used in this study: solvent extraction with chloroform/methanol ($CHCl_3$/MeOH, 2:1 *v/v*; Evershed et al. 1994), and direct methanolic acid extraction (Correa-Ascencio & Evershed 2014).

2.2.1.1 Modern Reference Material

The modern reference milk samples were freeze dried, and the muscle tissues were sampled with a scalpel and freeze dried. The tissues were extracted using a direct methanolic acid extraction modified from Correa-Ascencio & Evershed (2014). Briefly, 5 % *v/v* methanolic acid (MeOH/H_2SO_4) solution was added to 0.02 g of the powdered tissue; the samples were then heated at 70 °C for 2 h, and H_2O (double-distilled, dichloromethane extracted) was added to quench the reaction. The supernatant was transferred to a clean culture tube after centrifugation and extracted with *n*-hexane. After blowing down under a stream of N_2, the extract was re-dissolved in *n*-hexane, and an aliquot of the extract was trimethylsilylated with *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) in readiness for the GC, GC-MS, and GC-C-IRMS analyses.

2.2.1.2 Potsherds

Potsherds were cleaned using a modelling drill, and a subsample of 1–2 g was removed from the sherd using a hammer and chisel. The potsherd samples were ground to fine powder using a glass mortar and pestle, and *n*-tetratriacontane was added to each sample as an internal standard.

Two different methods were used to extract the sub-samples of surface-cleaned sherds as follows:

1) Direct methanolic acid extraction (Correa-Ascencio & Evershed 2014). Briefly, MeOH/H_2SO_4 (4 % *v/v)* was added to the powdered sherd, and heated (70 °C, 1 h). H_2O (double-distilled, dichloromethane extracted) was added to the extract. After centrifugation, the supernatant was transferred to a clean culture tube and

extracted using *n*-hexane and dried under a stream of N_2. After the extraction, an aliquot was treated with BSTFA.

2) Solvent extraction (Evershed et al. 1994). Briefly, the extraction was performed by sonicating powdered sherd in $CHCl_3$/MeOH (2:1 *v/v*). Supernatant was collected and the aliquots of the total lipid extracts (TLEs) were filtered and treated with BSTFA prior to the GC analysis. Identification of individual fatty acids was carried out with GC-MS. In order to prepare the FAMEs from the selected sherds, methanolic sodium hydroxide (NaOH, 5 % *v/v*) was added to an aliquot of the sample, and the sample was acidified to pH 3. Boron trifluoride-methanol (BF_3-MeOH) was added, and FAMEs were extracted using $CHCl_3$ and dried under N_2. In order to analyse the DHYAs from the selected solvent extracted potsherds, the previously powdered ceramic fabric was extracted using direct methanolic acid extraction.

All potsherds in Article **II** and the Kiukanen Ware sherds studied in Article **III** were extracted using solvent extraction. All of the sherd samples in Article **IV**, and all but the Kiukainen Ware sherds in Article **III**, were extracted using direct methanolic acid extraction. The extraction method was changed in the middle of the project because the direct methanolic acid extraction was reported to produce a higher concentration of lipids than the traditional solvent extraction. In addition, in the direct methanolic acid extraction, methyl esters are formed during the extraction, and thus, as mentioned earlier, there is no need to perform an alkaline extraction to release the DHYAs bound to the ceramic matrix. However, there are also disadvantages to direct methanolic acid extraction, as the acylglycerols and wax esters are lost (Correa-Ascencio & Evershed 2014).

2.2.2 Analytical Techniques

After extraction, the TLEs or FAMEs were first screened using GC, and identification of the compounds was achieved by comparing the retention times to an external standard. If the lipid extracts contained over 5 μg/g lipids, they were submitted to further analyses using GC-MS, and GC-C-IRMS. It has been reported that due to problems with contamination, lipid concentrations under 5 μg/g cannot be reliably interpreted (Evershed 2008a). Calculated lipid concentrations are shown in Articles **II–IV**. The equation used for calculating concentration is show in Appendix 2.

If screening with GC revealed modern contamination arising from plasticisers, i.e., plastic contamination derived from post-excavation storage of the potsherds, in most cases, those samples were not analysed further with GC-MS or GC-C-IRMS. However, in some cases, especially with Corded Ware pottery, even samples with traces of modern phthalate contamination were chosen for further analysis to obtain a reasonably sized dataset. GC-MS was used to confirm the lipid structures and also to detect possible biomarkers. Identification of the compounds was based on previously published mass spectra and MS database libraries. GC-C-IRMS was used to determine the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids.

2.2.2.1 Gas Chromatography

GC analyses were conducted using Agilent Technologies 7890A GC. Diluted lipid extracts were introduced via on-column injection to DB-1hT (15 m × 0.32 mm i.d., coated with dimethylpolysiloxane, a film thickness of 0.10 µm, Agilent Technologies) column. The peaks were identified by their retention times, and quantification was achieved by referencing the internal standard.

2.2.2.2 Gas Chromatography-Mass Spectrometry

GC-MS analyses of FAMEs were undertaken using a Finnigan Trace MS quadrupole mass spectrometer coupled to a Trace GC (Thermo Finnigan). Diluted samples were introduced onto a non-polar HP-1 column (50 m × 0.32 mm i.d., fused-silica capillary coated with dimethylpolysiloxane, film thickness of 0.17 µm, Agilent Technologies). FAMEs of modern ecological reference fats were separated using the polar VF-23ms column (60 m x 0.32 mm i.d., capillary coated with cyanopropyl polysiloxane, a film thickness of 0.15 µm, Agilent Technologies).

The structural identification of the APAAs was carried out using polar GC-MS (VF-23ms column). Specific ions for APAAs were detected using SIM mode. Identification of the DHYAs was carried out by GC-MS (HP-1 column or RTX-1, 50 m × 0.32 mm i.d. fused-silica capillary column coated with dimethylpolysiloxane, a film thickness of 0.17 µm, Restek). Specific ions for the DHYAs were detected using the SIM mode. Where mass spectra were recorded for GC peaks, these were identified manually or by a library search using Thermo Xcalibur 3.0 software (ThermoFisher Scientific).

2.2.2.3 Gas-Chromatography-Combustion-Isotope Ratio Mass Spectrometry

The carbon isotope compositions of the $C_{16:0}$ and $C_{18:0}$ fatty acids were determined by GC-C-IRMS using an Agilent Technologies 7890A GC coupled to an IsoPrime 100 via an IsoPrime GC5 combustion interface with a CuO and silver wool reactor maintained at 850 °C. Diluted samples were introduced onto a HP-1 column. For modern ecological reference material, either an Agilent Technologies 7890A GC coupled to an IsoPrime 100 via an IsoPrime GC5 or Agilent 6890 GC coupled to a

ThermoFinnigan DeltaPlus XL mass spectrometer via a Finnigan MAT GCCIII interface, with a Cu/Ni reactor maintained at 950 °C, was used. For modern ecological reference material, a polar VF-23ms column was used. Each sample was run as a duplicate.

An external standard was run every four runs, and when necessary every two runs. The external standard consisted of five FAMEs ($C_{11:0}$, $C_{13:0}$, $C_{16:0}$, $C_{21:0}$, and $C_{23:0}$) with known carbon isotope composition (-27.70, -32.26, -30.10, -27.76, and -32.02, respectively). CO_2 was used as the reference gas, and injected into the ion source at the beginning and at the end of each run. The results obtained were calibrated against the used reference gas. Instrument precision was ± 0.3 ‰. The $\delta^{13}C$ values in this thesis are reported relative to the VPDB (Vienna Pee Dee Belemnite) standard. The equation for correcting the $\delta^{13}C$ values for the exogenous carbon added after methylation is shown in Appendix 2.

2.2.3 Statistical Methods

In Article **I**, the Mann-Whitney U-test was used to compare the differences between two groups. The Kruskal-Wallis test was used to compare the differences between more than two groups. The differences were reported using p-values with Bonferroni correction. The level of significance was set at $p \leq 0.05$.

In Article **II**, Spearman’s correlation coefficient (r_s) was used to detect differences between the lipid concentrations, the vessel rim diameter, and the rim type of the studied vessels. The level of significance was set at $p \leq 0.05$. Statistical analyses for Articles **I** and **II** were carried out using SPSS 23.0 software (IBM).

3 Results and Discussion

Results will be scrutinized in the following order: modern ecological reference fats (Article **I**), Comb Ware pottery (Article **II**), Late Neolithic and Early Metal period pottery from South Finland (Article **III**), and Early Metal Period pottery from North Finland and North Norway (Article **IV**). In articles **II** and **III**, the identifications were based on $\delta^{13}C$ values, $\Delta^{13}C$ proxy, and biomarker identifications. In Article **IV**, identifications were carried out using only a $\Delta^{13}C$ proxy and biomarker identifications. To have more uniform representation of the results between the articles, the data presented in Article **IV** is re-evaluated here using $\delta^{13}C$ values, $\Delta^{13}C$ proxy, and biomarker identifications. In addition, after gaining more experience in data evaluation, the intra-observer error is tested, and the data from Article **II** is re-evaluated. Original identifications can be found from Articles **II** and **IV**.

3.1 Modern Ecological Reference Material (I)

Due to the lack of published local modern reference material, it was important here to create comparison data for the Baltic area. Local ecological conditions might create variations in the diet of animals, and thus, affect the $\delta^{13}C$ values of the animal dairy and adipose tissues.

3.1.1 Statistical Analyses of Modern Ecological Reference Material

As the ecological environment of freshwater systems provide conditions where the $\delta^{13}C$ values are more depleted compared to marine ecosystems (Boutton 1991), fish are usually found to be more ^{13}C-depleted in freshwater than they are in brackish environments (Kiljunen et al. 2006). This circumstance was also seen in the material that was studied for this research. Freshwater fish had significantly ($p < 0.01$) more depleted $\delta^{13}C$ values than brackish-water fish and the grey seal sampled from the Baltic Sea.

The $\delta^{13}C$ values of $C_{16:0}$ and the $C_{18:0}$ fatty acids of the freshwater species presented in this thesis were more depleted and significantly different ($p < 0.01$) that those of the marine species (Cramp & Evershed 2014) from the UK. In Article **I**, brackish and marine species (Cramp & Evershed 2014) did not show significant difference in $\delta^{13}C$ values ($p = 0.413$ and $p = 0.097$ for $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$, respectively). Interestingly, fish from the different basins of the Baltic Sea were found to have significantly different $\delta^{13}C$ values for their $C_{16:0}$ and $C_{18:0}$ fatty acids. This circumstance is likely due to the different environmental conditions and salinity gradient of the Baltic Sea, as the more depleted $\delta^{13}C$ values of fish caught in the Sea of Bothnia correlated with the salinity. Salinity is lower in the Sea of Bothnia than in the Finnish Archipelago Sea and the Sea of Åland (DeFaveri et al. 2013: 2533–2534). Other environmental factors also affect the Baltic Sea and the $\delta^{13}C$ values of organisms inhabiting the Baltic. Alkalinity and the dissolved inorganic carbon content of riverine inflow are higher in the eastern parts of the Baltic Sea than they are in the inflow coming from Scandinavia. Thus, the dissolved inorganic carbon and the alkalinity of the Gulf of Finland and the Sea of Bothnia are low (Thomas & Schneider 1999: 57). Primary productivity also has an effect on the stable carbon isotope values of dissolved inorganic carbon (Filipsson et al. 2017). In addition, the Baltic Sea sediments have different $\delta^{13}C$ values, in the coastal areas the $\delta^{13}C$ values are lower than they are in the basin (Voss et al. 2000). These environmental factors will also have an effect on the $\delta^{13}C$ values of organisms living and caught from the different parts of the Baltic Sea.

The $\Delta^{13}C$ proxy is designed to remove ecosystem differences and accentuate metabolic differences between the origins of the fatty acids. Thus, no significant difference was observed in the $\Delta^{13}C$ values of the freshwater fish, brackish species (this study), and the marine species (Cramp & Evershed 2014) from the UK ($p = 0.113$). In Article **I**, it was observed that the wild terrestrial animals (brown bear, *Ursus arctos*; Eurasian beaver, Eurasian lynx, mountain hare, and wild boar, *Sus scrofa ferus*) and aquatic organisms had similar $\Delta^{13}C$ values. Thus, when dealing with ancient fat residues from regions where both terrestrial and fresh and brackish/marine material could have been used for food, it is important not to rely only on the $\Delta^{13}C$ proxy.

The $\Delta^{13}C$ proxy has made it possible to identify ruminant carcass fats from other fats (Copley et al. 2003). Reindeer and wild forest reindeer have a different diet compared to other ruminant animals, as they both eat lichen. In Article **I**, it was noticed that due to that differing diet, adipose tissue samples from *Rangifer* could be identified from other ruminant adipose fats based on their $\delta^{13}C$ values (Fig. 6). This data is in accordance with the previously published $\delta^{13}C$ values of caribou (*Rangifer tarandus*), which also feed on ^{13}C-enriched lichen (Taché & Craig 2015). Thus, Article **I** showed that there are advantages when using local and more versatile modern reference fats, especially where diverse ecosystems are involved. If ancient fats from archaeological pottery are identified via the $\Delta^{13}C$ proxy to derive from ruminant animal, and when dealing with archaeological material from areas with reindeer/wild forest reindeer, the more enriched $\delta^{13}C$ values can reveal when reindeer/wild forest reindeer meat was processed in the clay vessels.

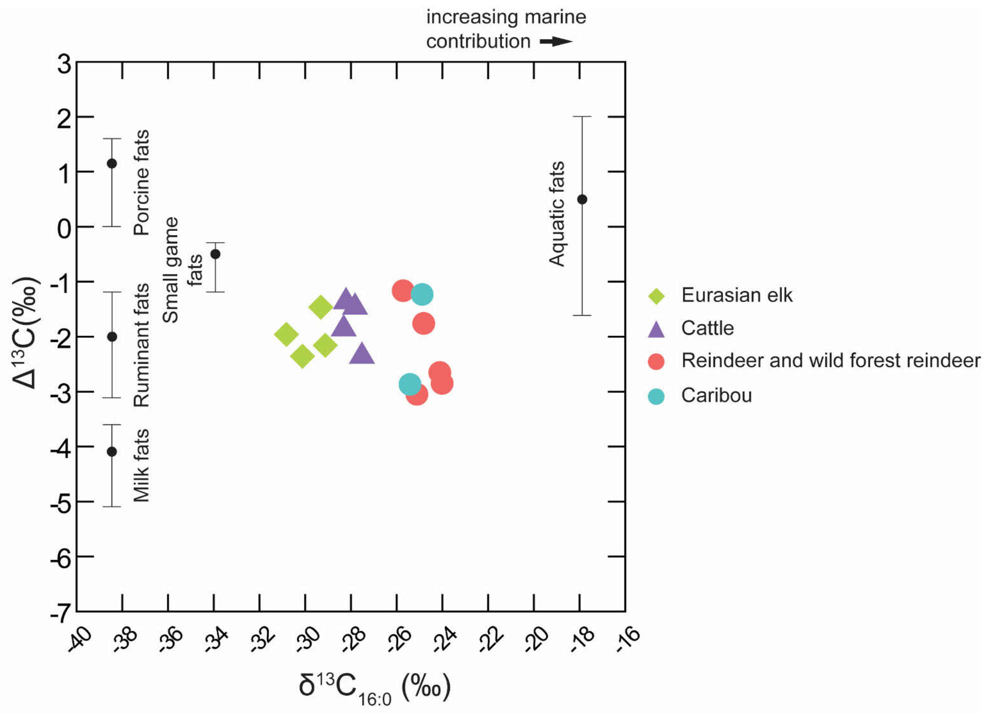

Figure 6. Distribution of the $\delta^{13}C$ values of the fatty acids of the studied modern muscle tissues from reindeer and wild forest reindeer, caribou, Eurasian elk, and cattle. Reindeer and wild forest reindeer can be distinguished from Eurasian elk and cattle based on their $\delta^{13}C$ values. In order to make the data comparable with archaeological fats, the $\delta^{13}C_{16:0}$ values shown in this figure have been corrected for the effects of post-Industrial Revolution fossil fuel burning by an addition of 1.3 ‰ (Friedli et al. 1986). Data for the North American caribou taken from Taché & Craig (2015).

3.1.2 Human Contact of Modern Animals Sampled for Ecological Reference Tissues

Particular caution should be exercised when collecting tissue and milk for use as modern ecological references. While collecting modern reference tissue samples, the most difficult aspect was to find samples from animals without any direct human contact. When comparing modern stable carbon isotope values to archaeological values, it should be noted that the values of modern fats, even from wild animals, are likely to be affected by human impact. Thus, the purity or representativeness of these modern fats requires critical consideration. In Article **I**, it was demonstrated that even wild animals could and were even likely to have had direct human contact by living near human settlements or feeding from carcasses left by humans. Thus, some of the modern ecological reference tissue samples came from animals that had been in contact or were living in the environment modified by humans, so that their environment was isotopically different than the prehistoric ecosystems.

The aim, therefore, was to collect samples from animals that have been grown with pure C_3 diet. As mentioned earlier, if the animals have been fed with C_4 plants, it will have an effect on the $\delta^{13}C$ values of their fats (Roffet-Salque et al. 2016). For example, when collecting material for Article **I**, a farmer claimed that their animals are raised with organic food, even though the farmer did not yet have an official certificate for organic farming. However, in order to lure the animals to be milked for the sampling, they were given bread. This detail clearly demonstrated the importance of having a discussion with the farmers on how the animals were fed. In this case, the animals were fed, at least to some degree, with a diet that was likely atypical for prehistoric animals. It needs to be stressed that stable carbon isotopes of wild animals could also be affected by human contacts. One of the brown bears (M61) studied in Article **I** was shot in an oat field, which makes it likely that this specimen had been living near human settlements for longer time periods.

One studied wolf (MM126) had more depleted $\delta^{13}C$ values than other wolves. It was suspected that this specimen could possibly have been feeding from carcasses left in the forest by humans. Leaving carcasses is a common practise used to lure animals near hide outs where people who are interested in observing or photographing large carnivores can gain close proximity of the animals. The remains of fish guts are a permissible material for use at such carcass sites (Pohja-Mykrä & Kurki 2009: 25–26).

