Estonian Journal of Archaeology, 2020, **24**, 1, 45–69
https://doi.org/10.3176/arch.2020.1.02

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# COOKING FOR THE LIVING AND THE DEAD: LIPID ANALYSES OF RAUŠI SETTLEMENT AND CEMETERY POTTERY FROM THE 11TH–13TH CENTURY

This paper is intended as a contribution to the understanding of Late Iron Age food consumption patterns and dietary preferences along the lower course of the River Daugava. The multidisciplinary study analysed the ceramic vessels from the 11th–13th century Rauši settlement and cemetery. We used lipid residue analysis employing GC-MS (gas chromatography-mass spectrometry), GC-C-IRMS (gas-chromatography-combustion-isotope ratio mass spectrometry) and bulk EA-IRMS (elemental analyser-isotope ratio mass spectrometry) of food-crusts for identifying vessel contents. The results are compared and assessed in the context of food refuse finds at the site, and the carbon and nitrogen isotopic baseline of River Daugava. Other evidence of dietary practices reported in previous research and historical sources is also integrated in the discussion.

The results point to the Liv burial pottery being taken directly from the household as a secondary use. The pottery analyses and bone refuse indicate that the people of Rauši mostly based their diet on fish, beef and milk. Pork, however, seems to have gone through alternative cooking practices like drying, curing or fermenting. Surprisingly none of the analysed pots had been used for extensive processing plant matter. Cultivated crops seem to have been used as a supplement to the protein rich diet.

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## Introduction

Ancient diet and food procurement strategies have long been in the focus of archaeological research (Bīrons et al. 1974; Rasiņš & Tauriņa 1983, 152–175). However, recent scientific research on the ancient diets in the eastern Baltic has mainly fallen on the Stone Age and the establishment of agrarian societies (Eriksson et al. 2003; Schmölcke et al. 2016; Meadows et al. 2018). Further discussions on diet in Iron Age Latvia, with rare exceptions (Zariņa 2015) has been left to speculation, with some preliminary examples from Estonia (Oras et al. 2018; Aguraiuja-Lätti & Lõugas 2019).

This is the first scientific study of Iron Age dietary practices in Latvia that combines various methods from different fields. We examine the material from the Rauši archaeological complex (settlement and cemetery) and provide a snapshot of Late Iron Age dietary practices in the region. The aim is to gain a deeper insight into the diet of the chosen society and, where possible, also into the food preparation preferences.

The Rauši settlement provides a good overview of food macro remains. Furthermore, previous research provides a possibility to compare our results with a closely related study of stable isotope analysis of the human skeletal material from Ikšķile cemetery (Zariņa 2015). Lipid residues, on the other hand, provide an insight into the direct food consumption and preparation in particular.

## Material

### *Rauši settlement and cemetery*

The case study looks at a site located on Dole Island, a centre of the Iron Age Daugava Liv population (Fig. 1). The island has been inhabited since the Bronze Age (Vasks & Zariņa 2014, 5, 29), but Rauši settlement and cemetery was in use mainly during the Late Iron Age (11th–13th century AD) (Šnore 1970, 63; 1996, 111 f.). Excavations in Rauši cemetery (next to the settlement) unearthed in total 169 burials, but most likely originally contained more, as some have been destroyed by looting (Šnore 1974, 68 f.; 1996, 114, 128). The cemetery mostly consists of flat graves, but some indications of barrows are present (Šnore 1974, 68; Spirģis 2008, 22, 32). Most burials were inhumations with occasional cremations (Šnore 1974, 68). The majority of inhumations date from 11th–13th century, with only a few exceptions from late 10th and early 14th century (Šnore 1991, 69; 1996, 114, 128).

Rauši settlement was used mostly during 11th–12th century, with a notable decrease of habitation during the 13th century and only a few items indicating continuous use during the 14th century (Daiga 1972, 61; Šnore 1991, 86). After Livs abandoned the settlement, it was only briefly used by the Swedish military during the 17th century (Šnore 1991, 86) .

The finds of bronze cauldrons, workshops (Daiga 1970, 30, 31; 1972, 63; Šnore 1970, 68; Daiga & Šnore 1971, 42) and a significant amount of beaver bones (fur

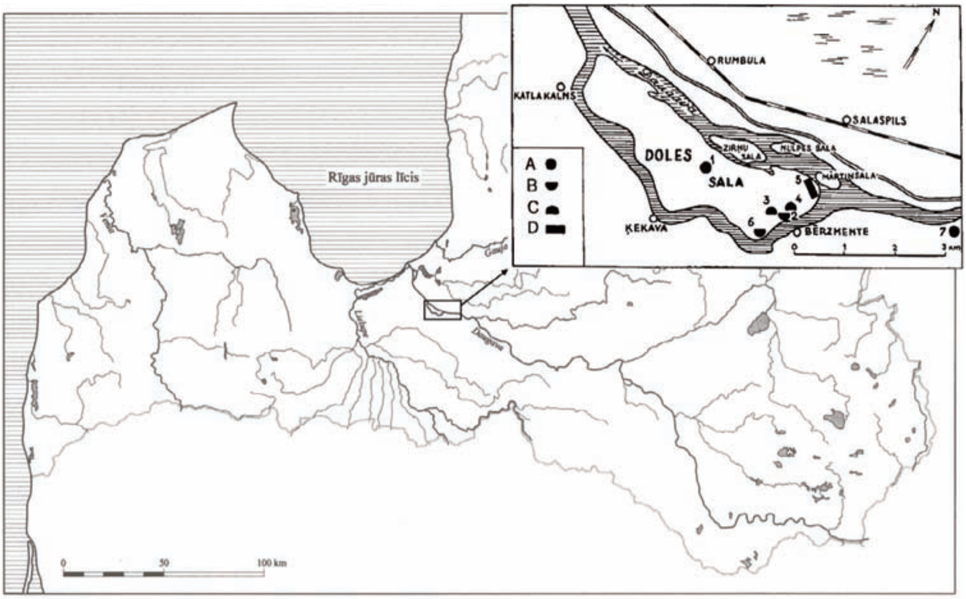

**Fig. 1.** Archaeological sites on Dole Island in River Daugava, Latvia. A – fortified settlement, B – cemetery, C – burial mound, D – village; 1 – Ķivutkalns hill-fort, 2 – Vampenieši I, 3 – Vampenieši II, 4 – Rauši cemetery, 5 – Rauši settlement, 6 – Dūdiņas cemetery, 7 – Daugmale hill-fort.

trade) indicate that Rauši was part of the trade network that was most prominent along the River Daugava. However, the lack of any direct trader's items (scales, weights) show that the settlement was not itself a trading place with merchants present who might have had different dietary preferences. Neither was it a residence of notable nobility.

During the excavation of Rauši settlement, the food waste macro remains (animal bones) were identified by species and noted in the documentation (INV Nr Pd 145-14). However, the complete excavation report for the settlement was never submitted. The documentation consists of yearly publications, a list of artefacts, drawings and different notes taken during the excavations. The bones were mostly redeposited and only a small selection remains in the Latvia National History Museum (LNVM) storage. Rauši settlement material has been sampled (2 samples) and analysed by Alfrēds Rasiņš and Marta Tauriņa as part of a larger study on cultivated plants and weeds in the archaeological material of Latvia (Rasiņš & Tauriņa 1983, 152–175).

## *Sampling*

Most of the pottery used in the site was the so-called Baltic ware. Pottery from the settlement and burials is visually indistinguishable. The burial pottery has the same use marks as the settlement pottery. Many of the pots have noticeable, thick food crust (Fig. 2). In some instances, the food crust/residue covers cracks and dents, which indicates repeated use (Fig. 3). As such, the pots found in burials appear to have been used repeatedly. Hence, on the basis of visual assessment, it seems that we see evidence of a reuse of the household pottery in the burials (see Rice 1992, 233).

Rauši settlement excavations in 1968–1974 (14 × 100 m and 30 × 70 m) extended along the bank of the River Daugava. Most disturbed by the 17th century military

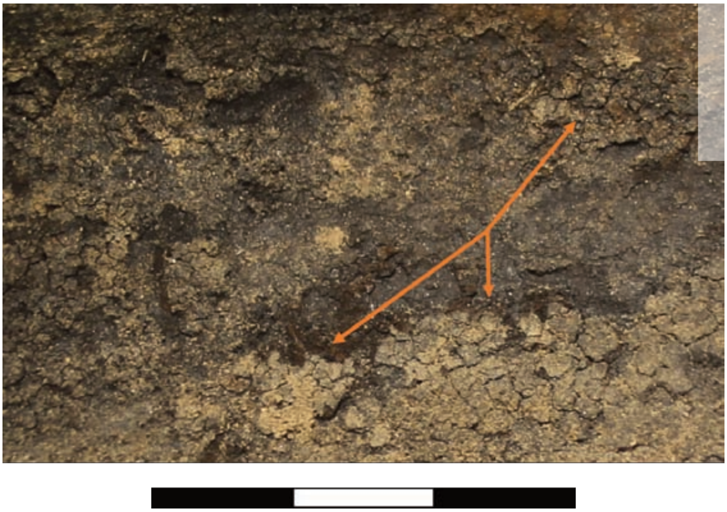

**Fig. 2.** Food crust on the pot in the 19th burial**.** LNVM, Archaeological department, Rauši cemetery, 19th burial, VI 146: 121.

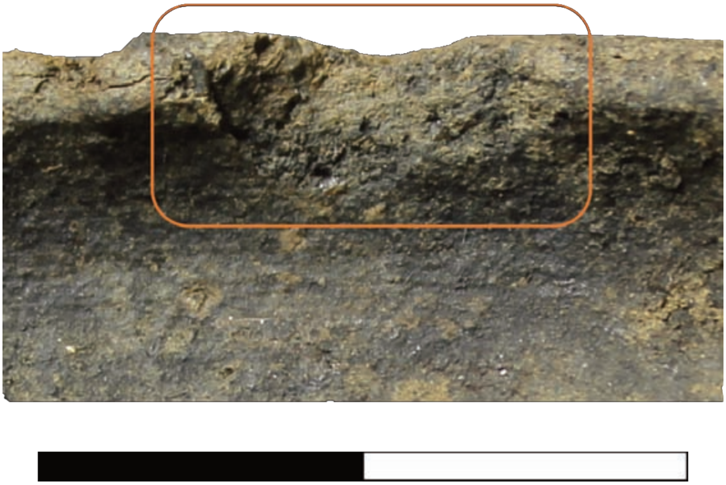

**Fig. 3.** A break with food residue on the pot in the 120th burial**.** LNVM, Archaeological department, Rauši cemetery, 120th burial, VI 146: 823.

activity was the farther SE part of the excavated area. All the samples presented in this study were taken from the middle of the excavated area which was the least disturbed by later activity (Šnore 1991, 86).

Samples for organic residue analysis of pottery from the settlement context were taken only from established features. This provides a certain context for each sample. Location in an undisturbed or minimally disturbed feature minimized the possibility of sampling one pot multiple times.

The features found in Rauši settlement were mainly composed of different types of hearths, food pits and stoves. Among them were also visible remains of buildings. The typological identification of the features was made based on the excavation notes, drawings, as well as publications by the leading archaeologists (Šnore 1970, 63 ff.; 1974, 68 ff.; 1991, 69 ff.; Zariņa 1978, 76 ff.; INV Nr PL 145-3:176, 178, 179, 184, 195, 197; INV Nr Pd 145-14; INV Nr Pd 145-1; INV Nr Pd 145-8).

In the excavation notes a list of excavated bones (fish, bird, large stock, small stock, sheep, pig, cow, horse, beaver, wild boar, deer or elk) was made for each feature. Preference for sampling pottery from a particular feature was given based on the composition of bone remains. The samples were predominantly taken from hearths (1st, 2nd, 3rd, 4th, 5th, 7th sample) (Table 1). One sample was also taken from a feature that is a combination of a hearth and an ash or offering pit at the bottom (6th sample). The features were mostly undisturbed with dating covering the period from the 10th till the 14th century. Based on the shape of the sampled pottery it was possible to narrow down the dataset to the 11th–13th century.

Where possible, samples were obtained from the neck and shoulder region of the pot. These had a potentially better lipid preservation (Evershed 2008a). In some cases the features of the shoulder shard (clay mass, thickness, pot size and curvature) allowed to conclude that it was from the same pot as another rim shard in the same pit, and thus avoid simultaneous sampling of the same vessel and provided a more precise relative dating of the sample (5th, 6th, 7th sample).

Samples were also collected from the Rauši cemetery. In the Late Iron Age Latvia, only Liv peoples had a tradition of placing whole pots in the burials. The pots were typically placed at the feet or head of the deceased (Zariņa 2006, 302). As not many burials contained pottery, the selection was narrowed down to available material. In total six samples were taken. Of these, five were from inhumation burials (9th, 10th, 11th, 12th, 13th sample) and one from a cremation burial (8th sample), with the pot added to the burial after the cremation had been carried out.

Two of the deceased were male, two female and one female child (sex ascribed based on grave goods) (Table 1). The sex of the deceased in the cremation burial is unknown. The child burial (13th sample) was located next to another burial (possibly a double burial), but each in a separate coffin (INV Nr PL 146-4:191; INV Nr PL 146-2:58, 66, 103; INV Nr PL 146-3:167, 170). Three burials (10th, 11th, 12th sample) had been disturbed by looting. This complicated the dating of the burial, but had minimal effect on the analysed pottery. Four of the burial pots can be dated to the 12th century, two to 12th–13th century (Table 1).

**Table 1.** List of samples with principal information

| Sample No. | Feature type | Feature No. | Feature (relative dating, centuries AD) | Sample (relative dating, centuries AD) |
|---|---|---|---|---|
| 1 | Hearth | 1 | 13th–14th | 13th |
| 2 | Hearth | 3 | 11th–13th | 11th–13th |
| 3 | Hearth | 7 | 12th–13th | 12th–13th |
| 4 | Hearth or Stove | 17 | 10th/11th–13th | 11th–13th |
| 5 | Hearth | 19 | 10th–14th | 12th–13th |
| 6 | Feature (hearth with a pit) | 134 | 10th–13th | 11th–13th |
| 7 | Hearth | 135 | 11th–13th | 12th–13th |
| 8 | Cremation | 120 | 12th–13th | 12th–13th |
| 9 | Inhumation | 11 | 12th–13th | 12th–13th |
| 10 | Inhumation | 19 | 11th–12th | 12th |
| 11 | Inhumation | 52 | 12th | 12th |
| 12 | Inhumation | 99 | 11th–13th | 12th |
| 13 | Inhumation | 102 | 12th | 12th |

LU LVI, Nr. Pd: 145-3: 176, 178, 179, 184, 195, 197.

LNVM, VI 145: 643a, 740, 946, 1144a, 1868-69, 1886, 2245, 2256-58, 2724-28, 2809, 2866.