In Finland, the most important prey species for wolves is Eurasian elk. However, wolves have been reported to eat fish in low amounts. Typically, fish forms under 0.5 % of the diet of the wolves (Gade-Jørgensen & Stagegaard 2000: 541). Based on the low abundance of fish in the typical diet of wolves and on the unexpectedly depleted $\delta^{13}C$ values obtained from the tissue sample MM126, in Article **I**, it was found likely that this wolf individual had been feeding regularly on fish guts that were left at a carcass site.

In addition to the challenges related to the sampling of modern fats, it needs to be considered that during prehistoric times, animals could have been foddered or fed differently than in modern periods. For example, in Finland, sheep have been given lichen as winter fodder (Kortesalmi 1975: 370). As shown for the reindeer/wild forest reindeer in Article **I**, consuming lichen alters their adipose fat fatty acid $\delta^{13}C$ values compared to the values that were recorded for other ruminant animals. Another example of unexpected foddering comes from Medieval and Early Modern Iceland, where cattle fodder was supplemented with a range of animal products, including fish, fish offal, and seal fat (Amorosi et al. 2013: 47). It cannot be ruled out that this kind of foddering would not have also been carried out in prehistoric Finland or in North Norway.

3.2 Finnish Neolithic Comb Ware (II)

Altogether 64 sherds from the Early Comb Ware and Jäkärlä Ware period were studied. The results of Early Comb Ware and Jäkärlä Ware vessels presented in Article **II** were re-evaluated. The new interpretations of the origins of organic residues that were surviving in the pottery matrix are presented in this chapter.

3.2.1 Comb Ware and Jäkärlä Ware Vessels and Result Reassessment

Aquatic biomarkers were found from Early Comb Ware and Jäkärlä Ware vessels. However, none of the studied organic residue extracts showed the full range of APAAs with C_{18}–C_{22} chain lengths. The lipid extract of one (4.3 %[1]) Early Comb Ware sherd contained C_{16}–C_{20} APAAs and possibly APAAs with a C_{22} chain length. From Early Comb Ware vessels, taken all together, extracts of 10 (43.5 %) sherds contained either 4,8,12-TMTD, phytanic or pristanic acid. Extracts of seven (30.4 %) vessels contained DHYAs, although in some vessels they were only in low concentrations. In Article **II**, residues of aquatic or possibly aquatic fats were found in 12 (92.3 %) vessels from the Kokemäki Kraviojankangas site. However, after a re-evaluation (see Appendix 1) only nine (69.2 %) vessels from this site were identified as having residues of aquatic or possibly aquatic origin.

After a reassessment of the results from Pomarkku Myllytörmä/Patakoski and Turku Jäkärlä, a similar drop in the abundance of aquatic and possible aquatic residues was observed. In the Pomarkku Myllytörmä/Patakoski site, seven (70.0 %) vessels were previously identified as containing aquatic or possibly aquatic residues, but with the new identifications, only three (30.0 %) of these studied vessels were found to contain aquatic or possibly aquatic fat residues. Thus, the food procurement pattern during the Early Comb Ware period seems to be have been based more on terrestrial resources than previously interpreted in Article **II**.

After re-evaluating the data, the Turku Jäkärlä site also seems to have been more terrestrial than interpreted in Article **II**. In the previously published Jäkärlä Ware results in Article **II**, residues with possible aquatic origin were found from four (80 %) vessels and residues of ruminant fats were identified in one (20.0 %) of the sherds. Based on the new identifications, two (40.0 %) of the sherds previously identified to contain residues of aquatic fats, are now considered to show a mixing

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[1] Percentages are calculated from number of sherds with identified organic residues.

aquatic and terrestrial non-ruminant adipose fats. However, still half of the degraded animal fats obtained from the Early Comb Ware and the Jäkärlä Ware sherds did originate or possibly originated from aquatic sources, or they indicated a mixing of aquatic species, i.e., fish or seal, with non-ruminant terrestrial animal fats (see Fig. 7).

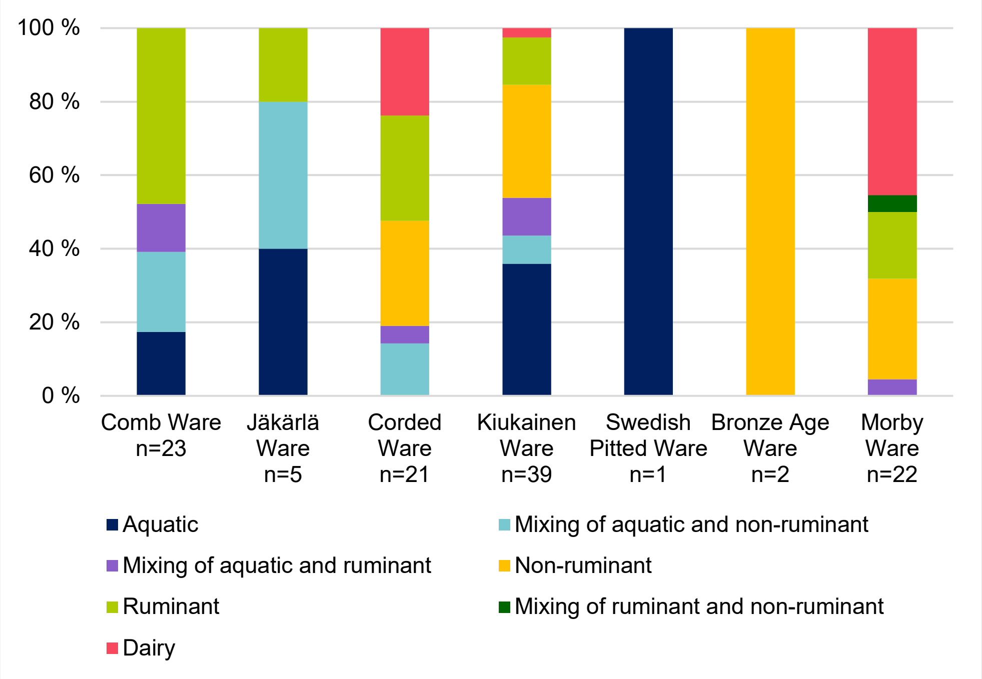


Figure 7. The distribution of organic residues from the sherds collected from Neolithic and Early Metal Period sites located in South Finland. This figure summarises the results from the organic residue analysis, where certain and uncertain identifications are combined to create a more visual and simplified interpretation of the obtained data. More detailed results can be found in Appendix 1.

The zooarchaeological material from the studied sites that are included in Article **II** were found to be typical for Stone Age settlement site fauna. The majority, i.e., 95 % of the identifiable bone material, consisted of seal and fish (Fortelius 1980a; b; Vormisto 1985; Bläuer 2015a; Fig. 8). Based on the organic residue analysis, 54 % of the Early Comb Ware and Jäkärlä Ware vessels with identifiable fatty acid content showed a likely or possible presence of aquatic fats. Thus, the fatty acid content of the studied Early Comb Ware sites indicated slightly more terrestrial diet than did the bone material recovered from the sites. The $\delta^{13}C$ values from the Kraviojankangas site were more enriched than were those from the Myllytörmä/Patakoski site, indicating a greater aquatic origin of fat residues (see Fig. 9). Interestingly, the bones of terrestrial mammals, including the bones of European beaver and possible Eurasian elk bones, were found at the Kraviojankangas site and not the Myllytörmä/Patakoski site. However, it should be noted that the number of identified bones from Myllytörmä/Patakoski is much smaller than the number of identified bones from Kraviojankangas. Due to this difference in the number of identified bone material no definitive conclusions should be made.

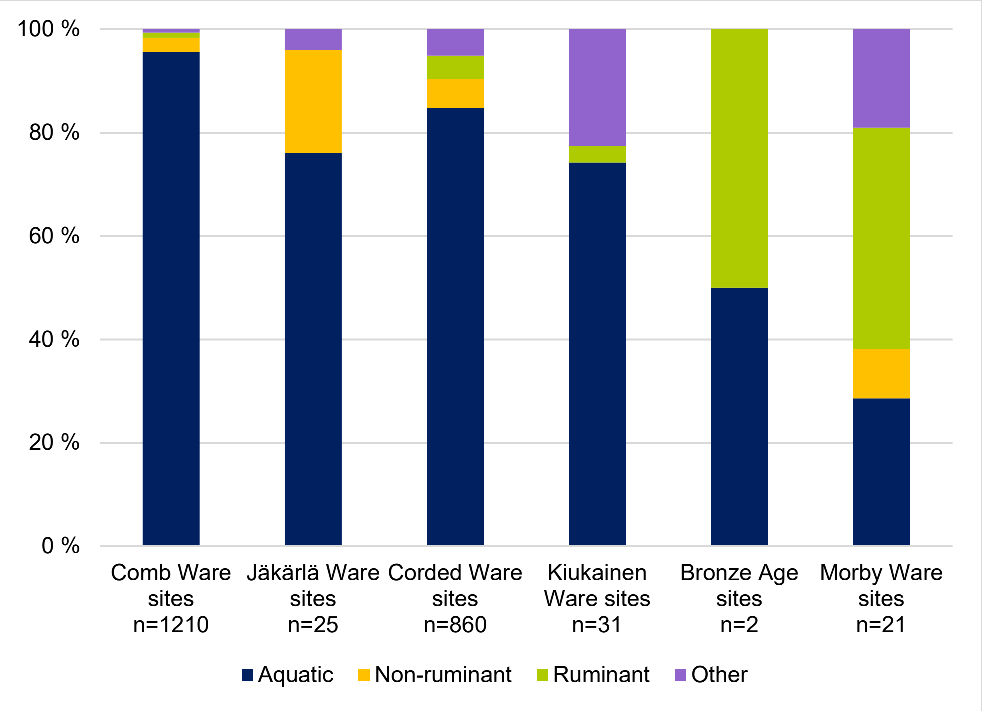


Figure 8. Distribution of identified bone material from studied Neolitichic and Early Metal Period sites in South Finland. Class 'other' includes bones of birds, fur-bearing animals (brown bear, *canidae*, dog, Eurasian otter *Lutra lutra*, pine marten *Martes martes*, red fox *Vulpes vulpes*, wolf), and human (*Homo sapiens*). Percentages are calculated from number of identified specimens (NISP). Osteological analyses have not been carried out for all of the studied sites. More detailed data can be found in Articles **II** and **III**. Data for identified bone material for Comb Ware sites is from Fortelius (1980 a; b). Data for the site with Jäkärlä Ware from Vormisto (1985) and Bläuer (2015). Data for sites with Corded Ware from Fortelius (1980c), Leskinen & Pesonen (2008: 262), Bläuer & Kantanen (2013), Mannermaa (2013), and Bläuer (2015a; b). Data for Kiukainen Ware sites from Ailio (1909: 83) and Bläuer & Kantanen (2013). Data for Bronze Age site from Bläuer & Kantanen (2013). Data for the sites with Morby Ware from Fortelius (1980e), Ukkonen (1996a; 1998), Bläuer & Kantanen (2013), and Bläuer (2015a; b).

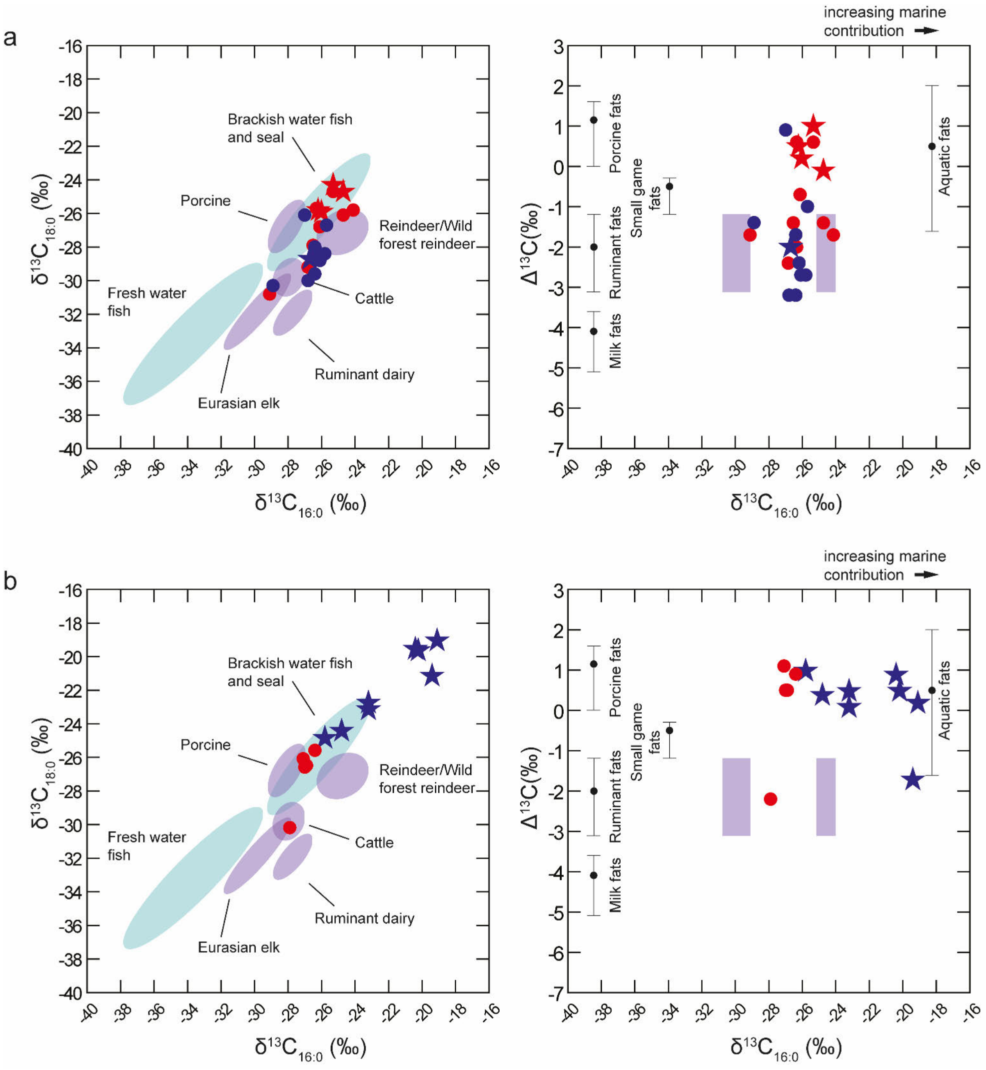


Figure 9. Graphs show the scatter plots of $\delta^{13}C_{16:0}$ values against $\delta^{13}C_{18:0}$ values as well as graphs of the $\Delta^{13}C$ proxy from Early Comb Ware and Jäkärlä sites. (a) Kokemäki Kraviojankangas (red) and Pomarkku Myllytörmä (blue); (b) Turku Jäkärlä (red) and Typical Comp Ware (blue; data from Cramp et al. 2014a). Ellipses in the plots represent a confidence of 68.27 % as derived from the modern reference dataset (Article **I**). The organic residues plotting to the right contain a greater marine component compared to those plotting more to the left. The rectangles represent the $\delta^{13}C_{16:0}$ range of Eurasian elk and reindeer/wild forest reindeer (Article **I**). The star symbols represent organic residues that contained biomarkers of aquatic origin. Modern terrestrial and freshwater fats have been corrected for the contribution of post-Industrial Revolution carbon burning by adding 1.3 ‰ to the values (Friedli et al. 1986).

Differences in the $\delta^{13}C$ and $\Delta^{13}C$ values between the studied Early Comb Ware sites could be explained by the different spatial locations of the sites. The

Myllytörmä/Patakoski site was located on the shore of the Baltic Sea, and Kraviojankangas was located on an island (Alhonen & Huurre 1991: 151, 157). Thus, the location of the Myllytörmä/Patakoski site probably offered easier access for its inhabitants to large terrestrial game species than for the people living on the Kraviojankangas site. The island location of Kraviojankangas offered more effortless access for its inhabitants to be able to exploit the Baltic Sea as their major food source. However, it has to be taken into consideration that the differences in the $\delta^{13}C$ and $\Delta^{13}C$ values between these two sites could be explained by the seasonal sedentism practiced by the Comb Ware people. Thus, the sites could have been in use during different seasons.

Even though aquatic biomarkers, especially APAAs with C_{18}–C_{22} chain length, have previously been reported from other Finnish Early Comb Ware, Jäkärlä Ware, and Typical/Late Comb Ware sites (Cramp et al. 2014a; Papakosta & Pesonen 2019), they were not found in high quantities from the studied Early Comb Ware and Jäkärlä Ware vessels. In addition, the $\Delta^{13}C$ proxy values of the ancient residues from the Typical/Late Comb Ware vessels reported by Cramp et al. (2014a) indicate there was more influence from the Baltic Sea than for the sherds studied in Article **II**. The residues studied by Cramp et al. (2014a) plot more toward the right side of the $\Delta^{13}C$-plot, which can be interpreted as a sign of a greater marine component of the fats processed in the vessel (Copley et al. 2004; Fig. 9). The more enriched $\delta^{13}C$ values from the Typical/Late Comb Ware vessels could be explained if the commodities processed in the vessels would have been caught from the Baltic Sea after the saline water exchange from the North Sea.

The results presented by Papakosta & Pesonen (2019) are similar to those shown here. They studied Säräisniemi 1 (Sär 1), Sperrings 1 (Ka I:1), Sperrings 2 (Ka I:2), and Jäkärlä Ware and reported on the processing of aquatic and terrestrial animal resources from most of the studied sherds. The studied groups were using the most available resources in their local environments, regardless if the site had previously been considered as a coastal or an inland site (Papakosta & Pesonen 2019; Papakosta 2020: 20). This observation is in line with the results obtained from the Comb Ware vessels studied in the current thesis.