## Methods

### *Sample preparation*

Lipid analysis was conducted for seven vessels from Rauši settlement and six vessels from the cemetery. For all the pots lipids absorbed into ceramic matrix were analysed, however, when available, food-crusts on the surface of the vessels were studied as well. Samples of food-crust were removed using clean scalpels. Ceramic matrix samples were taken with clean drill bits from the internal surface of the sherds: first removing and discarding the upper ca 1 mm layer to avoid any direct contamination, and then drilling into the sherd to remove up to 1 g of ceramic powder.

Lipid extraction was carried out from ca 1 g of ceramic powder or up to 20 mg of food-crust using acid-catalysed ($H_2SO_4$) methylation with methanol (MeOH) followed by heating on a heating block at 70 °C for 4 h (Craig et al. 2013; Heron et al. 2015). Lipids were extracted with *n*-hexane (3 × 2 ml) and dried under the gentle stream of nitrogen at 37.5 °C. Samples were dissolved in 100 ml of *n*-hexane with the addition of 10 µg of internal standard (*n*-hexatriacontane).

### *GC-MS and FID analysis*

GC-MS (gas chromatography-mass spectrometry) analysis for detecting different lipid molecules was conducted at the Institute of Chemistry (University of Tartu) with an Agilent 7890A Series gas chromatograph and Agilent 5975C Inert XL mass-selective detector with a DB5-MS (5%-phenyl)-methylpolysiloxane column (30 m × 0.25 mm × 0.25 µm). Injected sample size was 1 µl. The splitless injector and interface were maintained at 300 °C and 280 °C respectively, helium 6.0 was used as the carrier gas at a constant flow. The GC column was inserted directly into the ion source of the mass spectrometer. The ionization energy was 70 eV and spectra were obtained by scanning between *m/z* 50 and 800 amu. The temperature program was set as follows: 50 °C for 2 min, thereafter a gradient of 10 °C/min up to 325 °C and kept there for 6.5 min. Compounds were identified with Agilent Chemstation software using the NIST mass spectral library.

For estimating general preservation and quantity of lipids GC with flame ionization detector (FID) was employed using an Agilent 7890B Series gas chromatograph fitted with an Agilent DB-1HT GC column (PN: 123-1111; 15 m × 0.32 mm × 0.1 µm), at the University of York BioArCh facility prior to the GC-C-IRMS analyses. Injected sample size was 1 µl. The split/splitless injector was held at 300 °C and the injection performed in splitless mode with helium carrier gas set at constant pressure of 16.6 psi. The oven temperature programme was set at 100 °C for 2 min, then increasing to 325 °C at a rate of 20 °C/min then held at the final temperature for 3 min with the total run time of 16.25 min. The FID was heated to 300 °C with hydrogen flow of 30 ml min$^{-1}$, air flow of 400 ml min$^{-1}$, and makeup gas (nitrogen) flow of 25 ml min$^{-1}$.

### *Bulk IRMS analysis of food-crusts*

Bulk IRMS (isotope ratio mass spectrometry) analysis of food-crusts from a selection of pots was conducted at the Department of Geology at the University of Tartu with Thermo Scientific Delta V Plus + Thermo Finnigan Flash HT Plus instrument. The analysis aimed at determining $\delta^{13}$C and $\delta^{15}$N relative to VPDB and AIR standards as well as proportional contributions (%) of both C and N in the crust samples. About 1 mg food-crust sample was weighed into tin capsules and thereafter measured. The instrument precision and accuracy were controlled using standards of IAEA-N2 (the mean ± S.D. values within run 20.35 ± 0.024), IAEA-CH3 (−24.36 ± 0.14‰), IAEA-CH6 (−10.39 ± 0.056‰).

### *GC-C-IRMS analysis*

GC-C-IRMS (gas chromatography-combustion-isotope ratio mass spectrometry) analysis was conducted at the York BioArCh facility using acid extracted samples previously analysed with GC-MS and FID. The samples were analysed using an Agilent 7890B GC (Agilent Technologies, Santa Clara, CA, USA) instrument coupled to an Agilent 5975C MSD and an Isoprime 100 IRMS (Isoprime, Cheadle, UK) with an Isoprime GC5 combustion interface (Isoprime, Cheadle, UK). All samples were diluted with hexane and subsequently 1 µl of each sample was injected onto a DB-5MS UI (PN: 122-5562UI; 60 m × 0.25 mm × 0.25 µm) fused-silica column. The temperature was set at 50 °C for 0.5 min and raised by 25 °C min$^{-1}$ to 175 °C, then raised by 8 °C min$^{-1}$ to 325 °C where it was held for 10 min. The carrier gas was ultra-high purity grade helium with a flow rate of 3 ml min$^{-1}$. The gases eluting from the chromatographic column were split into two streams. One of these was directed into an Agilent 5975C inert mass spectrometer detector (MSD), for sample identification and quantification, while the other was directed through the GC5 furnace held at 850 °C to oxidize all carbon species to $CO_2$. A clear resolution and baseline separation of the analysed peaks was achieved in both systems.

Eluted products were ionized in the mass spectrometer by electron impact. Ion intensities of *m/z* 44, 45, and 46 were monitored in order to automatically compute the $^{13}C/^{12}C$ ratio of each peak in the extracts. Computations were made with IonVantage and IonOS Software (Isoprime, Cheadle, UK). The results from the analysis are reported in parts per mille (‰) relative to an international standard (V-PDB).

The accuracy and precision of the instrument was determined on *n*-alkanoic acid ester standards of known isotopic composition (Indiana standard F8-3). The mean ± S.D. values of these were −29.84 ± 0.05‰ and –23.53 ± 0.05‰ for the methyl ester of $C_{16:0}$ (reported mean value vs. VPDB –29.90 ± 0.03‰) and $C_{18:0}$ (reported mean value vs. VPDB –23.24 ± 0.01‰) respectively. Each sample was measured in replicate (mean of S.D. 0.17‰ (range of 0–0.69) for $C_{16:0}$ and 0.075‰ (range of 0.02–0.16) for $C_{18:0}$), with one sample – Rau 9a – left out from the final report due to high S.D. value (1.35‰) for $C_{16:0}$. Values were also corrected subsequent to analysis to account for the methylation of the carboxyl group that occurs during acid extraction. Corrections were based on comparisons with a standard mixture of $C_{16:0}$ and $C_{18:0}$ fatty acids of known isotopic composition processed in each batch under identical conditions.

### *IRMS analysis of animal bone collagen*

In order to provide a wider dietary background for the pottery-related organic residue results, collagen[1] stable isotope analysis were revisited in contemporaneous sites along River Daugava. C and N stable isotope baseline for River Daugava was established by analysis of archaeological fish bones from Daugmale hill-fort (approximately 10 km from Rauši settlement). Additionally, terrestrial animal bones from Daugmale hill-fort and Aizkraukle hill-fort (approximately 60 km from Rauši

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[1] Here and thereafter ‘collagen’ refers to the organic extract from bone samples that consist of mostly collagen with a small amount of other proteins.

settlement) were included in this study. Inhabitation of both hill-forts was contemporary with the Rauši site (Fig. 1).

Bones from Daugmale and Aizkraukle were sampled from the LNVM collections. Both collections were selected based on the preservation of the bones, sample availability and if the bones had been arranged by species. Only untreated bones were selected to avoid degraded and/or contaminated collagen that could be caused by chemicals that are frequently used in conservation process.