In Estonia, the arrival of pottery is connected to the aquatic resource exploitation. The new storage type could have provided novel and efficient ways of storing and processing the oils obtained from fish and aquatic mammals. It has also been suggested that the increased seasonal exploitation of aquatic resources and the new ways of storing them in ceramic vessel, caused a decrease in the need for seasonal migrations (Oras et al. 2017: 117). The dominance of aquatic fats in the studied Finnish Comb Ware vessel is not as strong as it is in the Estonian material, as the remains of fats that are deriving also from terrestrial animals were found. However, it has been suggested that also in Finland the adoption of the ceramic vessels was a technology that allowed a better handling of animal products, such as train oil from seals (Pesonen & Leskinen 2009: 299). It has also been argued that in Finland the adoption of ceramics was not connected to any major change when compared to the previous hunter-gatherer-fisher lifestyle (Torvinen 2000: 3). As the arrival of pottery can be strongly linked to the exploitation of aquatic resources in Estonia, similar reasons cannot be solely ruled out in the Finnish context.

Additionally, in Article **II** the correlation between rim diameter and form was studied. No correlation between rim type or rim diameter and the organic residue concentration was found. This result indicates that vessels with different sizes were used for storing or preparing food. Rim diameter were measured using rim chart. This method is challenging when studying small sherds of hand-made pottery (Orton & Hughes 2013: 210). As no correlation was found, and due to uncertainty in measuring rim diameter from small fragments of sherds, this type of statistical analysis was not carried out in the other articles used in this thesis.

3.3 Hunter-Gatherers and Farmers in South Finland during the Late Neolithic and Early Metal Period (III)

Studied Late Neolithic and Early Metal pottery came from 31 sites located in South Finland and the Åland Islands (see Fig. 1 and Table 2).

3.3.1 Corded Ware

In Article **III**, 30 Corded Ware sherds were studied and 21 of these were selected for further analysis. Based on the biomarker and stable carbon isotope analyses, a variety of different commodities were processed or stored in the vessels (See Fig. 7, Fig. 10, Appendix 1). The combination of aquatic biomarkers (i.e. APAAs and DHYAs with C_{18}–C_{20}, or IFAs) that are typically considered as reliable markers, were not detected in the lipid extracts of the Corded Ware sherds. Thus, the identification of aquatic fats was based on the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids and on the $\Delta^{13}C$ proxy.

Based on the $\delta^{13}C$ values and $\Delta^{13}C$ proxy only four (19.0 %) Corded Ware sherds showed any evidence of processing of fats deriving from the aquatic organisms. This finding may suggest that in their food procurement patterns, the groups using Corded Ware, chose to utilise terrestrial resources over aquatic resources. Corded Ware settlement sites were usually located in different environments than the settlement sites of hunter-gatherers in earlier periods. Corded Ware groups chose sites near meadows and river valleys, whereas hunter-gatherer groups settled in areas near water bodies (Äyräpää 1973: 202; Halinen 2015: 114).

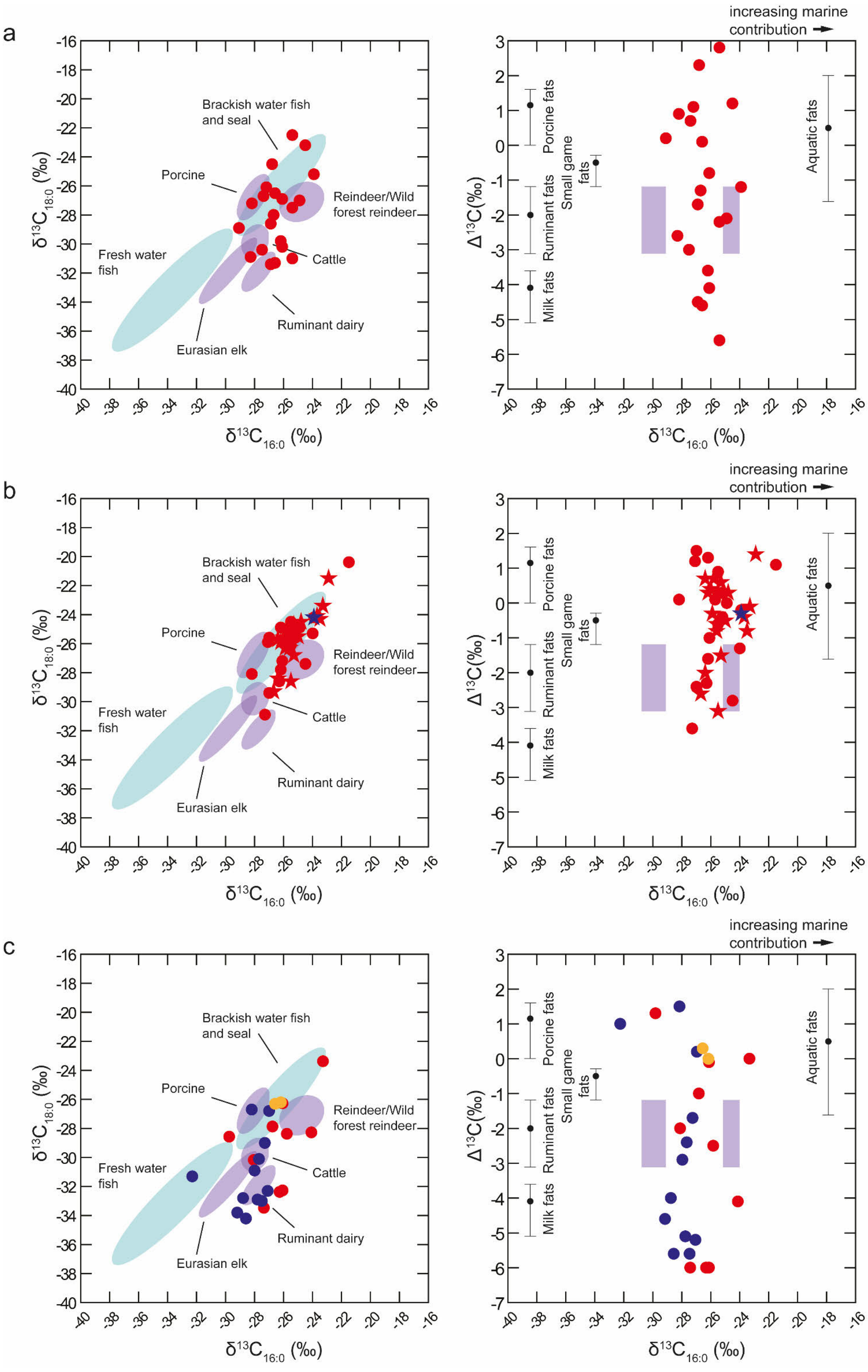

a
b
c
$\delta^{13}C_{18:0}$ (‰)
$\delta^{13}C_{16:0}$ (‰)
$\Delta^{13}C$(‰)
Brackish water fish and seal
Porcine
Reindeer/Wild forest reindeer
Cattle
Fresh water fish
Ruminant dairy
Eurasian elk
increasing marine contribution
Porcine fats
Small game fats
Ruminant fats
Milk fats
Aquatic fats
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
3
2
1
0
-1
-2
-3
-4
-5
-6
-7

Figure 10. Graphs showing scatter plots of $\delta^{13}C_{16:0}$ values against $\delta^{13}C_{18:0}$ values and graphs of the $\Delta^{13}C$ proxy from different cultural groups of Late Neolithic and Early Metal Period South Finland. (a) Corded Ware; (b) Kiukainen Ware (red) and Swedish Pitted Ware (blue); (c) Bronze Age Ware (orange), Morby Ware from mainland Finland (red), and Morby Ware from the Åland Islands (blue). The ellipses in the plots represent confidences of 68.27 % as derived from modern reference datasets. The rectangles represent the $\delta^{13}C_{16:0}$ range of Eurasian elk and reindeer/wild forest reindeer (Article **I**). The star symbols represent organic residues that contained biomarkers of aquatic origin. Modern terrestrial and freshwater fats have been corrected for the contribution of post-Industrial Revolution carbon burning by adding 1.3 ‰ (Friedli et al. 1986).

As mentioned earlier, even though the $\delta^{13}C$ values and the $\Delta^{13}C$ proxy indicate the processing of aquatic fats in 19.0 % of Corded Ware vessels, aquatic biomarkers were not found in the studied Corded Ware vessels. This lack of aquatic biomarkers could also be explained by different cooking habits of the Corded Ware people compared to those of other prehistoric cultures in the same area. The paucity of food crusts and soot in the Corded Ware sherds suggests that the vessels were not held over an open fire in the same way as the vessels from preceding and later periods. As mentioned earlier, APAAs are formed at high temperatures (Matikainen et al. 2003; Hansel et al. 2004; Evershed et al. 2008; Bondetti et al. 2021). It is possible that the groups using Corded Ware had differing cooking habits and prepared their aquatic commodities at lower temperatures than did the other studied cultures. Only one of the studied Corded Ware vessels, CW31 from Hämeenlinna Hauho Perkiö, had traces of any food crust on the surface. Unfortunately, this sherd contained modern plasticiser contamination that was introduced during storage, and therefore, it was only screened with GC and not analysed any further with GC-MS or GC-C-IRMS.

Animal bones were recovered from most of the Corded Ware sites included in this study (Fig. 8). However, the majority of these studied locations were multi-period settlements with several occupation phases. Due to the thin and mixed cultural layers, it is difficult to connect any individual bone with a given occupation phase without performing extensive radiocarbon dating. The surviving bone material found from the Corded Ware sites in Finland is mostly burnt with a few unburnt fragments, which most likely date to later periods of use. Unburnt bone does not survive well in acidic soils, and thus these are often considered as later intrusions (see Bläuer & Kantanen 2013). No burnt domestic animal bones were recovered from the studied sites. One unburnt cattle and a pig bone were found from the studied sites, however it is likely that they date to later periods (Fortelius 1980c; d; Vormisto 1985; Mannermaa 2013; Bläuer 2015a; b).

The results from the Corded Ware vessels demonstrated that they were used for processing various commodities, including ruminant animals and dairy products. In addition, tissues of non-ruminant animals were processed in the studied vessels. The results obtained are in accordance with those published by Cramp et al. (2014a), where residues of dairy, ruminant carcass, and possible aquatic fats were detected. Based on these results, groups using Corded Ware were not limited to narrow-based food procurement patterns and probably practised animal husbandry to some extent. At the same time, they continued the traditional hunter-gatherer lifestyle, but possibly also chose to utilise less aquatic resources than the preceding Comb Ware had.

3.3.2 Kiukainen Ware and Swedish Pitted Ware

Even though residues of dairy fats were detected on five (23.8 %) sherds from the Corded Ware period, dairying seems to have been much less common during the Kiukainen Ware period. Residues of dairy fats were detected on only one (2.6 %) Kiukainen Ware sherd.

Previously, it has been reported that organic residues of both marine and ruminant carcass products have been found on the Kiukainen Ware vessels (Cramp et al. 2014a). In Article **III**, it was shown that possibly dairy and non-ruminant terrestrial animal products, likely game, were processed in the Kiukainen vessels. Evidence of processing aquatic organisms were detected in 21 (53.8 %) of the lipid extracts from the Kiukainen Ware vessels (see Fig. 7). This finding is in accordance with the zooarchaeological data, as the animal bone assemblages from the Kiukainen culture sites consists mainly of seal and fish bones (Bläuer & Kantanen 2013).

As mentioned previously, several cereal grains from the Turku Niuskala site have been radiocarbon dated to the Kiukainen culture period, indicating cereal cultivation (Pihlman & Seppä-Heikka 1985; Vuorela & Lempiäinen 1988; Asplund et al. 1989; Asplund 2008: 292, Lempiäinen-Avci et al. Manuscript). In addition, a bone of a sheep/goat has been also radiocarbon dated to the Kiukainen period (Bläuer & Kantanen 2013). In the previous research, it has been suggested that in this period, Baltic Sea resources complemented early agrarian practices of cultivation and farming (Asplund et al. 1989: 126; Soisalo & Roiha 2022). Residues of dairy fats found at the Turku Niuskala site provide further evidence that agriculture was practised, or at least attempted, in Southwest Finland during the Late Stone Age. However, it is also likely that the cultivation of cereal crops and possible dairy farming was only of local or minor importance among the groups using Kiukainen Ware.

It is suggested that the changes in the climate at the end of the Stone Age delayed the transition to farming in Finland (e.g. Cramp et al. 2014a: 7; Heyd 2022). Based on tree-ring carbon isotopes, climate conditions with increased cloud cover and precipitation took place in the subarctic Europe between 2190–2100 BC (Helama & Oinonen 2019). This increased cloud coverage and precipitation are simultaneous with dating of the Kiukainen Ware. The environmental productivity in Finland had started to decrease around 3000 cal BC. Thus, the natural resources available for the groups living in the area also decreased (Tallavaara et al. 2010: 256). Some archaeologists believe that agriculture was not carried out only due to nutritional needs. Even with a cooling climate, cereal cultivation spread toward the north. Contacts with South Scandinavian farming communities increased during the end of Stone Age. It has been suggested that the contacts with agrarian cultures acted as a stimulus for early farming in Finland (Halinen 2015: 69). Thus, the climate induced decrease in environmental productivity might have urged groups with Kiukainen Ware to experiment with farming.

In addition, it should be pointed out that a cooling climate does not always indicate a decline in agricultural practises. This aspect has been especially observed from the Bronze Age onwards in Finland, as population size seems to grow despite the cooling climate. It is possible that farming communities were more resilient towards a changing climate, as climate-induced crop loss and famine were likely to cause only short population declines when compared to long-term population growth (Tallavaara & Seppä 2012: 222; Tallavaara 2015: 48).

It is not clear if the Neolithic farming practises continued directly to the Early Metal Period in Finland. Usually, there is no evidence of continuity of using the same settlement sites from the Stone Age to the Early Metal Period (Lavento 2012: 22). However, it has been suggested that at least in Southwest Finland, the same settlement sites were inhabited from the Kiukainen Ware period to the Early Bronze Age. Nevertheless, this is still an open question and there is no clear evidence if this continuity lasted to the Morby Ware period (Asplund 1997b: 41).

In general, based on previous research, terrestrial animals did not play a major role in the food procurement pattern of Swedish Pitted Ware groups that were living along the coast of the Baltic Sea (Eriksson et al. 2008; Fornander et al. 2008: 293). However, in Sweden, traces of both marine/fish and terrestrial animal organic residues have been detected from the Swedish Pitted Ware vessels (Isaksson 2009: 138). The faunal bone assemblages from the Åland Islands indicate the importance of marine resources there. Terrestrial animal bones are found, however, in low frequencies, in the Swedish Pitted Ware culture layers in the Åland Islands. There seals dominate the zooarchaeological assemblages (Storå 2000: 69). Bones of mountain hare, European beaver, Eurasian elk, and red deer (*Cervus elephus*) have also been identified. It is probable that the bones of both Eurasian elk and red deer do not indicate that these animals were part of the local diet, but they were more likely transported to the Åland Islands as raw material for bone tool production (Storå 2000: 73–74).

Bones of cattle and sheep recovered from the Åland Islands have been radiocarbon-dated to the same period as the Swedish Pitted Ware (Storå 2000: 70). Thus, the residues of ruminant carcass fats recovered from a sherd LN58 from

Saltvik Härdalen, which has characteristics of both Swedish Pitted Ware and Kiukainen Ware, might derive from domesticated animal as well as from wild game. However, it has been suggested that domesticated animals had only limited importance for the Swedish Pitted Ware groups, with marine resources playing the most important role in the food procurement cycle (Storå 2000: 74). This focus is also seen in the surviving zooarchaeological material, as the only identified animal bones from the Swedish Pitted Ware cultural layer of Saltvik Härdalen were from harp and ringed seals (Storå 2000: 64). Thus, the organic residue evidence obtained from the studied Swedish Pitted Ware sherd is in accordance with previous archaeological knowledge, especially as evidence of the processing of fish or seal in the vessel was detected.

Seals are also believed to have held ideological importance for the Swedish Pitted Ware groups. Based on the isotopic data gathered from human bone remains from Sweden, predominant protein content of the diet of the groups with Swedish Pitted Ware came from seals. This evidence has been seen as ideological emphasis on seal hunting (Fornander et al. 2008). Storå (2001) has suggested that some of the clay figurines found from the Pitted Ware sites on the Åland Islands show characteristics both derived from seals and humans. In addition, seal skull bones from the Jettböle I, Jettböle II, and Ajvide sites have been found in different parts of excavation sites than bones from other parts of seals' body. This finding has been suggested as a sign of treating the heads of the seals with special attention and has been considered as an indicator of a close relationship between humans and seals (Storå 2001: 48–51; Stenbäck 2003).

Only one Swedish Pitted Ware vessel and one sherd with similarities with the Swedish Pitted Ware was studied in this thesis. This low number of studied sherds makes it difficult to make any broad scale interpretations of the food habits of the Swedish Pitted Ware groups in the Åland Islands. However, if similar belief practises were carried out in groups with Kiukainen Ware, then the dominance of seal bones in osteological assemblages of the Kiukainen Culture sites could be due to other cultural reasons, than just nutritional needs or for production of train oil.

3.3.3 Early Metal Period Vessels: Bronze Age Ware and Morby Ware

Only two Bronze Age sherds were included in this study. These sherds contained fat residues from non-ruminant terrestrial animals, indicating a processing of commodities from either small game animals or pigs. In previous research, dairy fat residues have been detected in two Late Bronze Age sherds (Cramp et al. 2014a: 6). Cereal grains dating back to the Bronze Age have been found at several settlement sites in South Finland (e.g. Pihlman & Seppä-Heikka 1985; Asplund 2008: 292;

Holmblad 2010: 135; Uotila 2014; Vanhanen & Koivisto 2015). Thus, during the Bronze Age, evidence shows that agricultural practises started to become more common than during the preceding periods.