Given the fragility of the majority of samples – fish bones – bone collagen extraction was done with a relatively mild method, generally following laboratory protocol established by Longin (Longin 1971) with some modifications (Chisholm et al. 1983). Bone chunks were demineralized in 0.5M HCl solution over a course of days, depending on each individual sample. Repeated rinsing in a deionized $H_2O$ followed. 'Collagen' gelatinization was done in a pH=3 solution at ~72 °C for approx. 48 hours. The gelatine was filtered with 60–90 µm Ezee filters and freeze-dried. The collagen samples were then analysed for $\delta^{13}C$ and $\delta^{15}N$ with SerCon Callisto CF-IRMS system at the Research Laboratory for Archaeology and the History of Art, University of Oxford (RLAHA). Delta notation (δ) expresses ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ relative to the international standards V-BDP for carbon and AIR for nitrogen in parts per mille (‰). Standard deviations are <0.2‰ for $\delta^{13}C$ and <0.3‰ for $\delta^{15}N$, according to control protocols for CF-IRMS runs at the RLAHA.

Altogether, 30 bones were sampled – 22 fish bones of different species, including migratory, two domesticated pig bones from the Daugava hill-fort, and six terrestrial animal bones, including domesticated birds from the Aizkraukle hill-fort (Fig. 1). Only one sample failed to produce any organic matter. Two samples had organic extraction that failed one or more collagen purity standards. These three samples are therefore excluded from further discussion.

## Results

Relying on biomarker based GC-MS analysis it was possible to identify the origin of lipids in 14 samples out of 20 analysed in total. Several samples (1b, 2a, 3a–b, 4, 5a, 6a, 8a, 10a–b, 12b) included full aquatic biomarkers i.e. *ω*-(*o*-alkylphenyl) alkanoic acids (APAAs) with carbon atoms ranging from C16 to C20 formed during the heating of polyunsaturated fatty acids of aquatic organisms, which together with one of the isoprenoid fatty acids (phytanic, pristanic, and 4,8,12-trimethyltridecanoic (TMTD)) (Hansel et al. 2004; Craig et al. 2007) indicate that lipids of aquatic origin (fish or aquatic animals) have been processed in those vessels. For two samples (6b, 7a) partial aquatic biomarkers combining APAAs with 18 carbon atoms together with one of the isoprenoid fatty acids were identified. In sample 1a cholesterol as a biomarker for animal product (either aquatic or terrestrial) was the main bases of identification. There was no clear identification of typical plant biomarkers, although in sample 3b a slight indication of the possibility of including plant substance can be derived from the higher amount of $C_{18:1}$ fatty acid.

Additionally, the vast majority of samples included various terpenes: mainly abietic acid derivatives, but also betulin and lupenol (also phenanthrene dicarboxylic acid) and their derivatives, indicating coniferous trees and/or birch respectively being used as fuel during cooking (Aveling & Heron 1998; Lucquin et al. 2007). The long-chain ketones identified in sample 13a most likely relate to the heating of triacylglycerols (c.f. Raven et al. 1997). Ergostanol in the selection of samples is most likely fungal biomarker relating to later degradation processes of organic substances, which were also indicated by several oxo-products of fatty acids.

GC-C-IRMS results (Fig. 4) provide further information on the origin of food sources processed in the Rauši pots. In comparison with biomarker-based

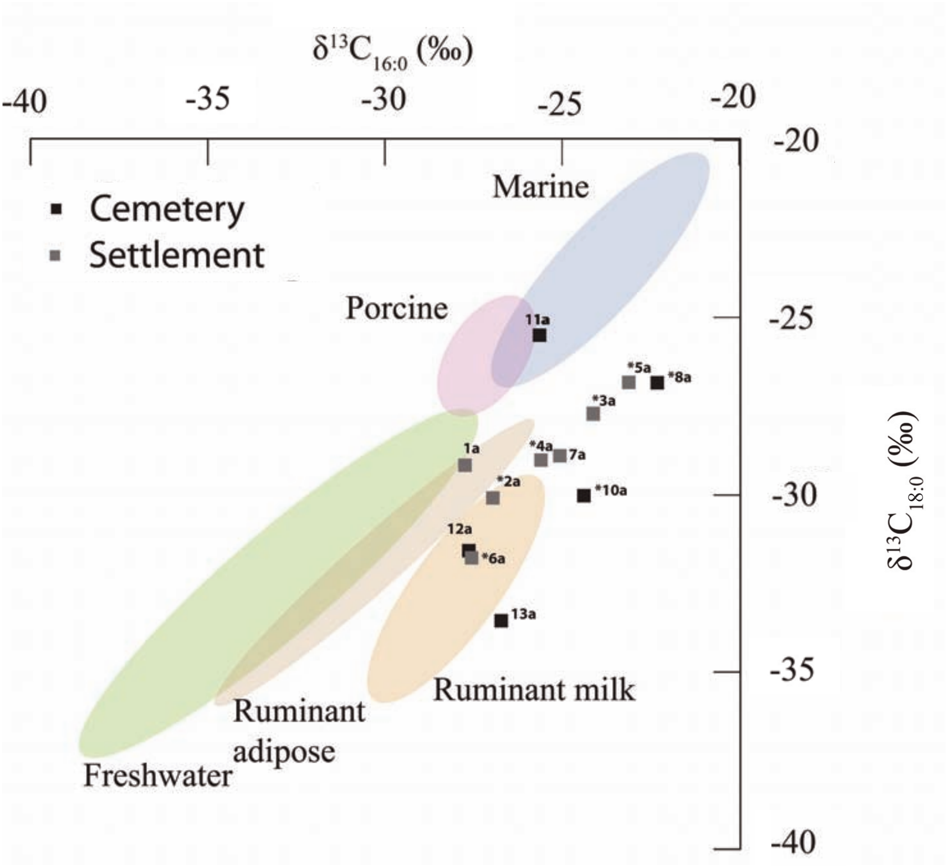

**Fig. 4.** Single compound stable isotope analysis (GC-C-IRMS results) of Rauši samples. (Plotted on newly established eastern Baltic reference data.) * indicates full aquatic biomarkers identified in the sample. The ellipses are derived from modern authentic reference animals and are plotted at 95% confidence (Dudd 1999; Oras unpublished; Oras et al. unpublished; Pääkkönen et al. accepted).

identification (showing aquatic biomarkers), based on isotopic measurements there is more clear evidence of ruminant milk as well as adipose tissues being processed, with only a single clear sample falling within the marine range. The porcine and freshwater organisms, as well as potential plants (expectedly plotting in the extreme depleted end of the freshwater ellipse) seem to be lacking. However, a large number of samples (six in total) fall out of the established reference fat ellipses. This is a phenomenon that most likely related to the mixing of different substances (e.g. Evershed 2008b), as previously established relating to the mixing of marine and terrestrial ruminant products (cf. Craig et al. 2011; Evershed 2008b). The latter is most likely the case in these Rauši samples as well, especially when considering the high number of full aquatic biomarkers noted in almost all of those out-of-ellipses samples with the GC-MS analysis.

Bulk IRMS (6 food-crust samples in total) results show relatively good correlation with GC-MS and GC-C-IRMS results (Fig. 5). The higher $\delta^{15}$N values and low C/N atomic ratio (ranging 18.9–13.2) for five samples indicate higher trophic level and richer protein content substances in these vessels. We are most likely seeing a combination of terrestrial animal and/or aquatic sources in these crust samples. However, one crust sample (No. 11c, an internal crust from a pot from burial 52) stands out for its low $\delta^{15}$N value and high C/N ratio, reaching 48.99. This indicates the carbohydrate-rich plant substances being present in this internal food-crust sample (Yoshida et al. 2013). Unfortunately, there is not enough material for detailed GC-MS analysis that would help to further identify the origin of the substance.

The animal bone collagen IRMS results provide an aquatic C and N stable isotope baseline of 19 fish samples (Table 2; Fig. 6). The analysed freshwater fish (bream, pike, zander, perch, chub, ide) show extremely varied $\delta^{13}$C values from –26.01 to –17.5 and untypically low $\delta^{15}$N values from 6.62 to 11.22. This is somewhat exacerbated by bottom feeders (bream, ide) having $\delta^{13}$C values from –26.01 to –18.39 and $\delta^{15}$N values from 6.62 to 10.98. The freshwater omnivore (perch, chub) $\delta^{13}$C values range from –22.07 to –17.50 and $\delta^{15}$N values from 9.68 to 10.42. The freshwater carnivores (pike, zander) $\delta^{13}$C values range from –21.25 to –25.42 and $\delta^{15}$N values from 9.47 to 10.89.

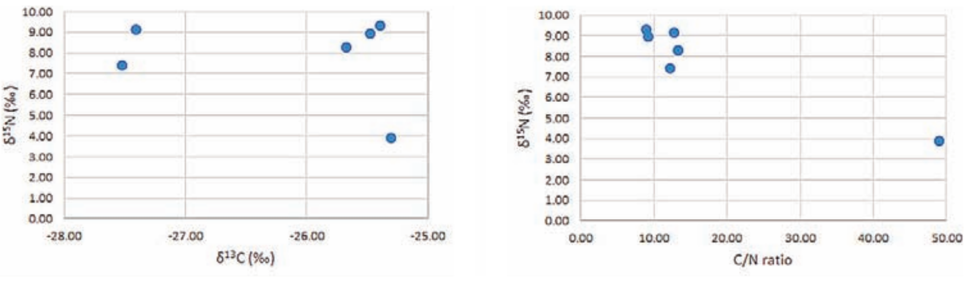

**Fig. 5.** Bulk IRMS analysis results of the Rauši food-crust samples.

**Table 2.** Bone collagen stable isotope analysis results from Daugmale and Aizkraukle

Daugmale hill-fort animal bone collagen

| Species | Sample No. | $\delta^{15}N$ | $\delta^{13}C$ | C/N | %N | %C |
|---|---|---|---|---|---|---|
| Bream (Abramis brama) | Dau1* | 7.6 | –25.8 | 3.2 | 15 | 42 |
| Sturgeon (Acipenseridae) | Dau2* | 10.4 | –17.7 | 3.3 | 16 | 46 |
| Bream (Abramis brama) | Dau3 | 6.6 | –25.5 | 3.2 | 16 | 44 |
| Pike (Esox lucius) | Dau4 | 11.2 | –21.3 | 3.3 | 13 | 38 |
| Pike (Esox lucius) | Dau5 | 10.5 | –22.2 | 3.4 | 11 | 31 |
| Pike (Esox lucius) | Dau6 | 10.9 | –21.7 | 3.4 | 16 | 46 |
| Sturgeon (Acipenseridae) | Dau7* | 10.4 | –17.2 | 3.4 | 15 | 43 |
| Zander (Lucioperca lucioperca) | Dau8* | 10.2 | –24.4 | 3.2 | 16 | 44 |
| Zander (Lucioperca lucioperca) | Dau9* | 9.5 | –25.4 | 3.4 | 12 | 37 |
| ~~Zander (Lucioperca lucioperca)~~ | ~~Dau10*~~ | ~~7.3~~ | ~~–25.6~~ | ~~5.1~~ | ~~3~~ | ~~11~~ |
| Perch (Perca fluviatilis) | Dau11 | 9.9 | –17.5 | 3.2 | 18 | 49 |
| Perch (Perca fluviatilis) | Dau12 | 9.7 | –20.7 | 3.3 | 17 | 48 |
| Perch (Perca fluviatilis) | Dau13 | 9.7 | –19.1 | 3.2 | 16 | 45 |
| Chub (Squalius cephalus) | Dau14 | 9.9 | –22.0 | 3.3 | 16 | 45 |
| Chub (Squalius cephalus) | Dau15 | 10.4 | –22.1 | 3.3 | 13 | 38 |
| Roach (Rutilus rutilus) | Dau16 | (no organic matter extracted) | | | | |
| Ide (Leuciscus idus) | Dau17 | 11 | –18.4 | 3.4 | 15 | 45 |
| Salmon (Salmo sala) | Dau18 | 7.6 | –16.5 | 3.3 | 12 | 34 |
| Whitefish (Coregonus lavaretus) | Dau19 | 10.8 | –19.0 | 3.3 | 16 | 46 |
| Vimba (Vimba vimba) | Dau20 | 6.7 | –22.3 | 3.2 | 16 | 44 |
| Atlantic cod (Gadus morhua) | Dau21 | 14.8 | –13.8 | 3.2 | 16 | 44 |
| ~~Salmon (Salmo sala)~~ | ~~Dau22~~ | ~~9.8~~ | ~~19.2~~ | ~~4.4~~ | ~~10~~ | ~~39~~ |
| D. pig (Sus scrofa domestica) | Dau23 | 6.2 | –22.4 | 3.2 | 15 | 41 |
| D. pig (Sus scrofa domestica) | Dau24 | 6.7 | –21.6 | 3.2 | 18 | 49 |

Aizkraukle hill-fort animal bone collagen

| Species | Sample No. | $\delta^{15}N$ | $\delta^{13}C$ | C/N | %N | %C |
|---|---|---|---|---|---|---|
| D. Horse (Equus caballus) | Aiz1 | 5.6 | –22.7 | 3.3 | 14 | 41 |
| Cattle (Bos taurus) | Aiz2 | 5.5 | –23.3 | 3.2 | 16 | 44 |
| Beaver (Castor fiber) | Aiz3 | 6.9 | –23.1 | 3.2 | 16 | 43 |
| Brown Bear (Ursus arctos) | Aiz4 | 6.5 | –21.8 | 3.3 | 15 | 43 |
| Chicken (Gallus gallus domesticus) | Aiz5* | 8.4 | –23.0 | 3.3 | 15 | 43 |
| Goose (Anser anser domesticus) | Aiz6 | 6.4 | –20.9 | 3.2 | 15 | 42 |

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Standard – two measurements / * data by one measurement Strikethrough – failed samples.

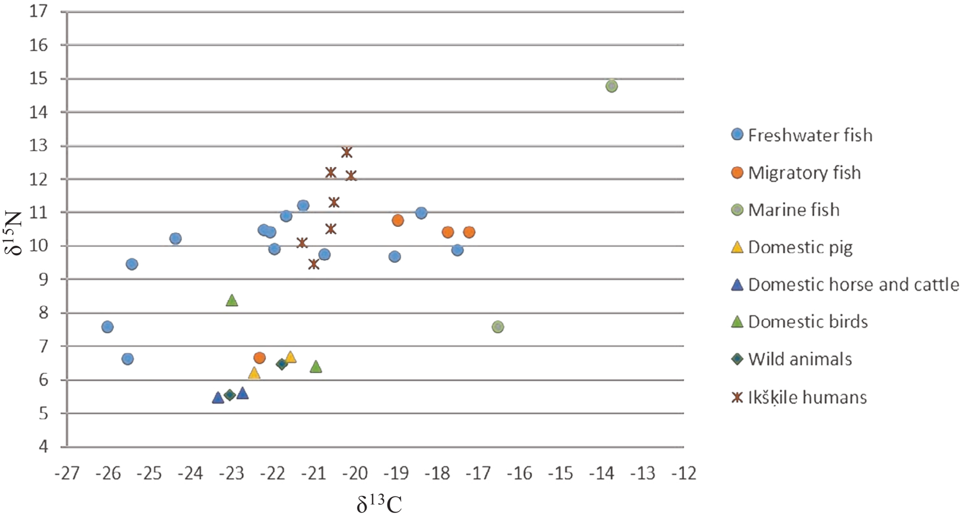

**Fig. 6.** Stable isotope analysis from Daugmale and Aikraukle hill-forts compared with human bone collagen from Ikšķile cemetery (Table 2; Zariņa 2015, 102, table 7).