It has also been suggested that during the same time period when Morby Ware was in use in Finland, a more intensive form of agriculture that utilized indoor winter feeding of animals and manuring of fields was taking place in Norrland Sweden. This change enabled more efficient animal husbandry and cultivation (Viklund et al. 1998: 17; Welinder et al. 1998: 255–256). Perhaps similar agricultural innovation increased the productivity of cultivation in Finland as well, thereby contributing to the spread of agriculture. Geochemical and archaeobotanical data from the Pre-Roman Iron Age (500–1 BC) at the site of Bäljars 2 in South-West Finland has been interpreted as an indication of the use of manured fields, ard-ploughing, and managing fields with fire (Vanhanen & Koivisto 2015). Bone material from one of the studied Morby settlement sites included domesticated species, i.e., sheep/goat, dog (*Canis familiaris*), and possible cattle bones, as well as wild mammal bones (Ukkonen 1998; Bläuer 2015a).

Altogether 32 Morby Ware sherds from settlement sites or burial cairns were sampled. The 18 sherds from mainland Finland were collected from settlement sites, one of which was also related to a burial cairn. Most of the 14 sherds from the Åland Islands were collected from burial cairns with only one sherd coming from a settlement site. Morby Ware vessels obtained from sites located in South Finland and the Åland Islands indicated dairy farming, as residues of dairy fats were found in ten (45.5 %) vessels. However, the only site with dairy residues in mainland Finland was Espoo Bolarskog I. It thus needs to be kept in mind that the lack of residues of dairy fats from mainland Finland could be due to either sampling bias or for cultural reasons. Based on the results of the organic residue analysis, groups using Morby Ware had similar cooking and food consumption habits on both mainland Finland and the Åland Islands. The food cultures of these groups also seem to have been based on terrestrial animals and dairy products (Fig. 10).

In some of the Early Metal Period sites, seal bones dominate the osteological material (Bläuer & Kantanen 2013). In the Arctic Norwegian coastal areas, archaeological features called 'slab-lined pits' are found. They are elliptical or rectangular depressions in the soil with the bottom and the sides lined with slabs. These structures date to 600–900 AD. The slab-lined pits have been used to process marine mammals, as confirmed with a GC-MS analysis for marine biomarkers and bulk carbon isotope analyses of charcoal, sediment, fire-cracked rocks, and from mixtures of organic material, sand, and gravel. Interestingly, no seal bones have been found from these sites, suggesting that only blubber was transported to the sites. (Heron et al. 2010). It is possible that constructs for processing marine mammals could also have been used in Finland, as they have been found from sites in the Åland Islands and Swedish coastal areas (Nilsen 2016a).

In Finland and Sweden, constructs called ‘cooking pits’ have been found. The majority of these date to Early Metal Period. However, some are from the Late Stone Age. These cooking pits are typically funnel-shaped and usually contain burned and unburned stones and charcoal. It is possible that the cooking pits are related to the processing of seal blubber; however, this explanation has been debated. Most of them are found in the coastal areas and some are located inland. It has been suggested that some of the cooking pits could have been used for smoking meat and fish rather than the processing of seal blubber (Äikäs 2009; Nilsen 2016a).

Interestingly, even though there is zooarchaeological evidence of seal hunting during the Morby period (Bläuer & Kantanen 2013), organic residues obtained from Early Metal Period Morby vessels did not indicate the presence of aquatic fats to any great extent (see Fig. 7; Appendix 1). Out of the studied Morby vessels retrieved from both mainland Finland and the Åland Islands, only one (4.5 %) vessel was identified as containing possible residues of aquatic fats. This detail raises an interesting question. What actually happened to the hunted seals? Were seals hunted for train oil, but that oil was not stored or processed in ceramic vessels? It has been experimentally shown that successful separation of oil from seal blubber requires a temperature of 80–400 °C (Nilsen 2016b: 206). Thus, it would be likely that APAAs would have been formed and survived in the pottery matrix. However, DHYAs and IFAs were also found only in low abundances from Morby Ware vessels, which could indicate that train oil was not stored in ceramic vessels.

The lack of clear signs of processing seal fat in the studied vessels could be interpreted as sampling bias. It must also be kept in mind that surviving bone material from the studied Morby sites was scarce (Fig. 8), and the number of identified seal bones were also low. Out of 20 identified animal bones, only four were from seals (Fortelius 1980e; Ukkonen 1996a, 1998; Bläuer 2015a; b; Article **III**).

There are also Early Metal period sites where animal bone assemblages are dominated by domesticated animal bones instead of seal bones. Sometimes a few seal bones are found from these sites, but for some sites the seal bones are absent (Bläuer & Kantanen 2013). Such duality between the compositions of bone assemblages could indicate that groups were using different sites for sealing and agricultural purposes. It also cannot be ruled out that the separate groups were practising two different subsistence strategies. Some groups could have continued the Kiukainen culture tradition of seal hunting while others invested more time and energy in animal husbandry and farming.

As mentioned earlier, most of the Morby vessels from Finland came from the settlement sites while most of the Morby vessels from the Åland Islands came from burial cairns. As the organic residue findings from the Morby Ware are similar for mainland Finland and the Åland Islands, it seems that the vessels chosen to be deposited in burial cairns had been used in a similar way as the vessels for domestic use. Based on this finding, it appears that vessels used in burials had been in domestic use before being placed in burial cairns.

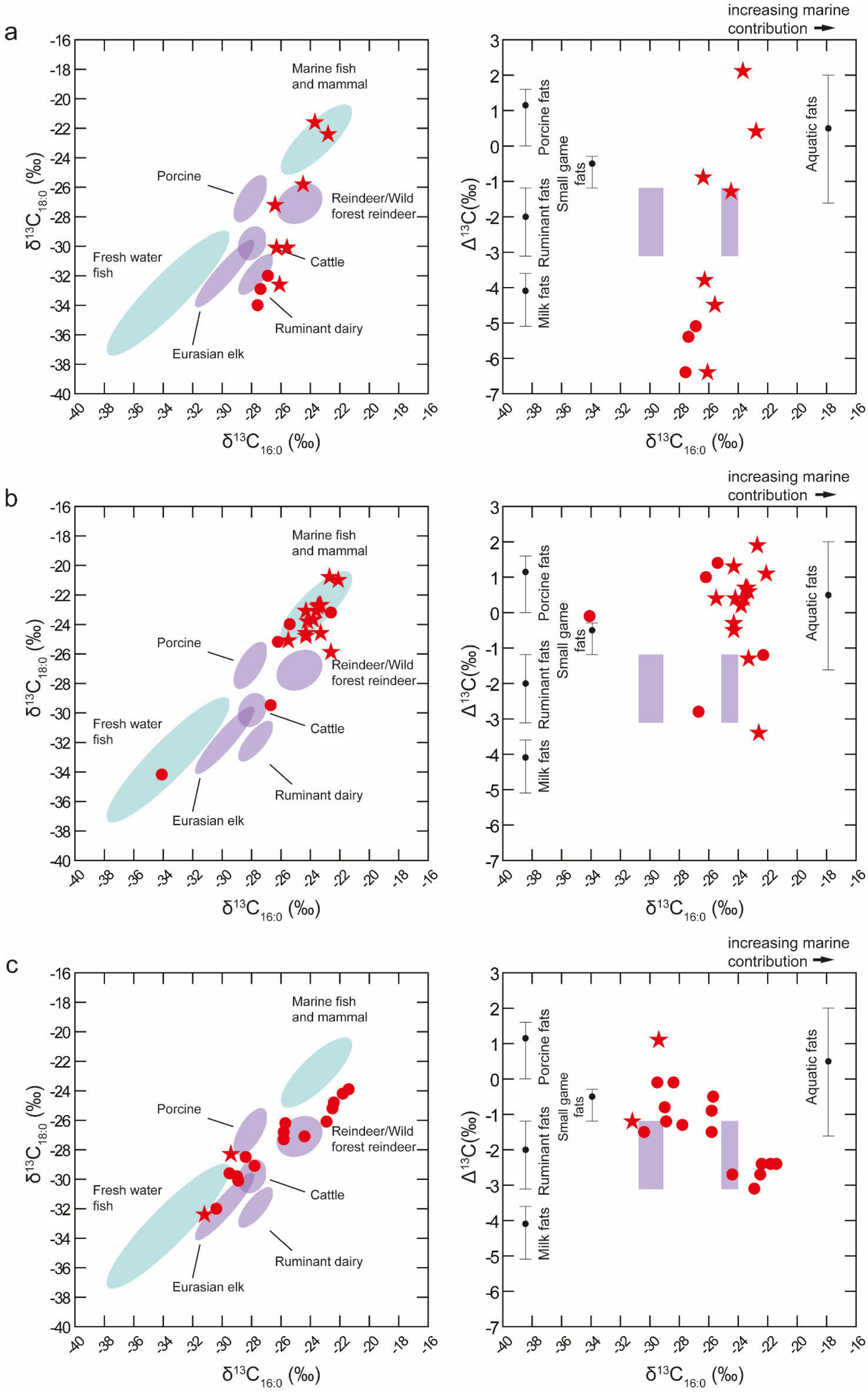
Hunting and gathering have been used to supplement the diet up to modern times in the northern areas. Thus, a similar clear-cut division for the transition to farming cannot be found as, for example, reported in the UK and Ireland (Cramp et al. 2014b). Finland is not the only place where the hunting and gathering were practised alongside farming. A similar pattern of slowly changing the food culture can be seen, for example, in Denmark and North Germany when transitioning from Ertebølle to Funnel Beaker pottery (Craig et al. 2011). There early farmers combined agricultural practises with exploitation of natural resources.

3.4 Farmers and Hunter-Gatherers in the North (IV)

In Article **IV**, the identifications of organic residues from North Norwegian and North Finnish material were based only on biomarkers and the $\Delta^{13}C$ proxy. Herein, the results are reinterpreted by including the $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values. As mentioned earlier, unburnt bone preservation in Finland is generally poor due to acidic soil (Kibblewhite et al. 2015). However, in Norway bone preservation is better with many archaeological sites yielding considerable assemblages of unburnt bone material (Olsen 1967; Olsen 1984). This circumstance creates better opportunities to compare Norwegian bone material to the results of organic residue analysis than for organic residues found in Finnish pottery.

3.4.1 Coastal Farmers with Risvik Pottery

Nine coastal sites with Risvik pottery were investigated in Article **IV**. The sherds from five sites yielded organic residues that likely came from dairy products. Of the studied sherds, based on their $\Delta^{13}C$ values, the lipid residues from three (30.0 %) vessels were interpreted as being dominated by dairy fats. In addition to dairy fats, the organic residues from three (30.0 %) other vessels indicated the presence of APAAs, DHYAs, and in one case phytanic acid. Nevertheless, the $\Delta^{13}C$ values of these residues indicated a predominantly dairy origin (Fig. 11). It is likely that these pots were used to process both dairy and marine products. In four (40.0 %) sherds, the $\delta^{13}C$ values, the $\Delta^{13}C$ proxy, and the detection of APAAs, DHYAs, and IFAs are evidence that the vessels were used to process mainly marine products (see Appendix 1).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Marine fish and mammal
Porcine
Reindeer/Wild forest reindeer
Cattle
Fresh water fish
Ruminant dairy
Eurasian elk
increasing marine contribution
Porcine fats
Small game fats
Ruminant fats
Milk fats
Aquatic fats

Figure 11. Graphs showing the scatter plots of $\delta^{13}C_{16:0}$ values against $\delta^{13}C_{18:0}$ values and the $\Delta^{13}C$ proxy plotted from different economical groups of North Norway and North Finland (a) coastal agrarian groups using dairy and aquatic products; (b) coastal hunter-gatherers using marine mammals and fish; (c) interior hunter-gatherers with a diverse food procurement pattern. Ellipses in the plots represent confidence of 68.27 % as derived from modern reference datasets (Article **I**). The organic residues plotting to the right side contained a greater marine component compared to those plotting more to the left side. The rectangles represent the $\delta^{13}C_{16:0}$ range of Eurasian elk and reindeer/wild forest reindeer (Article **I**). The star symbols represent organic residues that contained biomarkers of aquatic origin. Data for marine fish and mammal taken from Cramp & Evershed (2014). Modern terrestrial and freshwater fats have been corrected for contribution of post-Industrial Revolution carbon burning by adding 1.3 ‰ (Friedli et al. 1986).

It has been suggested that animal husbandry played a minor role in food procurement practises of the groups that were using Risvik pottery, as the economy was otherwise based mostly on the hunter-gatherer lifestyle (Olsen 1988: 429). The high frequency of marine product biomarkers and the findings of dairy fat residues in the Risvik pottery support this interpretation.

The zooarchaeological assemblages of the coastal Early Metal Period sites in Norway included marine mammals and fish. However, bones of the terrestrial species are also widely represented (Denham 2014; University Museum of Bergen Osteological Sub-fossil Collection Database 2017). The general assessment based on the bone material is that hunting and fishing dominated subsistence patterns. Nevertheless, bone assemblages found from Early Metal Period coastal settlement sites in North Norway, including Risvik pottery settlements, include fragments of teeth and the bones of cattle and sheep or goats (Johansen 1982; Arntzen 2013, 2015; Denham 2014). It has been suggested that early cultivation procedures in North Norway were carried out using flexible subsistence strategies as hunting, fishing, and possible herding, were practised simultaneously with small scale cultivation (Bergman & Hörnberg 2015: 60).

Cultivation practised by the groups with Risvik pottery could have been similar to the cultivation strategies carried out by the indigenous people in the subarctic area during the historical period. The indigenous Sámi had knowledge of how to manage and harvest certain plants to ensure their successful growth again in the next growing season. However, the traditional way of using the plants of the Sámi has not generally been considered as cultivation (Bergman & Hörnberg 2015: 60, 62). Well-dated traces of cereal cultivation, i.e., pollen and grains, have also been identified at coastal sites from Risvik period (Arntzen 2013). Based on paleoecological investigations, cultivation has been carried out in the North Norway during the Early Metal Period. Barley (*Hordeum*), and further, possibly other cereals, were cultivated in North Norway during the Bronze Age (1100–500 BC). It has also been suggested that the forests were cleared by fire. It is not clear whether a slash-and-burn type of cultivation was used. During the Pre-roman Iron Age (500–1BC), both wheat (*Triticum*) and barley were cultivated. Seeds of corn spurrey (*Spergula arvensis*), a plant that is considered a weed, have also been found, and it is possible that these seeds were collected alongside seeds from actual crops. Pollen evidence suggests that the environment during the last millennium BC was open pasture or meadow, and it is likely that a fallow system was used (Sjögren & Arntzen 2013: 10–11).

Zooarchaeological assemblage compositions (Fig. 12) from the coastal early agrarian sites are in agreement with the findings of residues of aquatic and dairy fats in potsherds. Even though terrestrial animal bones have been recovered from the studied coastal early agrarian Risvik sites, no indication of any processing of terrestrial carcass products was detected in the organic residues from these pots (Fig. 13).

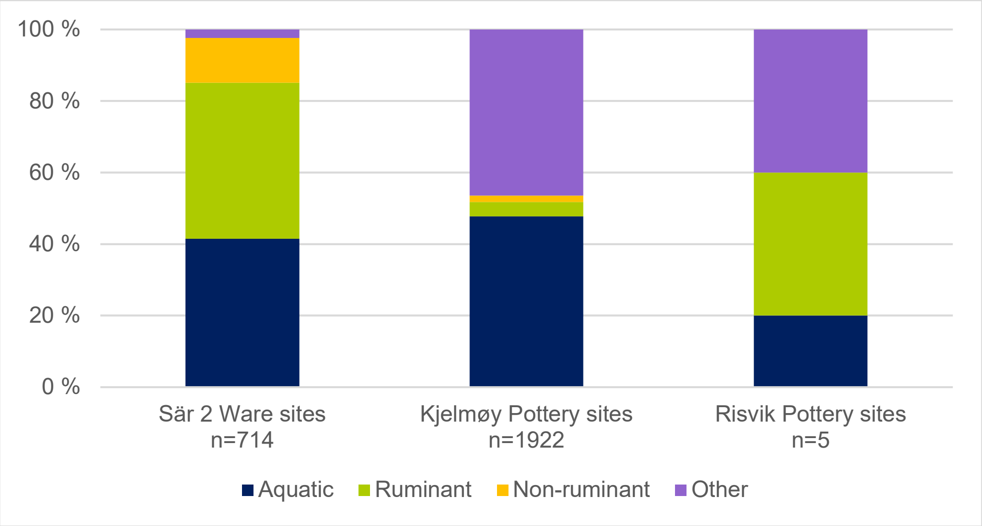

Figure 12. Distribution of identified bone fragments from studied sites in North Norway and North Finland. Class 'other' includes birds, fur-bearing animals (brown bear, *Canis* sp., Eurasian otter, pine marten, and red fox), *Rattus* sp., and rodentia. Percentages are calculated from NISP. Identified bone material was not reported from all of the studied sites. More detailed data can be found in Article **IV**. Bone material from Sär 2 sites are from Suomussalmi Kalmosärkkä, Suomussalmi Kellolaisten Tuli, and Kemijärvi Neitilä 4 (Fortelius 1980f; g; Ukkonen 1996 b; c; d; Mannermaa 2003). Bone material from sites with Kjelmøy pottery are from Sørvaranger Mestersanden and Mortensnes Nesseby. In the Sørvaranger Mestersanden site percentages for ruminant and aquatic might be higher than presented here, as exact NISP for reindeer, harp seal (*Pagophilus groenlandicus*), and harbour seal (*Phoca vitulina*) are not given (Olsen 1984; Schanche 1988). Bone material from sites with Risvik pottery is from Tromsø Sandvika. Percentage of bone material of aquatic animals is likely higher in the Tromsø Sandvika site than presented here, as fish bones were reported to be present but no NISP was given (Denham 1994). Bone material was also found from the Træna Kirkhellaren site, but NISP for this site was not given (University Museum of Bergen Osteological Sub-fossil Collection Database 2017).