The migratory fish (sturgeon, whitefish, vimba) mostly have a range in $\delta^{13}C$ values from – 18.97 to –17.22 and $\delta^{15}N$ values from 10.40 to 10.76, with one exception of a bottom feeder (vimba) with –22.33 $\delta^{13}C$ and 6.65 $\delta^{15}N$. Although both marine fish (Atlantic cod, salmon[2]) are carnivores they have very different $\delta^{15}N$ values. The Atlantic cod has –13.76 $\delta^{13}C$ and 14.78 $\delta^{15}N$, but the salmon has –16.54 $\delta^{13}C$ and 7.59 $\delta^{15}N$. The noticeable difference between the two most probably reflects their different habitats – Baltic Sea for the salmon, and more oceanic waters for the Atlantic cod.

The domesticated animals (domesticated pigs from Daugmale and domesticated horse, cattle from Aizkraukle) have a range in $\delta^{13}C$ values from –23.34 to –21.57 and $\delta^{15}N$ values from 5.48 to 6.70. The domesticated birds (chicken, goose) from Aizkraukle range in $\delta^{13}C$ values from –22.99 to –20.94 and $\delta^{15}N$ values from 6.41 to 8.37, with chicken having the higher $\delta^{15}N$ values. Wild animals (beaver, brown bear) from Aizkraukle range in $\delta^{13}C$ values from –23.04 to –21.79 and $\delta^{15}N$ values from 5.54 to 6.46, with the bear having the higher $\delta^{15}N$ values. Thus the distribution of terrestrial animals stable isotopes form a rather compact dietary group, in contrast with the fish.

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[2] Although adult salmons migrate for breeding, they do not feed in freshwater, therefore their bone collagen reflects exclusively marine diet.

## Discussion

### *Burial pottery*

As previously mentioned, the burial pottery had the same shape and use marks as household pottery. One of the questions was whether this pottery was made specifically for burials or whether it was taken from the household as a secondary use. The analysis shows no significant difference in what kind of food was prepared in the pots from the settlement and the burials. If the use marks had been from some type of ritual feast, we would have seen a slightly different product composition. This seems to confirm the hypothesis that in the burials we can see a secondary use for the household pottery. The reuse of household pottery in burial rites provides additional information on the funeral traditions at the time.

As there are no notable differences between the two sets of samples, they are further discussed as one group. This allows to widen the material base, and a larger sample size provides a more statistically valid assessment of the dominant use of pottery and the implications on the diet as a whole.

### *The Rauši settlement diet*

Considering the Rauši site location in time and space, results of the lipid analyses are somewhat unexpected. The available archaeological material (bones and plant macro remains) (Fig. 7; Table 3) had indicated that Rauši was primary an agrarian site with a strong reliance on fishing (Šnore 1970, 66; 1974, 71; Daiga & Šnore 1971, 42; Daiga 1972, 64; Bīrons et al. 1974, 253). The lipid analyses show main contributions from aquatic sources and terrestrial animals (ruminants and dairy products) with little input from cultivated crops (Fig. 1).

## Fish and fishing

According to lipid analyses, fish is one of the three dominant food groups, but surprisingly, none of the pots contained local freshwater fish. Dole Island is located in the River Daugava, approximately 30 km from the sea. The fish bone finds in food waste pits and hearths, show that a wide variety of fish was consumed. In total 16 types of fish have been identified: asp, common bream, blue bream, white/silver bream, chub, cod, eel, ide, perch, pike, pike perch, roach, salmon, sturgeon, tench, whitefish (Daiga 1972, 64; Rauši settlement collection, VI 145). The most common of these was sturgeon (*Acipenseridae*), which is typical to Daugava Livs in general (Šnore 1970, 66; Daiga 1972, 64; Bīrons et al. 1974, 253).

The sturgeon is a migratory fish that spends most of its life in the sea and swims up river to spawn. Sturgeon can reach up to 6 m in length and would be at their maximum age when coming to spawn (Kļaviņš 2019). The finds of sturgeon bones in Rauši suggest that this was the case, as the largest ear bones (otolith) reached 11cm in size.

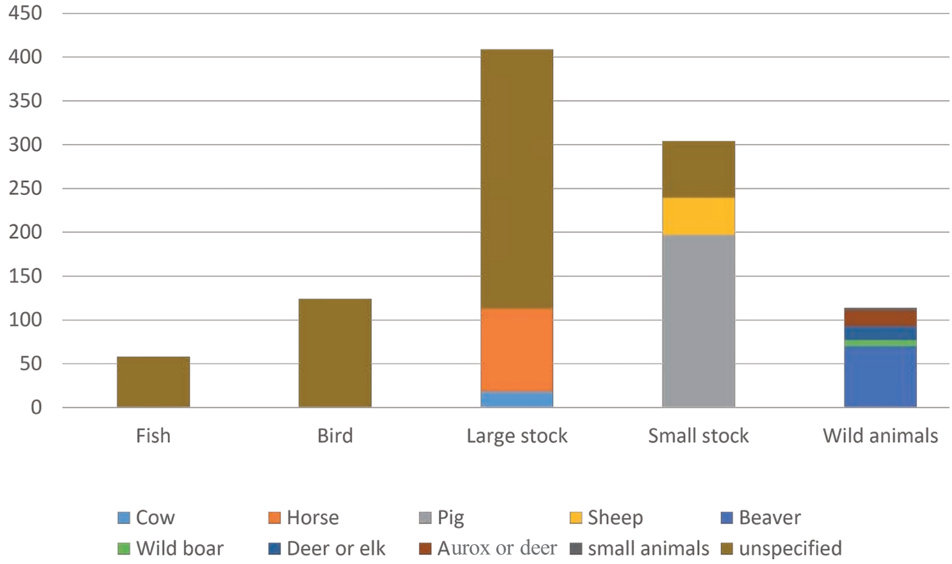

**Fig. 7.** Number of recorded bone material in Rauši settlement (NISP)**.** LU LVI, Repository of Archaeological Material. INV Nr Pd 145-1, 8, 9, 10, 14.

**Table 3.** List of plant macro fossil remains found in Rauši

| Plants | Seed No. in Rauši settlement 11th–12th century (two samples) |
|---|---|
| Oats (*Avena sativa*) | 2 |
| Barley (*Hordeum vulgare*) | 2 |
| Wheat (*Triticum aestivum*) | 2 |
| Turnip (*Brassica campertris*) | 2 |
| Broad bean (*Faba bona*) | 1 |
| Garden pea (*Pisum sativum*) | 2 |

By Rasiņš & Tauriņa 1983, table 5.