The lack of terrestrial carcass fats in the Risvik material could result from sampling bias or it could be an indication of specialised food preparation practises, where terrestrial carcass products were dried, smoked, or processed in containers made from organic material rather than using ceramic pots. The main conclusion, however, is that the early coastal farmers used pottery mainly for processing both marine and dairy products. As an interesting note, the Kirkhellaren site is located on a remote island more than 40 km from the Norwegian coast. However, in addition to dairy fat residues, bones of domesticated ruminant animals have been recovered from the Kirkhellaren site (University Museum of Bergen Osteological Sub-fossil Collection Database 2017). These findings can be seen as evidence of early agrarian groups populating even the most challenging environments.

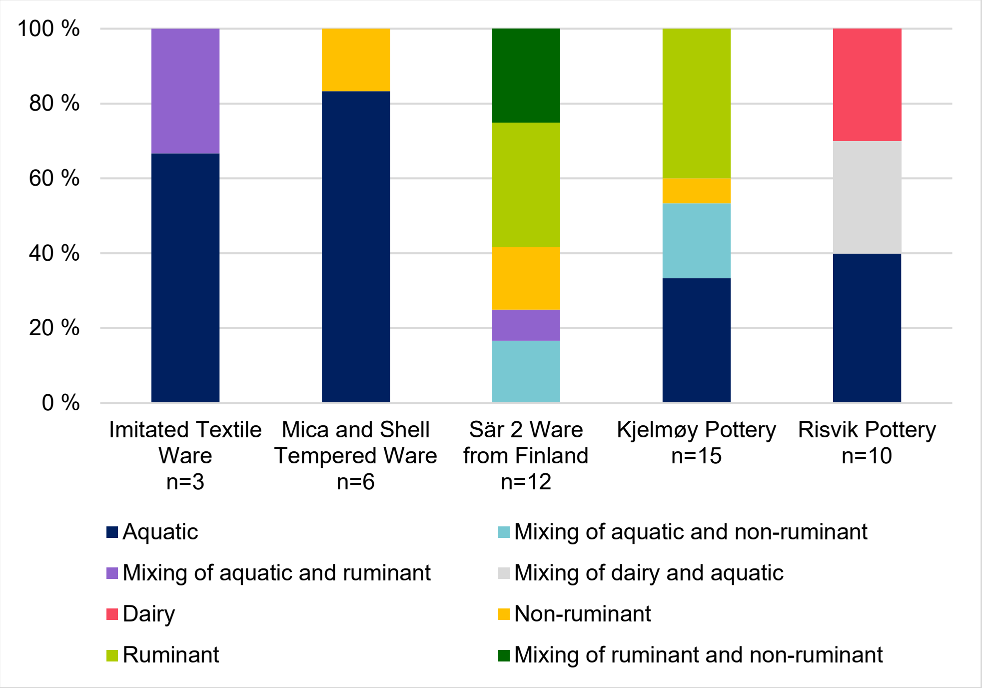

Figure 13. Distribution of organic residues from the sherds collected from North Norway and North Finland. This figure summarises the results from the organic residue analysis, where both certain and uncertain identification are combined to create a more visual and simplified interpretation of the obtained data. More detailed results can be found in Appendix 1.

Reindeer are known to have been used as draught animals at least since 1300 AD (Salmi et al. 2021). However, possible evidence of tame reindeer can also be found from the prehistoric period. Remains, similar to Sámi-type sledges, dating to 1500 BC, have been found from a burial in the Murmansk fjord in the Kola Peninsula

(Murashkin et al. 2016: 190). These remains of possible sledges have been considered as possible evidence of early reindeer herding (Røed et al. 2018: 284). However, if the prehistoric groups had some tame reindeer, they are not necessarily a sign of reindeer domestication or herding. Reindeer could have been kept as decoy animals used for hunting or, as mentioned above, as draught animals (Hansen & Olsen 2022: 189). Thus, residues of dairy fats detected in the Risvik pottery could, in principle at least, derive from the reindeer rather than from animals typically being used in milk production i.e. cattle, sheep, or goats. However, it is unlikely that the detected residues of dairy fats would have come from milk obtained from reindeer, as based on the osteological material, reindeer were more important for groups using Kjelmøy pottery than for groups with Risvik pottery. Plenty of reindeer bones have been found from the dwelling sites with Kjelmøy pottery. Thus, if reindeer would have been used for milking in any great extent, the effort would have more likely happened by groups with Kjelmøy pottery rather than by groups with Risvik pottery.

3.4.2 Coastal Hunter-Gatherers

In North Norway, the coastal hunter-gatherers resided areas north of the early agrarian societies. Several species, mostly marine mammals and fish, have been identified from the bone assemblages of these sites. Terrestrial species are also represented, for example, reindeer and European beaver. In addition, bones from 27 different bird species have been identified (Olsen 1984; Schanche 1988).

The studied Kjelmøy, mica and shell -tempered pottery, and the IT pottery sherds from Norwegian coastal hunter-gatherer sites yielded residues with C_{16}–C_{22} APAAs, long-chain DHYAs, and IFAs (see Fig. 14). These are an indication of a substantial marine contribution to the typical diet. However, coastal groups using Kjelmøy or mica and shell -tempered pottery in the Sørvaranger Mestersanden and the Nesseby Mortensnes sites did not exploit only marine foods, as lipid residues from three (18.8 %) vessels were shown to originate from ruminant animals or possibly other terrestrial animals, but not aquatic animals (see Appendix 1). This is largely in line with the zooarchaeological findings and can be considered as indication of flexible use of resources. In addition, recent organic residue analysis study has demonstrated that processing of aquatic resources dominated in coastal dwelling sites (Jørgensen et al. 2023). Thus, based on organic residue analysis, both marine and terrestrial resources were important for the coastal hunter-gatherer groups in North Norway.

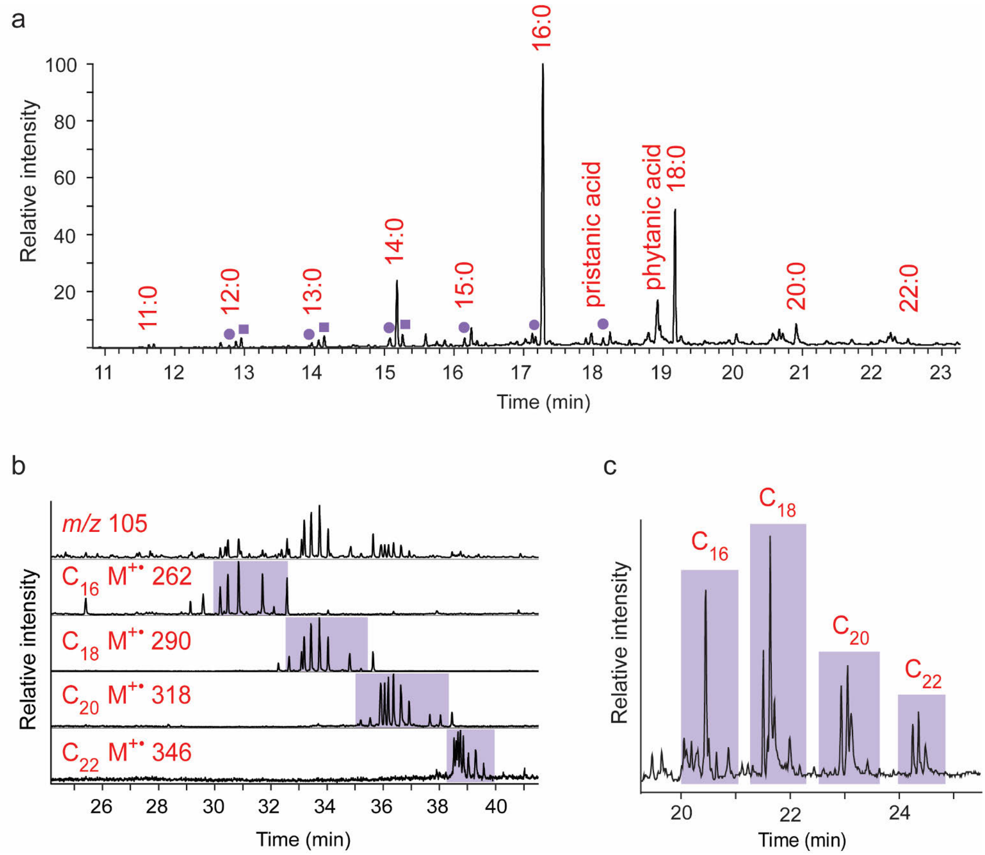

Figure 14. Partial gas chromatogram of fat residues extracted from potsherd. Organic residues of aquatic origin were identified from a mica and shell -tempered potsherd (SÄR10B). The findings of APAAs and DHYAs strongly indicate the processing of marine commodities in the vessel. (a) Partial gas chromatogram showing fatty acid distribution of sherd SÄR10B. Circles indicate alkanes and squares indicate α,ω-dicarboxylic acids. (b) Partial SIM chromatogram showing the *m/z* 105 (dialkylbenzene fragment ion) of the APAAs and the distribution of APAAs with chain lengths C_{16} (molecular ion *m/z* 262), C_{18} (*m/z* 290), C_{20} (*m/z* 318), C_{22} (*m/z* 346). (c) Partial SIM chromatogram showing the distribution of DHYAs. C_{16}, C_{18}, C_{20}, and C_{22} indicate the carbon chain lengths of the DHYAs.

3.4.3 Interior Hunter-Gatherers

The zooarchaeological bone assemblages from the interior hunter-gatherer sites consisted of terrestrial animals, including European beaver, Eurasian elk, and reindeer. Fish are also present, including pike (*Esox lucius*) and those from the carp family (*Cyprinidae*). Terrestrial animal bones dominated the zooarchaeological assemblages of the interior Finnish sites, Suomussalmi Kellolaisten Tuli and Kemijärvi Neitilä 4. Fish bones were found in high quantities from the Suomussalmi Kalmosärkkä N site and the Kalmosärkkä S site (Fortelius 1980f; g; Ukkonen 1996b;

c; d; Mannermaa 2003; Fig. 12). The large quantity of European beaver bones from these sites suggests that beaver were actively hunted for food and not just for fur or castoreum.

The zooarchaeological bone material and the results of the organic residue analyses of the pottery from interior sites largely agreed with each other. The organic residues in the potsherds indicated the cooking/storing of ruminant products, together with those of other terrestrial animals and lesser contributions from freshwater resources. The vessels from the interior sites of North Norway and North Finland did not contain DHYAs with chain-lengths of C_{20}–C_{22} even though APAAs and IFAs were detected from several vessels (Appendix 1). Results from organic residue analysis for three (16.7 %) vessels suggest that both aquatic and terrestrial products were stored or prepared in these vessels.

Vessels from the Kautokeino Virdnejávri 106 site were dominated by residues of ruminant fats, whereas the biomarker and stable carbon isotope evidence from extracts of the Sär 2 vessels from inland Finland indicated the processing of ruminant animals, non-ruminant terrestrial animals, and fish. However, the abundance of aquatic fats from the Suomussalmi Kalmosärkkä S and Kalmosärkkä N pottery was lower than expected based on the high abundance of fish bones in the zooarchaeological assemblages.

Based on the new interpretations of the lipid data, it is likely that most, i.e. residues from nine (69.2 %) pots, from interior locations identified as ruminant fats, or residues likely to originate from ruminant fats, derive from reindeer/wild forest reindeer, with four (30.8 %) of the organic residues likely to derive from Eurasian elk. It has been suggested that reindeer hunting intensified during the Early Metal Period. The extensive use of bifacial arrow points is considered a potential indicator for this practice (Hood & Olsen 1988: 121). In addition, it has been suggested that the increase in reindeer hunting is due to the declining of the elk population, as the pine forests retreated (Sjögren & Damm 2019: 31). The findings of ruminant carcass fat residues in vessels from the inland sites, such as Kautokeino Virdnejávri 106, are well in line with the interpretation that suggests intensified reindeer hunting in the area.

In contrast to the Gulf of Bothnia, the Norwegian coast is ice-free during winters. Therefore, it is considered to be more productive for both marine and terrestrial resources during the winter than the inland sites (Jørgensen 1986: 67). The compositional differences of the lipid residues from the pottery obtained from the coastal and the interior hunter-gatherer sites can be explained by the differing environmental productivities of these regions. The groups from the interior had to use most of the available resources, as their more challenging environment led to a more diversified subsistence economy. As the Norwegian coastal areas are economically richer than the interior, food procurement strategies in the coastal areas could be more selective. Nevertheless, while studying food and diversity, one must take into account that the seasonal settlement sites with short-term occupation are less likely to exhibit diversity than the more permanent settlements (Twiss 2012: 378). This scenario can be seen for example in the Virdnejávri 106 site. Seasonal occupation, instead of a specialised food procurement pattern, is likely the reason for the dominance of ruminant carcass fats and lack of diversity in fat residues in the pot sherds.

3.4.4 Norwegian Coastal Farmers and Northern Hunter-Gatherers

The studied vessels from the Norwegian coastal areas showed that groups using Risvik pottery had already transitioned toward farming, although yet supplementing their diet with marine organisms. The groups using Kjelmøy pottery continued their hunter-gatherer lifestyle. This duality was likely due to cultural influences arising from the groups with Risvik Ware having contacts with agrarian South Scandinavian groups and the groups with Kjelmøy Ware having contact with the Eastern hunter-gatherer communities (Hansen & Olsen 2022: 39–40, 53–54).

Fishing has been important to coastal farming communities in North Norway up to modern times. The rich natural resources of North Norway possibly allowed some coastal communities to experiment with animal husbandry and cereal cultivation. The richness of natural coastal resources would have buffered failures in cultivation and animal husbandry against possible nutritional crisis. The adoption of farming can also be seen as a cultural and social orientation toward South Scandinavian farming societies. Groups with Risvik pottery possibly adopted farming or at least dairying, in order to strengthen their relationships, both economically and socially, with other agrarian groups (Olsen 1988: 430). At the same time, while the rich natural resources enabled groups with Risvik pottery to experiment with farming, these rich natural resources likely delayed the transition to farming of other groups. Groups that had access to a rich marine environment had no need to change their food procurement strategies and were able to continue hunting and gathering.

Within the groups using Risvik pottery, hunting, fishing and farming were practiced simultaneously. The presence of domesticated animal bones and cereals in the Risvik pottery sites can be regarded as evidence indicating a gradual transition towards agriculture. In contrast, the communities living further north in the coastal zone and in the interior chose to continue economically less-risky hunting and gathering. Based on these results, the North Fennoscandian economic landscape during the Early Metal Period can be divided into three categories: 1) coastal agrarian communities with a food economy based on dairy and marine products; 2) coastal hunter-gatherers with an emphasis placed on marine mammals and fish; and 3) interior hunter-gatherers with a more diverse food procurement pattern consisting of terrestrial animals and freshwater fish.

However, when explaining the transition to farming among the coastal groups in North Norway, economic factors alone cannot explain everything. All coastal groups could have based their economies on fishing and marine mammal hunting, as marine resources were so abundant. In some areas, hunter-gatherer groups might have moved toward more dairy-orientated economies because of nutritional and economic gains. Previously, it has been suggested that animal domestication could have been practised simply to increase the quantity of meat in the diet (Johansen 1979: 31). The latter reason, however, seems unlikely, as residues of only aquatic and dairy fats were observed in the Risvik potsherds. Nevertheless, it is possible that ruminant carcass products were not processed in pottery and thus left no traces that could be detected in this study.

3.5 Suggestion for Future Practises, Research, and Ethical Considerations

Archaeological collections in different institutes are kept under varying conditions. Some of the potsherds used in this study had been kept in plywood cabinets for several years. When going through these archaeological collections for sampling, the cabinet door was opened and an instantly noticeable distinct odour of the cabinet was observed. The potsherds had the same distinct odour in them. A couple of months later, these sherds were sampled, and the same odour persisted on them. When the samples were screened using GC, most were found to contain so much contamination that they were not analysed further using GC-MS or GC-C-IRMS. In future studies, samples that have been stored in plywood cabinets should be avoided. Based on this observation, museums would be strongly advised to consider how their archaeological material is stored in order to avoid contamination of the sherds. Nevertheless, museums and other collections do often have limited storage space, so it is not realistic to demand perfect storing conditions for every archaeological specimen.

In some of the studied sherds, plasticizer contamination was notable. Interestingly, sherds that were stored in cardboard boxes also contained plasticizer contamination. It is possible that the contamination arose from the field work practises of storing finds in plastic bags during the excavations. Notably, in some of the collections, the samples had been stored in plastic bags for several years, even decades, and yet none or only very minor plasticizer contamination was observed in the analyses. This offers an interesting possibility for future research, namely, to seek an answer to the question why some archaeological ceramic seems to absorb phthalates more than others do. It would be interesting to check and see whether the plastic bags were made of different materials. After this study, suggestions and possible guidelines could be given to archaeologists and managers of archaeological collections on the best way of storing archaeological potsherds.

Pottery is often found in large quantities in archaeological excavations. In the prehistoric sites in Finland, this is not often the case. If pottery is found in quantities, it is typically fragmented into small pieces, or the potsherd may not carry any stylistic indications that can place it to a certain time period or pottery style. Thus, sampling sherds for destructive analysis is always a task that should be undertaken with great caution. In 2015, a method was published wherein the sample size was less than 0.1 g (Papakosta et al. 2015), which is considerably less than the 1–2 g used in this current study. However, Papakosta et al. (2015) conclude by stressing that *´working with samples as large as possible is in any case preferable, to ensure good and most reliable results´*.

Another important factor when sampling is how the sample is removed from the potsherd. In this study, a hammer and chisel were used. In some cases, potsherds that were being analysed suffered considerable damage, as they broke into several pieces instead of only chipping off a desired 1–2 g piece from the targeted part. As stated earlier, rims and upper body sherds of archaeological vessels generally contain higher concentration of lipids than do the lower parts of the vessels (Charters et al. 1993). Unfortunately, rim sherds are typically the most informative part of the vessels, as they can be used to identify the vessel type and, in some cases, also the pottery style. This unexpected breaking of the sherd creates pressure on the collection managers to decide whether they will allow sampling if there is no guarantee of the condition of the sherd after such sampling. Any scientist performing the sampling should choose between the different ways of chipping, or perhaps drilling, the sherd based on the brittleness of the sherd and thus try to eliminate any possible extensive and unnecessary breaking of the sherd.

It has also been suggested that smaller size collections with a number of sherds less than 20–30 from same period, style, etc. should not be chosen for organic residue analysis (Whelton et al. 2021: 13). Ceramic material from Finnish sites is often very limited. If the researcher aims for a collection size where statistical analyses can properly be carried out, the number of suitable sherds for sampling will become quite limited. Even though if pottery is found in large quantities, many sherds are not suitable for organic residue analysis. The sherds can, for example, be too small to reveal their pottery type.

Researchers should also be more open to other researchers on their plans as to which time periods, cultures, and sites they study, so repeated sampling of similar material is avoided. In Finland, material from the same archaeological site can be stored in different museums or institutes. If the administration body that is permitting sampling, is not attentive enough, there is a risk that the same material, and even the same pot, might be sampled several times for similar analysis.

Discussions on the ethics of sampling of archaeological human remains and archaeofaunal remains for destructive analysis has been ongoing (e.g. Pálsdóttir et al. 2019; Squires et al. 2019). This type of discussion has also been ongoing for natural historical collections (Baars 2010; Freedman et al. 2018). Similar discussion is needed in Finnish archaeology on the sampling of archaeological material regarding to what extent archaeological artefacts should be preserved intact and when to grant permits for destructive sampling. It should to be stressed, that in years to come, the analysis techniques and instrumentation will likely improve and more information can be obtained from a smaller sample size. The obvious recommendation would be to choose minimal sampling always. Never should a cultural artefact be completely consumed in any analysis.

4 Summary

In this thesis, organic residues that have been absorbed in the walls of archaeological pottery were studied from the different cultural phases from several sites located in South Finland, North Norway, and North Finland. It should be stressed that the complete human diet can never be concluded by studying absorbed organic residues obtained from pottery. Sometimes food is processed in containers made from other materials, and some lipid-lean foods are not detectable. In addition, some foods are processed in other ways, e.g., drying and smoking and do not leave chemical traces in vessels.

Based on the previous archaeological record, the economy during the Early Comb Ware and Jäkärlä periods has been interpreted as being a hunter-gatherer lifestyle. The same conclusion has been made from the organic residues investigated here. Based on the organic residue analysis, groups using Early Comb Ware relied both on the Baltic Sea and terrestrial resources. A similar pattern was also found from the Jäkärlä Ware vessels. However, it seems that groups using Jäkärlä Ware utilised Baltic resources to a higher degree than groups with Early Comb Ware. As both cultures chose similar settlement locations, it is not surprising that the environmental food resources were exploited in similar ways by both cultures. However, similarities in the location of the dwelling sites and the used food sources could also derive from their similar cultural factors rather than the surrounding environment and what was most easily accessible at the time.

The first major change in the food consumption tradition in Finland was seen during the later period of the Neolithic. The first signs of a processing of dairy fats were found in Corded Ware vessels. However, dairy fat residues were found only from one of the Kiukainen Ware vessels. This finding can be viewed as an indicator that agricultural practises were not as important during the Kiukainen period as they had been during the Corded Ware period. However, it is still likely that during the Kiukainen period agriculture was practised at least to some degree in South Finland.

During the Morby Ware period, the importance of terrestrial resources was emphasised, as residues of terrestrial and dairy fats were found from most of the studied vessels. One Morby vessel from the Åland Islands also contained possible residues of aquatic fats, thereby demonstrating that groups using Morby pottery did not rely solely on terrestrial resources. However, the importance of the Baltic Sea seems to have been relatively low compared to the previous cultural phases in Finland where findings of aquatic fats are more common. Ultimately, the food procurement pattern of the groups with Morby Ware seems to have been diverse.

Based on the results obtained from the North Norwegian and North Finnish pottery from the last millennium BC, the North Fennoscandian economic landscape can be divided into three categories: 1) coastal agrarian communities with an economy based on dairy and marine products; 2) coastal hunter-gatherer groups that focused their food procurement pattern on marine mammals and fish; and 3) interior hunter-gatherers with a diverse diet that consisted of terrestrial animals and freshwater fish.

The transition to agriculture in Finland and North Norway was a relatively slow process compared to other areas in Europe. For example, in northeast Atlantic Archipelagos, the importance of aquatic resources decreased after animal husbandry was introduced to area (Cramp et al. 2014b). In the northern latitudes, hunting and gathering has been a common way to supplement the diet up to modern times. In some areas of North Norway, rich marine resources were likely to have delayed the transition to farming, as there was no need to find new food sources. However, at the same time, the richness of the marine resources in Norway was also a probable reason why groups with Risvik pottery were able to experiment with the use of less stable farming. In South Finland, the resources obtained from the Baltic Sea were not as rich as the marine resources in North Norway. Moreover, in South Finland the food procurement patterns of the early agrarian groups were much more diverse than they were in North Norway. In Finland, the early farming could be seen as a way to supplement subsistence patterns. Nevertheless, it should not be forgotten that the agrarian way of life is actually more labour-intensive than the hunter-gatherer way of life (e.g., Dyble et al. 2019).

Still, animal husbandry and agriculture are also cultural identifiers. Thus, one should not forget the cultural implications and affiliations these new subsistence strategies could have produced for these prehistoric groups. As an example, even though the shores of the Baltic Sea could have offered a supplement to the daily food regime, the groups using Morby Ware chose not to utilise the Baltic to any great extent, as indicated by the detection of aquatic organism processing in only one vessel. This finding can be seen as an indicator that it was not only environmental factors affected the choice of the food being consumed. Cultural reasons for food choices were as important as environmental reasons.

In addition to archaeological material, modern ecological reference tissue samples were studied to create useful reference data for the interpretation of the archaeological pottery residues collected from Finland. These values can be used as a reference in future studies. This was the first study where reference material was studied to a greater extent in the Baltic Sea area. The values obtained were similar to those reported in earlier research. However, brackish-water organisms were found to exhibit more depleted $\delta^{13}C$ values compared to the previously reported values of modern marine reference fats. In addition, the importance of using local reference material was shown, as the $\delta^{13}C$ values of reindeer and wild forest reindeer varied from the values of other studied ruminant animals.

More organic residue studies should be carried out on the North Finnish and Norwegian material, as northern material has been only scratched on the surface. In addition, it would be beneficial to study Finnish archaeological sites from later periods, such as the Iron Age, with its higher quantities of archaeological bone assemblages. This effort would enable a comparison of the results of zooarchaeological analysis and organic residue analysis to a greater extent. It would also be interesting to study the changes that occurred throughout the Stone Age until the arrival of glazed pottery in a limited geographical area, such as a river valley. Thus, one could hopefully observe the changes caused by environmental issues, such as a post-glacial rebound and changing climate, and changes caused by human cultural shifts. Another suggestion for futures studies would be to investigate the correlation between vessel form, decoration, and the found organic residues. This focus, however, would require having well documented ceramic material where several sherds from different parts of a vessel's rim and body could be connected to a single vessel. These vessels should have a sufficient amount of surviving body sherds for the researcher to be able to identify decoration patterns and the vessel size. At least in Finland, this kind of material is rarely found, or it is poorly documented. Nevertheless, organic residue analysis has been proven to be a useful tool when tracing food procurement patterns through prehistory. Thus, hopefully in the future, similar studies focusing on Finnish and Norwegian material will continue.

The findings presented in this thesis have shown that food procurement patterns in Finland and North Norway were versatile during the Stone Age and Early Metal Period. Hunting and gathering were found to be the common denominator between all the studied cultures even after agricultural practises appeared and were used.

Abbreviations

APAA	ω-(*o*-alkylphenyl)alkanoic acid
BF_3-MeOH	boron trifluoride-methanol
BSTFA	*N,O*-bis(trimethylsilyl)trifluoroacetamide
$C_{16:0}$	palmitic acid
$C_{18:0}$	stearic acid
$CHCl_3$	chloroform
$\delta^{13}C$	stable carbon isotope
$\Delta^{13}C$	proxy for $\delta^{13}C_{18:0}$-$\delta^{13}C_{16:0}$
DHYA	dihydroxy fatty acid
GC	gas chromatography
GC-C-IRMS	gas chromatography-combustion-isotope ratio mass spectrometry
GC-MS	gas chromatography mass spectrometry
FAME	fatty acid methyl ester
IFA	isoprenoid fatty acid
IT	Imitated Textile Ware
MeOH	methanol
m/z	mass-to-charge ratio
NaOH	sodium hydroxide
NISP	number of identified specimens
SIM	selected-ion monitoring
Sär 1	Säräisniemi 1 Ware
Sär 2	Säräisniemi 2 Ware
TMTD	4,8,12-trimethyltridecanoic acid
VPDB	Vienna Pee Dee Belemnite

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Appendices

Appendix 1. Description of the studied sherds. The following abbreviations were used to describe the biomarker composition of the vessels:

FFA – free fatty acids
APAAs – ω-(*o*-alkylphenyl)alkanoic acids
TMTD – 4,8,12-trimethyltridecanoic acid
Phy – phytanic acid
Pris – pristanic acid
DHYA – dihydroxy acids
di – dicarboxylic acids in the carbon chain length $C_{5:0}$ to $C_{10:0}$
br – branched chain fatty acids
? – uncertain identification of biomarker due to low abundance

Vessels MB10 and SÄR16 are represented as a strikethrough because the isotopic value indicated contamination; these vessels were not included in the discussion. Vessels without interpretation were screened with GC, but they contained phthalate esters that originated from plastic, constituting a modern contamination that was introduced during storage. Thus, these vessels were not studied further with GC-MS and GC-C-IRMS. Vessel LN58 was found at a site with Swedish Pitted Ware, but it also has the characteristics of Kiukainen Ware. * = sherd resembling Risvik pottery. In addition, some vessels contained lipids that were not related to food consumption, production, or storage, i.e., compounds related to pine tar or resins and other similar compounds. These other lipid classes are not listed in the table or discussed in this thesis.

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
Comb Ware							
CC1	TYA 116: 876	Kokemäki Kraviojankangas	-26.3	-25.7	0.6	FFA($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$–$C_{18:0Br}$	Non-ruminant, Aquatic?
CC2	TYA 151:1357	Kokemäki Kraviojankangas					
CC3	TYA 116: 980	Kokemäki Kraviojankangas					
CC4	TYA 116:717	Kokemäki Kraviojankangas					
CC5	TYA 151:1331	Kokemäki Kraviojankangas	-26.2	-25.8	0.5	FFA($C_{14:0}$–$C_{18:0}$); C_{18}–C_{20} APAAs; TMTD; Pris; Phy; C_{16} DHYAs?	Aquatic
CC6	TYA 151:1357	Kokemäki Kraviojankangas	-24.1	-25.8	-1.7	FFA($C_{14:0}$–$C_{18:0}$); $C_{17:0Br}$	Ruminant (Reindeer/Wild forest reindeer)
CC7	TYA 151:1331	Kokemäki Kraviojankangas					
CC8	TYA 116:620	Kokemäki Kraviojankangas	-29.1	-30.8	-1.7	FFA($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$	Ruminant (Eurasian elk)
CC9	TYA 116:977	Kokemäki Kraviojankangas					
CC10	TYA 151:1204	Kokemäki Kraviojankangas					
CC11	TYA 116:896	Kokemäki Kraviojankangas	-25.3	-24.3	1.0	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{18:0Br}$; C_{16}–C_{20} APAAs; TMTD; Phy	Aquatic
CC12	TYA 116:836	Kokemäki Kraviojankangas					
CC13	TYA 116:444	Kokemäki Kraviojankangas					
CC14	TYA 116:686	Kokemäki Kraviojankangas	-26.1	-26.8	-0.7	FFA($C_{16:0}$–$C_{18:0}$); C18 APAAs	Non-ruminant?, Aquatic?
CC15	TYA 151:1357	Kokemäki Kraviojankangas	-26.3	-28.3	-2.0	FFA($C_{14:0}$–$C_{20:0}$); $C_{15:0Br}$–$C_{18:0Br}$; C_{16}–C_{18} APAAs; TMTD; Phy; C_{16}–C_{18} DHYAs	Ruminant (Reindeer/Wild forest reindeer)
CC16	TYA 116:969	Kokemäki Kraviojankangas	-26.5	-27.9	-1.4	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18} APAAs; TMTD; Phy; C_{20} DHYAs?	Ruminant, Aquatic?
CC17	TYA 116:1005	Kokemäki Kraviojankangas	-26.0	-25.9	0.2	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0B}$; C_{16}–C_{20} APAAs; C_{16}–C_{20} DHYAs	Aquatic?

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
CC18	TYA 116:742	Kokemäki Kraviojankangas					
CC19	TYA 151:1224	Kokemäki Kraviojankangas					
CC20	TYA 116:518	Kokemäki Kraviojankangas	-24.7	-26.1	-1.4	FFA($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$; C_{18} APAAs; Phy	Ruminant? (Reindeer/Wild forest reindeer?), Aquatic?
CC21	TYA 151:1357	Kokemäki Kraviojankangas					
CC22	TYA 151:1331	Kokemäki Kraviojankangas					
CC23	TYA 151:1331	Kokemäki Kraviojankangas	-24.7	-24.7	-0.1	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{16}–C_{20} APAAs; TMTD; Phy; C_{18} DHYAs	Aquatic
CC24	TYA 151:1357	Kokemäki Kraviojankangas					
CC25	TYA 116:742	Kokemäki Kraviojankangas	-26.8	-29.2	-2.4	FFA($C_{12:0}$–$C_{20:0}$); $C_{16:0Br}$–$C_{18:0Br}$; C_{18} APAAs; TMTD; Phy	Ruminant (Reindeer/Wild forest reindeer)
CC26	TYA 151:1331	Kokemäki Kraviojankangas	-25.3	-24.7	0.6	FFA($C_{16:0}$–$C_{18:0}$); $C_{17:0Br}$; Phy	Non-ruminant, Aquatic?
CC27	TYA 151:1331	Kokemäki Kraviojankangas					
CC28	TYA 151:1186	Kokemäki Kraviojankangas					
CC29	TYA 151:1331	Kokemäki Kraviojankangas					
CC30	TYA 151:216	Kokemäki Kraviojankangas					
CC31	TYA 151:1331	Kokemäki Kraviojankangas					
CC32	TYA 116:734	Kokemäki Kraviojankangas					
CC33	SatM 18620:10	Pomarkku Myllytörmä/Patakoski	-26.7	-28.7	-2.0	FFA($C_{13:0}$–$C_{20:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{16}–C_{20} APAAs; C_{22} APAAs?; TMTD; Phy; C_{20} DHYAs?	Aquatic?, Ruminant (Reindeer/Wild forest reindeer?)
CC34	SatM 18620:11	Pomarkku Myllytörmä/Patakoski	-26.2	-28.6	-2.4	FFA($C_{15:0}$–$C_{18:0}$); C_{18} APAAs	Ruminant (Reindeer/Wild forest reindeer)

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
CC35	SatM 18620:6	Pomarkku Myllytörmä/Patakoski	-25.8	-28.4	-2.7	FFA($C_{12:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{16}–C_{18} APAAs	Ruminant (Reindeer/Wild forest reindeer)
CC36	SatM 18620:18	Pomarkku Myllytörmä/Patakoski	-26.4	-29.6	-3.2	FFA($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Ruminant (Reindeer/Wild forest reindeer?)
CC37	SatM 18620:7	Pomarkku Myllytörmä/Patakoski	-26.8	-30.0	-3.2	FFA($C_{14:0}$–$C_{20:0}$)	Ruminant (Reindeer/Wild forest reindeer?)
CC38	SatM 18620:14	Pomarkku Myllytörmä/Patakoski	-26.4	-28.0	-1.7	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{16}–C_{18} APAAs; Phy	Ruminant (Reindeer/Wild forest reindeer)
CC39	SatM 18620:29	Pomarkku Myllytörmä/Patakoski	-26.1	-28.8	-2.7	FFA($C_{14:0}$–$C_{18:0}$); $C_{17:0Br}$; C_{18} APAAs; C_{18}–C_{20} DHYAs	Ruminant (Reindeer/Wild forest reindeer)
CC40	SatM-18620:28	Pomarkku Myllytörmä/Patakoski					
CC41	SatM-18620:2	Pomarkku Honkakoski					
CC42	SatM 18620:50	Pomarkku Myllytörmä/Patakoski	-28.9	-30.3	-1.4	FFA($C_{14:0}$–$C_{18:0}$); $C_{17:0Br}$	Ruminant (Eurasian elk)
CC43	SatM-18620:2	Pomarkku Myllytörmä/Patakoski					
CC44	SatM 18620:17	Pomarkku Myllytörmä/Patakoski	-25.7	-26.7	-1.0	FFA($C_{14:0}$–$C_{18:0}$); $C_{17:0Br}$; C_{16}–C_{18} APAAs	Non-ruminant?, Aquatic?
CC45	SatM 18620:49	Pomarkku Myllytörmä/Patakoski	-27.0	-26.1	0.9	FFA($C_{14:0}$–$C_{18:0}$)	Non-ruminant, Aquatic?
CC46	SatM-18620:27	Pomarkku Myllytörmä/Patakoski					
Jäkärlä Ware							
JAK1	TYA 208:35	Turku Jäkärlä					
JAK2	TYA 208:57	Turku Jäkärlä					
JAK3	TYA 194:73	Turku Jäkärlä					
JAK4	TYA 194:11	Turku Jäkärlä	-27.0	-26.5	0.5	FFA($C_{9:0}$–$C_{20:0}$); $C_{15:0Br}$–$C_{18:0Br}$; Pris; Phy	Aquatic?, Non-ruminant
JAK5	TYA 194:8	Turku Jäkärlä					
JAK6	TYA 194:37	Turku Jäkärlä					
JAK7	TYA 313:28	Turku Jäkärlä	-26.9	-26.4	0.5	FFA($C_{14:0}$–$C_{18:0}$); C_{18} APAAs; TMTD; Pris; Phy	Aquatic
JAK8	TYA 208:48	Turku Jäkärlä					
JAK9	TYA 313:36	Turku Jäkärlä					
JAK10	TYA 313:72	Turku Jäkärlä					