The size of the fish makes it likely that they would have been too big for convenient drying/smoking but perfect for boiling in a pot. This would statistically increase the amount of sturgeon 'found' in pots. As most of the life of sturgeons is spent at the sea, these fish would show up as marine fish. Hence, sturgeon and other migratory fish would explain the predominance of aquatic signals in the lipid analyses of pottery.

Nevertheless, it is peculiar that none of the pots contained any local freshwater fish, especially as we see these in the bone refuse material (pike, perch). A possible indicator is the size of freshwater fish bones. Although the sample size is very fragmented, the lack of large freshwater fish bones could be an indication of intense fishing. If there had been some depletion of large freshwater fish in the region, the smaller sized fish would be more likely to be dried/smoked. This would further increase the offset of marine versus freshwater fish material found in lipid analyses of pottery. However, this still is a hypothesis without a firm foundation in the material.

According to the stable isotope analyses the $\delta^{13}$C values for freshwater fish in Daugava are extremely varied with low $\delta^{15}$N values (Fig. 6). The closest analysed material for discussing the whole diet of a comparative living site is the adult skeletal material from Ikšķile cemetery of 13th–15th century (7 burials) (Zariņa 2015, 102). The location of Ikšķile is upstream the River Daugava from Rauši (approximately 15 km). Although the dating of the site is slightly later, than the discussed Liv peoples, it covers the same culture as Rauši settlement. Here the comparison also shows a strong dominance of protein in the diet, due to fish and meat consumption.

## Meat consumption

Consumption of terrestrial animal products (carcass fats and dairy) can also be detected in the analyses of Rauši pottery (Fig. 1). A large number of samples indicated a mixing of marine and terrestrial ruminant products, by cooking these substances simultaneously or subsequently. Terrestrial results may include not only domesticated animals (cow, sheep, goat), but potentially also wild ruminants as well. However, the bone remains are mostly of domesticated animals (Fig. 7). This claim is strengthened by analyses also showing a notable use of ruminant milk products. Considering the content of the archaeological bone material from Rauši settlement, the dominance of beef and dairy in the diet is well supported (Fig. 7).

What is surprising is the lack or porcine products in pottery lipids. The bone material indicated a significant presence of pigs in the settlement and, presumably, also in the diet (Fig. 7). It should be remembered that lipid analyses of pottery are not a direct indication of the whole diet, but more of the preparation of food. Somewhat different cooking practices for ruminant and pig have been noted elsewhere in Europe (Mottram et al. 1999). It seems that there was a preference for cooking beef, while pork was mainly cured, smoked, air-dried or even fermented (Spry-Marqués 2017, 153 ff.). Pork is a more fatty meat and as such easier to keep soft. Although cattle meat can be air-dried or smoked, it becomes much more tough and stringy. Even nowadays cured/dried meat (even in sausages) is most commonly associated with pork. Having a preference for curing, smoking or air-drying pork would affect how often it would be found in pottery in comparison to beef.

## Grain and porridge

The most unexpected aspect of the lipid analyses is the absence of plant matter, as it was expected to be one of the main food groups. It is also clear that in general the Liv societies had access to grain and other cultivated plants. Daugava Liv crop fields are mentioned in the Livonian Chronicle of Henry (Indriķa hronika 1993, II, 6; IV, 3). Albeit not numerous, the presence of cultivated crops in Rauši is demonstrated by the seed finds (Table 3). It is clear that the Liv societies had access to grain and other cultivated plants. Other indicators for crop cultivation are farming tools. In Rauši settlement, amongst 3087 excavated artefacts (excluding ceramics), were found 3 scythes, 14 grinding stones and 1 millstone (LNVM, VI 145). Even if this does not seem to be extensive in comparison with the general amount of artefacts, the presence and preparation of grain is indisputable.

It has to be kept in mind that in comparison with meat products the lipid content of cereals is much lower (Evershed 2008a) and thus there is a potential that animal products may overwhelm plant biomolecular signatures to some extent. However, recent studies have shown that simultaneous cooking of meat and plants in the same vessel in fact increases the absorption of plant-related biomarkers into the ceramic matrix (Hammann & Cramp 2018), making them potentially better detectable. It is also known that considerable contribution of plants should be identifiable with biomolecules, since good general lipid profiles (e.g. higher concentration of unsaturated fatty acids) and biomarker evidence has been established for e.g. *Brassica* plants (Charters et al. 1997), more oil rich plant substances (Oras et al. 2017), and recently also for main cereals (Colonese et al. 2017) and other starchy plants (Shoda et al. 2018). Although for many of these results solvent extraction was preferred as a sample preparation, high content of plants and discovery of their main biomarkers (β-sitosterol, stigmasterol, etc.) are identifiable with acid extraction as well. Furthermore, if considerable consumption of plants were the case, this would be clearly evidenced by the compound specific isotope results (Fig. 4). In such cases plant-based results ought to plot in the more depleted regions of both $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ – close to depleted freshwater signals. The latter is certainly not the case in our results.

The only slight indication of plant consumption is evident from one food-crust sample bulk IRMS result. In general, the C and N bulk stable isotope analysis of food-crusts (6 samples) correlate with the animal-based substances as well. The only exception is an internal crust sample from pot 11 for which a high C/N ratio hints at a large proportion of carbohydrates and the low $\delta^{15}N$ value indicates that plant matter was most likely cooked in this vessel. Unfortunately, further identification is not possible due to small sample amount. The GC-MS analysis of ceramic matrix from this pot did not give any direct identification of substances cooked, the aquatic biomarkers were missing, yet the compound specific isotopes place it within the range of marine substances. In addition, the lipid preservation for the external crust from the same vessel was very low, thus not allowing any further identification of what might have been cooked (overboiled) in this vessel.

Based on these multisampling comparative results within one vessel it is most likely that the vessel had been used for cooking aquatic substances from which the marine isotopic range derives (yet lacking clear aquatic biomarkers). However, the more recent cooking event resulting in a crust formation most likely involved carbohydrate-rich plant substances (cereals?). Thus, so far we have only a single tentative example of plant-consumption in Rauši vessels, and even here its previous uses have at least included if not consisted of (aquatic) animal-based substances.

The absence of plant matter in the analysed pottery also cannot be simply attributed to sample selection or an inadequate sample size or selection. The present sample size of 13 pots should provide a comprehensive picture of the dominant products used in the diet. The samples were selected from specific, defined features with the potentially best representation of the diet.

So what can we tell about the porridge that is generally thought of as one of the most common foods of the time (Bīrons et al. 1974, 247)? The best known example for extensive amounts of grain in Late Iron Age Latvia is from Tērvete hill-fort. During the excavations, in the layer attributed to the 12th century, 18 tons of grain were found. Smaller amounts of grain have also been found in other contemporary hill-forts (Bīrons et al. 1974, 247). This indicates a wide production and consumption of grain products, and has often been referenced as a proof of an agrarian societies in Late Iron Age Latvia (Radiņš 2012, 109).

However, it must be pointed out that we do not have direct evidence for large amounts of grain in the Liv settlements along River Daugava. Is it possible that the extent of crop cultivation varied regionally? Two factors must be considered: resource availability and food preparation habits.

In modern times, with the construction of the hydroelectric dam, the landscape around River Daugava has changed considerably. However, during the 17th century Vidzeme (and Dole Island) was part of Sweden. At the time the king decreed that the whole territory of Sweden was to be surveyed and mapped to inventory the available resources and land use. These maps note that the soil on Dole Island and around River Daugava consists mainly of sand with occasional marshland (Fig. 8). The presence of sand dunes is also noted (Fig. 8: 1). During the 17th century, crop fields are cultivated only along the very edge of the river with the rest being grazing land, pine forests or heather moors (Fig. 9). Notable presence of pine and meadows in the area can also be seen in recent pollen analyses (Kalniņa et al. 2019, figure 11: 4, 7, 8).