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
JAK11	TYA 313:38	Turku Jäkärlä	-27.1	-26.0	1.1	FFA($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$–$C_{18:0Br}$	Non-ruminant, Aquatic?
JAK12	TYA 208:187	Turku Jäkärlä					
JAK13	TYA 313:49	Turku Jäkärlä					
JAK14	TYA 313:40	Turku Jäkärlä					
JAK15	TYA 194:58	Turku Jäkärlä	-26.4	-25.5	0.9	FFA($C_{14:0}$–$C_{24:0}$); $C_{16:0Br}$–$C_{18:0Br}$; C_{18} APAAs	Aquatic?
JAK16	TYA 194:28	Turku Jäkärlä					
JAK17	TYA 194:46	Turku Jäkärlä					
JAK18	TYA 208:35	Turku Jäkärlä	-27.9	-30.1	-2.2	FFA($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18} APAAs?	Ruminant (Eurasian elk?)
Kiukainen Ware							
LN1	TYA 245:42	Turku Kotirinne	-23.3	-23.4	-0.1	FFA ($C_{12:0}$–$C_{23:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris	Aquatic?
LN2	TYA 239:397	Turku Kotirinne	-25.3	-24.7	0.6	FFA ($C_{14:0}$–$C_{21:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; C_{16}–C_{18} DHYAs	Aquatic
LN3	TYA 245:76	Turku Kotirinne	-26.4	-28.4	-2.0	FFA ($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$; C_{18}–C_{20} APAAs; phy; C_{16}–C_{22} DHYAs	Ruminant?, Aquatic?
LN4	TYA 582: 38	Turku Kotirinne	-25.2	-24.9	0.3	FFA ($C_{14:0}$–$C_{20:0}$); C_{18} APAA; TMTD; phy; pris	Non-ruminant
LN5	TYA 489: 48	Turku Kotirinne	-27.3	-30.9	-3.6	FFA ($C_{14:0}$–$C_{20:0}$); $C_{16:0Br}$–$C_{17:0Br}$; phy	Dairy
LN6	TYA 446:532	Turku Kotirinne					
LN7	TYA 245: 391	Turku Kotirinne	-27.0	-25.6	1.5	FFA ($C_{14:0}$–$C_{18:0}$)	Non-ruminant
LN8	TYA 331:1183	Turku Kotirinne	-25.5	-24.5	0.9	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
LN9	TYA 239: 147	Turku Kotirinne	-26.1	-27.2	-1.0	FFA ($C_{14:0}$–$C_{20:0}$); phy; pris; C_{16}–C_{18} DHYAs	Non-ruminant
LN10	TYA 331:79	Turku Kotirinne	-23.5	-24.3	-0.8	FFA ($C_{14:0}$–$C_{20:0}$); $C_{16:0Br}$–$C_{18:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}–C_{18} DHYAs	Aquatic
LN11	TYA 287:92	Turku Kotirinne					
LN12	TYA 331:1055	Turku Kotirinne	-26.2	-25.9	0.3	FFA ($C_{14:0}$–$C_{24:0}$); C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}, C_{18}?, C_{20}? DHYAs	Aquatic
LN13	TYA 331:410	Turku Kotirinne	-26.7	-29.3	-2.6	FFA ($C_{14:0}$–$C_{22:0}$); $C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}–C_{18} DHYAs	Aquatic, Ruminant
LN14	TYA 331:258	Turku Kotirinne					
LN15	TYA 239: 546	Turku Kotirinne	-25.7	-25.6	0.1	FFA ($C_{14:0}$–$C_{20:0}$); C_{18} APAAs; TMTD; pris; C_{16}–C_{18} DHYAs	Non-ruminant?
LN16	TYA 582:393	Turku Kotirinne	-26.0	-25.6	0.4	FFA ($C_{14:0}$–$C_{20:0}$); C_{18}–C_{22} APAAs; TMTD; phy; pris; C_{16}–C_{22} DHYAs	Aquatic

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
LN17	TYA 582:485	Turku Kotirinne	-25.0	-25.5	-0.5	FFA ($C_{14:0}$–$C_{18:0}$); $C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; C_{16}–C_{20} DHYAs	Aquatic
LN18	TYA 582:552	Turku Kotirinne	-24.0	-25.3	-1.3	FFA ($C_{16:0}$–$C_{24:0}$)	Ruminant
LN19	TYA 331:428	Turku Kotirinne	-24.9	-24.9	0.0	FFA ($C_{14:0}$–$C_{18:0}$)	Non-ruminant
LN20	TYA 331:367	Turku Kotirinne					
LN21	TYA 239:6	Turku Kotirinne	-26.4	-25.7	0.7	FFA ($C_{14:0}$–$C_{20:0}$); $C_{15:0Br}$, $C_{17:0Br}$; C_{18}–C_{22} APAAs; TMTD; phy; pris; C_{16}–C_{22} DHYAs	Aquatic
LN22	TYA 582:35	Turku Kotirinne	-23.9	-24.2	-0.2	FFA ($C_{14:0}$–$C_{18:0}$); phy	Non-ruminant
LN23	TYA 582:336	Turku Kotirinne	-25.6	-26.3	-0.8	FFA ($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$, $C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}–C_{18} DHYAs	Aquatic, Non-ruminant?
LN24	TYA 245:349	Turku Kotirinne					
LN25	TYA 582:54	Turku Kotirinne					
LN26	TYA 239: 38	Turku Kotirinne					
LN27	TYA 582: 323	Turku Kotirinne					
LN28	TYA 239: 566	Turku Kotirinne					
LN29	TYA 331:1195	Turku Kotirinne	-25.9	-26.3	-0.3	FFA ($C_{14:0}$–$C_{20:0}$); $C_{16:0Br}$, $C_{17:0Br}$; C_{18}–C_{22} APAAs; TMTD; pris; C_{16}–C_{22} DHYAs	Aquatic
LN30	TYA 331:1135	Turku Kotirinne					
LN31	TYA 582: 247	Turku Kotirinne					
LN32	TYA 245:12	Turku Kotirinne					
LN33	TYA 245:426	Turku Kotirinne	-25.5	-25.3	0.3	FFA ($C_{14:0}$–$C_{20:0}$); $C_{15:0Br}$, $C_{17:0Br}$; C_{18} APAAs; TMTD; C_{16}–C_{22} DHYAs	Aquatic
LN34	TYA 489:120	Turku Kotirinne	-23.7	-24.1	-0.4	FFA ($C_{14:0}$–$C_{20:0}$); C_{18}–C_{22} APAAs; TMTD; phy; pris; C_{16}–C_{22} DHYAs	Aquatic
LN35	TYA 331: 435	Turku Kotirinne	-22.9	-21.5	1.4	FFA ($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$, $C_{18:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; C_{16}–C_{22} DHYAs	Aquatic
LN36	TYA 331: 998	Turku Kotirinne	-24.8	-24.5	0.3	FFA ($C_{12:0}$–$C_{20:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}–C_{18}, C_{20}? DHYAs	Aquatic
LN37	TYA 331:1126	Turku Kotirinne					
LN38	SatM-2658	Kiukainen Uotinmäki	-25.5	-24.6	0.9	FFA ($C_{14:0}$–$C_{18:0}$); C_{16}–C_{18}, C_{20}? DHYAs	Non-ruminant?
LN39	SatM-8157	Kiukainen Uotinmäki	-25.8	-25.1	0.7	FFA ($C_{14:0}$–$C_{18:0}$); C_{18}–C_{20} APAAs; TMTD; phy; C_{16}–C_{18} DHYAs	Aquatic?

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
LN40	SatM-8647	Kiukainen Uotinmäki	-24.5	-27.4	-2.8	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs; TMTD; phy; C_{16}–C_{18} DHYAs	Ruminant
LN41	SatM-8160	Kiukainen Uotinmäki	-25.5	-26.1	-0.6	FFA ($C_{12:0}$–$C_{18:0}$); C_{18} APAAs; TMTD; C_{16}–C_{18} DHYAs	Non-ruminant
LN42	SatM-8165	Kiukainen Uotinmäki					
LN43	SatM-8162	Kiukainen Uotinmäki	-26.3	-28.6	-2.3	FFA ($C_{14:0}$–$C_{20:0}$); C_{18} APAAs; TMTD; C_{16}–C_{18} DHYAs	Ruminant
LN44	SatM-10029	Kiukainen Uotinmäki	-25.5	-28.6	-3.1	FFA ($C_{12:0}$–$C_{20:0}$);$C_{15:0Br}$–$C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; pris; C_{16}–C_{18} DHYAs	Ruminant, Aquatic
LN45	SatM-8167	Kiukainen Uotinmäki	-28.2	-28.1	0.1	FFA ($C_{14:0}$–$C_{20:0}$); $C_{15:0Br}$, $C_{17:0Br}$; C_{18} APAAs; TMTD	Non-ruminant
LN46	SatM-8166	Kiukainen Uotinmäki	-27.1	-25.9	1.2	FFA ($C_{10:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
LN47	SatM-8170	Kiukainen Uotinmäki	-26.2	-24.9	1.3	FFA ($C_{12:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
LN48	SatM-10024	Kiukainen Uotinmäki	-25.3	-26.8	-1.5	FFA ($C_{12:0}$–$C_{22:0}$),$C_{17:0Br}$; C_{18}–C_{22} APAAs; TMTD; phy; pris; C_{16}–C_{20} DHYAs	Aquatic, Ruminant?
LN49	SatM-8159	Kiukainen Uotinmäki					
LN50	SatM-11888	Kiukainen Uotinmäki	-25.6	-26.3	-0.6	FFA ($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18}–C_{20} APAAs; TMTD; phy; C_{16}–C_{20} DHYAs	Non-ruminant, Aquatic
LN51	SatM-8158	Kiukainen Uotinmäki	-26.2	-27.8	-1.6	FFA ($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; C_{18} APAAs; TMTD; phy; C_{16}–C_{18} DHYAs	Ruminant
LN52	SatM-8180	Kiukainen Uotinmäki	-25.2	-25.6	-0.4	FFA ($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$, $C_{17:0Br}$; C_{18} APAAs; TMTD; phy; C_{16}–C_{20} DHYAs	Non-ruminant?, Aquatic?
LN53	SatM-8169	Kiukainen Uotinmäki	-21.5	-20.4	1.1	FFA ($C_{14:0}$–$C_{24:0}$)	Aquatic
LN54	SatM-10023	Kiukainen Uotinmäki					
LN55	SatM-10025	Kiukainen Uotinmäki					
LN58	ÅM 642:1	Saltvik Härdalen 21.11	-27.0	-29.4	-2.4	FFA ($C_{14:0}$–$C_{24:0}$)	Ruminant
Swedish Pitted Ware							
LN57	ÅM 649:110	Saltvik Härdalen 21.11	-23.9	-24.2	-0.3	FFA ($C_{14:0}$–$C_{24:0}$); C_{18}–C_{20} APAAs; TMTD; pris; C_{16}–C_{20} DHYAs	Aquatic
Corded Ware							
CW1	TYA 208:170	Turku Jäkärlä					
CW2	TYA 256:6	Piikkiö Isohepojoki Lausmäki					

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
CW3	TYA 427:14	Turku Jäkärlä	-26.2	-29.8	-3.6	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs; pris?; C_{16}–C_{18} DHYAs	Dairy
CW4	TYA 427:51	Turku Jäkärlä	-25.4	-22.5	2.8	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Aquatic, Non-ruminant
CW5	TYA 478:4	Västanfjärd Galtarby II	-24.5	-23.2	1.2	FFA ($C_{16:0}$–$C_{20:0}$); C_{18} APAAs; C_{16}?, C_{18}? DHYAs	Aquatic, Non-ruminant
CW6	TYA 478:20	Västanfjärd Galtarby II	-25.4	-27.5	-2.2	FFA ($C_{14:0}$–$C_{19:1}$); C_{18} APAAs; C_{16}? DHYAs	Ruminant
CW7	TYA 615:22	Turku Jäkärlä	-27.2	-26.1	1.1	FFA ($C_{14:0}$–$C_{18:0}$)	Non-ruminant
CW8	TYA 615:22	Turku Jäkärlä	-27.5	-30.4	-3.0	FFA ($C_{16:0}$–$C_{18:0}$)	Ruminant
CW9	KM 22008:146	Salo Märy Halikko					
CW10	KM 22008:157	Salo Märy Halikko					
CW11	KM 16288:59	Espoo Näkinkylä	-26.1	-26.9	-0.8	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
CW12	KM 21142:58	Siuntio Dalamalm					
CW13	KM 19914:594	Vantaa Jönsas-pohjoinen/itä Kaarela	-26.8	-24.5	2.3	FFA ($C_{14:0}$–$C_{19:1}$); C_{18} APAAs; C_{16} DHYAs	Non-ruminant, Aquatic?
CW15	KM 17281:289	Hämeenlinna Hauho Perkiö					
CW16	KM 22004:6400	Porvoo Böle Munkby	-27.4	-26.7	0.7	FFA ($C_{12:0}$–$C_{18:0}$), $C_{9:0di}$; C_{18} APAAs	Non-ruminant
CW17	KM 17281:149	Hämeenlinna Hauho Perkiö	-26.9	-28.6	-1.7	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Ruminant
CW18	KM 18564:38	Helsinki Malminkartano	-29.1	-28.9	0.2	FFA ($C_{14:0}$–$C_{19:1}$); C_{18} APAAs	Non-ruminant
CW19	KM9214:235	Lapinjärvi Malmbacken Norrby	-26.1	-30.2	-4.1	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Dairy
CW20	KM 21501:146	Kirkkonummi Tengo Nyåker	-25.4	-31.0	-5.6	FFA ($C_{14:0}$–$C_{22:0}$), $C_{18:0Br}$; C_{18}? DHYAs	Dairy
CW21	KM 22004:5911	Porvoo Böle Munkby	-23.9	-25.2	-1.2	FFA ($C_{16:0}$–$C_{18:0}$); C_{18}? DHYAs	Ruminant, Aquatic?
CW22	KM 22397:354	Inkoo Ragnvalds Tähtelä					
CW23	KM21501:151	Kirkkonummi Tengo Nyåker	-26.7	-28.0	-1.3	FFA ($C_{16:0}$–$C_{18:0}$); C_{18}? DHYAs	Ruminant

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
CW24	KM 22004:6127	Porvoo Böle Munkby					
CW25	KM9214:75	Lapinjärvi Malmbacken Norrby	-24.9	-27.0	-2.1	FFA ($C_{14:0}$–$C_{20:0}$); C_{18} APAAs	Ruminant
CW26	KM9214:62	Lapinjärvi Malmbacken Norrby	-28.2	-27.2	0.9	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
CW27	KM21501:92	Kirkkonummi Tengo Nyåker	-26.6	-31.3	-4.6	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Dairy
CW28	KM21501:78	Kirkkonummi Tengo Nyåker	-28.3	-30.9	-2.6	FFA ($C_{16:0}$–$C_{19:0}$); C_{18} APAAs	Ruminant
CW29	KM21501:107	Kirkkonummi Tengo Nyåker	-26.6	-26.5	0.1	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
CW30	KM16288:51	Espoo Näkinkylä	-26.9	-31.4	-4.5	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Dairy
CW31	KM 17073:272	Hämeenlinna Hauho Perkiö					
Bronze Age Ware							
BA1	KM 39506:1	Eura Kauttua	-26.6	-26.3	0.3	FFA ($C_{15:0}$–$C_{20:0}$), $C_{16:0Br}$–$C_{18:0Br}$; TMTD, pris	Non-ruminant
BA2	KM 39506:2	Eura Kauttua	-26.2	-26.2	0.0	FFA ($C_{16:0}$–$C_{20:0}$), $C_{17:0Br}$, $C_{18:0Br}$	Non-ruminant
Morby Ware							
LN56	ÅM 149:2	Jomala Dalkarlby	-28.6	-34.2	-5.6	FFA ($C_{14:0}$–$C_{20:0}$), $C_{17:0Br}$	Dairy
LN59	ÅM 165:1	Jomala Överby	-27.1	-32.3	-5.2	FFA ($C_{12:0}$–$C_{22:0}$), $C_{9:0di}$, $C_{17:0Br}$; C_{18} APAA; phy; C_{16}–C_{18} DHYAs	Dairy
LN60	ÅM 533:534	Finström Godby					
LN61	ÅM 533:535	Finström Godby	-29.2	-33.8	-4.6	FFA ($C_{14:0}$–$C_{20:0}$), $C_{17:0Br}$; C_{18} APAA	Dairy
LN63	ÅM 652:295	Jomala Överby 37.4	-28.8	-32.8	-4.0	FFA ($C_{14:0}$–$C_{20:0}$), $C_{17:0Br}$; C_{18} APAA; phy	Dairy
LN64	ÅM 652:283	Jomala Överby 37.4	-27.8	-32.9	-5.1	FFA ($C_{14:0}$–$C_{22:0}$), $C_{17:0Br}$; phy	Dairy
LN65	ÅM 652:128	Jomala Överby 37.4					
LN66	ÅM 652:80	Jomala Överby 37.4	-27.3	-29.0	-1.7	FFA ($C_{9:0}$–$C_{19:1}$), $C_{9:0di}$, $C_{16:0Br}$; C_{18} APAAs	Ruminant
LN67	ÅM 652:13	Jomala Överby 37.4	-27.0	-26.8	0.2	FFA (C_{14}–$C_{19:1}$), $C_{16:0Br}$, $C_{17:0Br}$; C_{18} APAAs	Non-ruminant
LN68	ÅM 652:193	Jomala Överby 37.4	-28.0	-30.9	-2.9	FFA ($C_{14:0}$–$C_{22:0}$); phy	Ruminant
LN69	ÅM 652:193	Jomala Överby 37.4	-27.5	-33.0	-5.6	FFA ($C_{14:0}$–$C_{18:0}$), $C_{15:0Br}$–$C_{17:0Br}$; phy; C_{16}–C_{18} DHYAs	Dairy
LN70	ÅM 652:206	Jomala Överby 37.4	-27.7	-30.1	-2.4	FFA ($C_{14:0}$–$C_{22:0}$); C_{18} APAAs; phy	Ruminant
LN71	ÅM 652:201	Jomala Överby 37.4	-28.2	-26.7	1.5	FFA ($C_{12:0}$–$C_{20:0}$), $C_{9:0di}$, $C_{16:0Br}$, $C_{17:0Br}$; C_{18} APAAs	Non-ruminant

Sample code	**Catalogue number**	**Site**	**$\delta^{13}C_{16:0}$**	**$\delta^{13}C_{18:0}$**	**$\Delta^{13}C$**	**Fatty acid composition**	**Identification**
LN72	ÅM 652:129	Jomala Överby 37.4	-32.3	-31.3	1.0	FFA ($C_{14:0}$–$C_{20:0}$)	Non-ruminant
MB1	TYA 665:90, 97	Turku Räntämäki Orhinkarsina	-23.3	-23.3	0.0	FFA ($C_{14:0}$–$C_{18:0}$),$C_{17:0Br}$; C_{18} APAAs; TMTD; pris; C_{16} DHYAs	Non-ruminant
MB21	TYA 34:1	Rauma Vermuntila Kaiku Kajantalo					
MB3	TYA 53:1	Nousiainen Koivumäki					
MB4	TYA 104:877	Lieto Pahka Pahamäki					
MB5	TYA 156:30	Rauma Vermuntila Kallio					
MB6	TYA 156:80	Rauma Vermuntila Kallio					
MB7	TYA 369:2	Piikkiö Moisio Moision Alitalo	-28.1	-30.1	-2.0	FFA ($C_{16:0}$–$C_{18:0}$); $C_{17:0Br}$; C_{18} APAAs; phy	Ruminant
MB8	TYA 860:6	Kemiönsaari Kåddböle	-26.8	-27.8	-1.0	FFA ($C_{12:0}$–$C_{19:1}$); C_{18} APAAs; C_{18}? DHYAs	Ruminant, Non-ruminant
MB9	TYA 112:7	Ulvila Suolisto Peltomäki	-26.1	-26.2	-0.1	FFA ($C_{16:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant
~~MB10~~	~~KM 19165:238~~	~~Espoo Bolarskog I~~	~~-26.3~~	~~-34.8~~	~~-8.5~~	~~FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs; phy~~	
MB11	KM 19165:307	Espoo Bolarskog I	-25.8	-28.3	-2.5	FFA ($C_{14:0}$–$C_{18:0}$); $C_{15:0Br}$–$C_{17:0Br}$; phy; C_{16}–C_{22} DHYAs	Ruminant, Aquatic?
MB12	KM 19165:314	Espoo Bolarskog I	-26.3	-32.3	-6.0	FFA ($C_{14:0}$–$C_{20:0}$); $C_{17:0Br}$; phy	Dairy
MB13	KM 19165:158	Espoo Bolarskog I	-24.1	-28.2	-4.1	FFA ($C_{12:0}$–$C_{18:0}$)	Dairy
MB14	KM 19165:185	Espoo Bolarskog I	-26.1	-32.2	-6.0	FFA ($C_{14:0}$–$C_{20:0}$); C_{18} APAAs; C_{18}? DHYAs	Dairy
MB16	KM 19165:228	Espoo Bolarskog I					
MB17	KM 19165:52	Espoo Bolarskog I	-29.8	-28.5	1.3	FFA ($C_{14:0}$–$C_{18:0}$); C_{18}? DHYAs	Non-ruminant
MB18	KM 19165:73	Espoo Bolarskog I					
MB21	KM 19165:14	Espoo Bolarskog I	-27.4	-33.4	-6.0	FFA ($C_{14:0}$–$C_{24:0}$); $C_{17:0Br}$; C_{18} APAA; C_{18}? DHYAs	Dairy

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
Kjelmøy Pottery							
SÄR1	C 21105/291c	Sørvaranger Mestersanden	-25.4	-24.0	1.4	FFA ($C_{12:0}$–$C_{24:0}$); $C_{9:0di}$; C_{16}–C_{18} APAAs	Non-ruminant?, Aquatic?
SÄR2	C 21105/309d	Sørvaranger Mestersanden	-34.1	-34.2	-0.1	FFA ($C_{14:0:}$–$C_{20:0}$); C_{16}–C_{18} APAAs; C_{18} DHYAs	Non-ruminanant?
SÄR4	C 21105/278	Sørvaranger Mestersanden	-22.3	-23.5	-1.2	FFA ($C_{12:0}$–$C_{20:0}$); $C_{9:0di}$; phy; C_{18}–C_{22} DHYAs	Aquatic?, Non-ruminant?
SÄR5	C 21105/311	Sørvaranger Mestersanden	-24.3	-23.1	1.3	FFA ($C_{12:0}$–$C_{20:0}$); $C_{9:0di}$; C_{16}–C_{20} APAAs; phy, pris; C_{18}–C_{22} DHYAs	Aquatic
SÄR6	UN 169	Sørvaranger Mestersanden	-23.4	-22.7	0.7	FFA ($C_{10:0}$–$C_{22:0}$); C_{16}–C_{22} APAAs; TMTD, phy, pris?; C_{18}–C_{22} DHYAs	Aquatic
SÄR7	UN 170	Sørvaranger Mestersanden	-22.1	-21.0	1.1	FFA ($C_{12:0}$–$C_{20:0}$); C_{16}–C_{22} APAAS; phy; C_{18}–C_{20} DHYAs	Aquatic
SÄR8	UN 172	Sørvaranger Mestersanden	-22.7	-20.8	1.9	FFA ($C_{12:0}$–$C_{20:1}$); $C_{9:0di}$; C_{18} APAAs; TMTD, phy, pris?; C_{16}–C_{18} DHYAs	Aquatic?, Non-ruminant?
SÄR9	UN 171	Sørvaranger Mestersanden	-24.3	-24.8	-0.5	FFA ($C_{12:0}$–$C_{24:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; pris?; C_{18}, C_{22} DHYAs	Aquatic
SÄR11	Ts 8761 La	Kautokeino Virdnejávri 106	-21.8	-24.2	-2.4	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$	Ruminant (Reindeer/Wild forest reindeer)
SÄR12	Ts 8761 Lp	Kautokeino Virdnejávri 106	-24.4	-27.1	-2.7	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$	Ruminant (Reindeer/Wild forest reindeer)
SÄR13	Ts 8761 ku	Kautokeino Virdnejávri 106	-22.4	-24.8	-2.4	FFA ($C_{14:0}$–$C_{24:0}$); $C_{9:0di}$	Ruminant (Reindeer/Wild forest reindeer)
SÄR14	Ts 8761 Lw	Kautokeino Virdnejávri 106	-22.9	-26.1	-3.1	FFA ($C_{14:0}$–$C_{22:0}$); $C_{9:0di}$; C_{18} APAAs	Ruminant (Reindeer/Wild forest reindeer)
~~**SÄR16**~~	~~Ts 8761 LL~~	~~Kautokeino Virdnejávri 106~~	~~-31.8~~	~~-27.1~~	~~4.7~~	~~FFA ($C_{14:0}$–$C_{26:0}$); C_{18}, C_{22} DHYAs~~	
SÄR17	Ts 8761 Lf	Kautokeino Virdnejávri 106	-22.5	-25.2	-2.7	FFA ($C_{14:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{20} APAAs	Ruminant (Reindeer/Wild forest reindeer)
SÄR21	Ts 4373 k	Sørvaranger Mestersanden	-26.7	-29.5	-2.8	FFA (C_{14}–C_{18}); C_{18} APAAs	Ruminant
SÄR22	Ts 6401:191	Nesseby Mortensnes	-23.3	-24.6	-1.3	FFA ($C_{12:0}$–$C_{20:0}$); C_{16}–C_{22} APAAs; TMTD, phy, pris; C_{18}–C_{22} DHYAs	Aquatic

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
Mica and Shell Tempered Ware							
SÄR3	C 21105/307	Sørvaranger Mestersanden	-23.5	-22.8	0.7	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$; C_{18}–C_{20} APAAs; phy, pris; C_{18}–C_{20} DHYAs	Aquatic
SÄR10A	UN 191	Sørvaranger Mestersanden	-24.2	-23.8	0.4	FFA ($C_{12:0}$–$C_{20:2}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; phy, pris; C_{16}–C_{22} DHYAs	Aquatic
SÄR10B	UN 191	Sørvaranger Mestersanden	-23.3	-22.7	0.6	FFA ($C_{12:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAS; phy, pris; C_{16}–C_{22} DHYAs	Aquatic
SÄR18	Ts 6321 ah	Sørvaranger Mestersanden	-23.6	-23.1	0.4	FFA ($C_{14:0}$–$C_{22:0}$); C_{16}–C_{22} APAAs; TMTD, phy, pris; C_{18}–C_{20} DHYAs	Aquatic
SÄR19	Ts 6321 dh	Sørvaranger Mestersanden	-24.3	-24.6	-0.3	FFA ($C_{12:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; TMTD, phy, pris; C_{16}–C_{22} DHYAs	Aquatic
SÄR20	Ts 6321 hh	Sørvaranger Mestersanden	-26.2	-25.2	1.0	FFA ($C_{14:0}$–$C_{18:0}$); TMTD, phy	Non-ruminant?
Imitated Textile Ware							
SÄR28	Ts 8229 m	Sørøysund Sandbukt Sørøy	-23.8	-23.7	0.2	FFA ($C_{14:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; TMTD, phy, pris; C_{16}–C_{22} DHYAs	Aquatic
SÄR29	Ts 8235 bm	Sørøysund Sandbukt Sørøy	-22.6	-25.9	-3.4	FFA ($C_{12:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; TMTD, phy, pris; C_{16}–C_{22} DHYAs	Aquatic, Ruminant (Reindeer/Wild forest reindeer)
SÄR30	Ts 8226 cr	Sørøysund Sandbukt Sørøy	-25.5	-25.1	0.4	FFA ($C_{12:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{18}, C_{22} APAAs; phy; C_{18}–C_{22} DHYAs	Aquatic
SÄR69	Ts 4033 4u	Træna Kirkhellaren					
Risvik Pottery							
SÄR23*	Ts 13792.6	Tromsø Sandvika					
SÄR24	Ts 3151	Steigen Bø	-26.4	-27.2	-0.9	FFA ($C_{12:0}$–$C_{18:0}$); C_{16}–C_{22} APAAs; pris; C_{18}, C_{20}?, C_{22} DHYAs	Aquatic
SÄR25	Ts 4066	Meløy Solheim Mesøy	-24.5	-25.8	-1.3	FFA ($C_{12:0}$–$C_{24:0}$); C_{16}–C_{22} APAAs; pris; C_{16}–C_{22} DHYAs	Aquatic
SÄR26	Ts 4190 a	Træna Røsnesvalen	-27.4	-32.9	-5.4	FFA ($C_{8:0}$–$C_{24:0}$); C_{18} APAAs; C_{18}–C_{20} DHYAs	Dairy
SÄR27	Ts 9736 b	Hamarøy Uteid	-26.9	-32.0	-5.1	FFA ($C_{14:0}$–$C_{24:0}$); $C_{9:0di}$; C_{16}–C_{18} APAAs	Dairy
SÄR61	Ts 3867 ddd	Træna Kirkhellaren					
SÄR62	Ts 3867 ccc	Træna Kirkhellaren					
SÄR63	Ts 4033 5g	Træna Kirkhellaren	-22.8	-22.4	0.4	FFA ($C_{14:0}$–$C_{22:0}$); C_{16}–C_{22} APAAs; phy; C_{18} DHYAs	Aquatic?
SÄR64	Ts 4033 5k	Træna Kirkhellaren	-26.1	-32.6	-6.4	FFA ($C_{14:0}$–$C_{24:0}$); C_{16}–C_{22} APAAs	Dairy, Aquatic?

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
SÄR65	Ts 4033 5h	Træna Kirkhellaren	-25.6	-30.1	-4.5	FFA ($C_{14:0}$–$C_{20:0}$); C_{16}–C_{22} APAAs; phy; C_{18} DHYAs	Dairy, Aquatic?
SÄR67	Ts 4033 5c	Træna Kirkhellaren					
SÄR71	Ts 9916 i	Meløy Texmoen	-23.7	-21.6	2.1	FFA ($C_{12:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs	Aquatic?
SÄR72	Ts 12150:3	Meløy Nedre Valla	-26.3	-30.1	-3.8	FFA ($C_{12:0}$–$C_{24:0}$); C_{16}–C_{22} APAAs; C_{18}–C_{22} DHYAs	Dairy, Aquatic
SÄR73	Ts 11945:061	Bodø Skålbunes	-27.6	-34.0	-6.4	FFA ($C_{14:0}$–$C_{24:0}$); C_{18} APAAs	Dairy
Sär 2 Ware							
SÄR31	KM 13289:2	Utsjoki Guatniljärvi	-21.4	-23.9	-2.4	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$; C_{16}–C_{18} APAAs; C_{18} DHYAs	Ruminant (Reindeer/Wild forest reindeer)
SÄR35	KM 14829:269	Suomussalmi Kalmosärkkä S	-27.8	-29.1	-1.3	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$	Ruminant (Eurasian elk)
SÄR36	KM 14829:353	Suomussalmi Kalmosärkkä S	-29.4	-28.3	1.1	FFA ($C_{12:0}$–$C_{20:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; C_{18}–C_{20} DHYAs	Aquatic, Non-ruminant?
SÄR37	KM 14830:1569	Suomussalmi Kalmosärkkä N	-28.9	-30.1	-1.2	FFA ($C_{12:0}$–$C_{24:0}$); $C_{9:0di}$; C_{18}–C_{20} APAAs; phy; C_{18} DHYAs	Non-ruminant?, Ruminant? (Eurasian elk)
SÄR38	KM 14830:1261	Suomussalmi Kalmosärkkä N	-29.0	-29.8	-0.8	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$; C_{16}–C_{20} APAAs	Aquatic?, Non-ruminant?
SÄR39	KM 14830:344	Suomussalmi Kalmosärkkä N	-29.5	-29.6	-0.1	FFA ($C_{14:0}$–$C_{22:0}$); $C_{9:0di}$; C_{18} DHYAs	Non-ruminant?
SÄR43	KM 16553:180	Kemijärvi Neitilä 4	-31.2	-32.4	-1.2	FFA ($C_{14:0}$–$C_{22:0}$); $C_{9:0di}$; C_{16}–C_{22} APAAs; TMTD, phy	Aquatic, Ruminant? (Eurasian elk)
SÄR45	KM 14830:1618	Suomussalmi Kalmosärkkä N	-28.4	-28.5	-0.1	FFA ($C_{14:0}$–$C_{20:0}$); $C_{9:0di}$; C_{18}–C_{20} DHYAs	Non-ruminant?
SÄR47	KM 14830: 671	Suomussalmi Kalmosärkkä N					
SÄR48	KM 14830:1014	Suomussalmi Kalmosärkkä N	-25.8	-27.3	-1.5	FFA ($C_{14:0}$–$C_{23:0}$); $C_{9:0di}$; C_{18}–C_{20} DHYAs	Ruminant (Reindeer/Wild forest reindeer)
SÄR49	KM 14830:926	Suomussalmi Kalmosärkkä N	-25.8	-26.8	-0.9	FFA ($C_{14:0}$–$C_{18:0}$); $C_{9:0di}$	Non-ruminant?, Ruminant? (Reindeer/Wild forest reindeer)
SÄR51	KM 14830:45	Suomussalmi Kalmosärkkä N	-25.7	-26.2	-0.5	FFA ($C_{14:0}$–$C_{18:0}$); C_{18} APAAs	Non-ruminant?, Ruminant? (Reindeer/Wild forest reindeer)
SÄR53	KM 14831:1414	Suomussalmi Kellolaisten Tuli	-30.4	-32.0	-1.5	FFA ($C_{14:0}$–$C_{24:0}$); $C_{9:0di}$; C_{20} APAAs; C_{18}–C_{20} DHYAs	Ruminant (Eurasian elk)

Sample code	Catalogue number	Site	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Fatty acid composition	Identification
SÄR54	KM 14831:1352	Suomussalmi Kellolaisten Tuli					
SÄR56	KM 14831:1304	Suomussalmi Kellolaisten Tuli					
SÄR57	KM 15671:447	Kemijärvi Neitilä 4					
SÄR59	KM 14831:406	Suomussalmi Kellolaisten Tuli					
SÄR60	KM 14830:782	Suomussalmi Kalmosärkkä N					

Appendix 2. Equation for calculating lipid concentration (1) and equation for correcting δ^{13}C values for addition of exogenous carbon (2).

Lipid concentration (in µg/g) of potsherds was calculated with following equation:

$$\text{concentration} = \frac{\left\{\frac{100 - \mathrm{A_{IS}} - \mathrm{A_{cont}}}{\mathrm{A_{IS}}}\right\} \mathrm{x}\ \mathrm{m_{IS}}}{\mathrm{m_{sherd}}} \tag{1}$$

where

A_{IS} = peak area (%) of internal standard
A_{cont} = peak area (%) of contamination in the sample
m_{IS} = mass of internal standard (µg)
m_{sherd} = mass of powdered potsherd (g)

The δ^{13}C values were corrected for the exogenous carbon added after methylation with following equation (Rieley 1994):

$$\delta^{13}\mathrm{C_{FA}} = \frac{\left((\mathrm{n}+1)\mathrm{x}\ \delta^{13}\mathrm{C_{FAME}}\right) - \delta^{13}\mathrm{C_{MeOH}}}{\mathrm{n}} \tag{2}$$

where

$\delta^{13}C_{FA}$ = corrected δ^{13}C value of the fatty acid (‰)
$\delta^{13}C_{FAME}$ = measured δ^{13}C value of the FAME (‰)
$\delta^{13}C_{MeOH}$ = correction factor for derivatising BF_3-MeOH or MeOH (‰)
n = carbon chain length of fatty acid

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