We should also consider that the area had quite a high population density (Radiņš 2012, 155). Two cemeteries in the southern part of Dole Island contained 483 burials, dated from the end of the 10th until the beginning of the 14th century. Across the river the biggest cemetery (Salaspils Laukskola) alone contained 610 burials, dated from the end of the 10th until the 13th century (Spirģis 2008, 22 ff.). The high population density probably contributed to a depletion of the already low-fertility land. Under these conditions, it might have been more beneficial to turn to animal husbandry and fishing instead of crop cultivation.

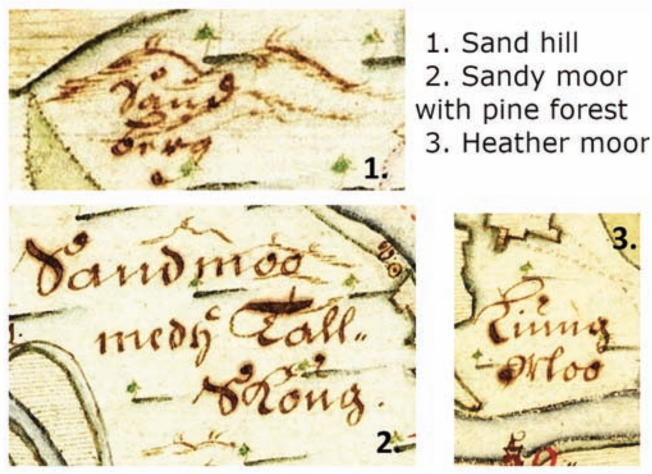

**Fig. 8.** Description of mid-17th century Dole Island and River Daugava waterside (1682). LVVA, Fonds 7404, Apr: 3, Dahlen, Kirchholm. Digital images from: Latvijas Arheologu biedrība.

**Fig. 9.** Land use on and around Dole Island (1682). LVVA, Fonds 7404, Apr: 3, Dahlen, Kirchholm. Digital images from: Latvijas Arheologu biedrība.

As this part of River Daugava was a well-known place of trade (Radiņš 2012, 155), the locals were quite wealthy and probably were able to purchase grain, as well as other goods. However, grain being an import seems to have contributed to the fact that it was not a staple of the diet, as is shown in the previously mentioned stable isotope analysis of adult skeletal material from Ikšķile (13th–15th century) (Zariņa 2015, 101 f.). Grain might have been a rarity or a supplementary food group similar to turnips, peas and beans (Table 3), and therefore might not show up in a medium sized pottery sample group.

Although several parallel facts indicate that grain was relatively rare in general, we should still discuss the possibility that we might have not found it in pottery because of 'out of the pot' preparation, i.e. bread-making.

The two best-known forms of preparing grain products are porridge (gruel) and bread. References to both porridge and bread can be found in Scandinavian sagas (Sturlason & Anderson 1901, 272; Sturlason 2009, 58. Miracle Of King Olaf In Denmark). A sample of bread has been found in Tērvete (LNVM, VI 24, paraugi).

The preparation of porridge seems more convenient as the grain does not need to be ground as thoroughly. Prolonged boiling will soften even roughly ground grain and make it digestible. Bread, on the other hand, requires the grain to be at least partially ground to flour. It does not need to be fully white flour (Sigfusson & Sturleson 1906, 79), but it needs to at least form a sticky, malleable mass. Without a sufficient amount of flour, it would be impossible to knead the dough. The positive feature of bread over porridge is the preservation and transportation. Although porridge can be consumed even in a sour form and transported in covered pots, bread is still tougher and more convenient on both points.

If grain was a restricted access food group, then it might have been preferable to bake bread instead of cooking porridge. However, if grain was easily available, the preparation of only bread to the exclusion of porridge would seem strange, considering the much more complicated preparation process.

The available material right now points to a pastoral society which focused on protein, where cultivated crops (even grain) were used as an addition to the diet, not as the base. However, to form a more cohesive picture, there is a need for comparative material to be investigated from a society that undoubtedly focused on cultivated crops, particularly grain. In this case a site like Tērvete would be ideal, as accessibility and even abundance of grain in this site is clear. Such a comparison might still suggest different explanations.

## Conclusions

The visual appearance, use marks and lipid analyses of Rauši pottery all point to the burial pottery being taken directly from the household as a secondary use. This claim is also strengthened by the lack of any previous traditions of special burial pottery. We did not detect considerable differentiation between funerary feasting and daily food consumption, at least in terms of used vessels. The results may pose the possibility for further study to try to link the specific burial pot to the deceased person. However, this analysis does not draw such conclusions.

The lipid analysis, supported by other data, indicates a substantial consumption of fish in the region. Rauši site was located at the River Daugava and had access to the spawning route of the sturgeon. The predominance of aquatic biomarkers could be connected to the preference of cooking the large sturgeons in pots while roasting, drying and/or fermenting the smaller river (freshwater) fish.

The other dominant products are ruminant meat and milk. Judging by the pottery analyses and bone refuse, the people of Rauši mostly consumed fish and beef. This claim is also strengthened by the collagen stable isotope analysis of bones from a site relatively close to Rauši. However, it should not be forgotten that the pottery analyses show the diet only indirectly. Food preparation is mostly, but not always done in pots. This is most clearly visible by the absence of pork in the analysed pottery. The food refuse leaves no question whether pork was consumed in the site – the amount of pig bones in the site is significant. At this point we must assume that pig was preferentially prepared “outside the pot” by drying, curing or fermenting.

Surprisingly, none of the analysed pots had been used for extensively processing plant matter. Only one pot included traces of plant presence in the bulk IRMS results. This poses problems as grain has been considered an important part of the diet of a 11th–13th century society. However, both the pot lipid analyses and related isotopic analyses of skeletal material point to a society that focused on animal and fish protein rather than starch rich plants. Cultivated crops (even grain) seem to have been just an addition to the diet. This preference of fishing and animal husbandry could mostly be explained by particular environmental factors, which of course does not exclude other contributing factors.

## Acknowledgements

This study was supported by the National History Museum of Latvia and the Estonian Research Council Institutional and Personal Research grants IUT20-7, MOBERC14 and PSG492. State Culture Capital Foundation (SCCF) provided the sponsoring for the multidisciplinary analyses. Our gratitude also goes to Eduards Plankājs who shared his data of skeletal material stable collagen analysis from the lower course of River Daugava. The publication costs of this article were covered by the Estonian Academy of Sciences, the Institute of History and Archaeology at the University of Tartu, and the Institute of History, Archaeology and Art History of Tallinn University.

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## TOIDUVALMISTAMINE ELAVATELE JA SURNUTELE: RAUŠI 11.–13. SAJANDI ASULAKOHA NING KALMISTU SAVINÕUDE LIPIIDIANALÜÜS

### *Resümee*

Artikli eesmärk on saada põhjalikum ülevaade hilisrauaaja ühiskonna toitumisest ja toiduvalmistuspraktikatest. On esitatud Rauši arheoloogilise kompleksi materjal, mida analüüsiti erinevate meetoditega.

Rauši muistised paiknevad Dole saarel Daugava liivlaste kesksetel aladel (jn 1). Rauši asula ja kalmistu peamine kasutusaeg oli 11.–13. sajandil. Rauši asula paikneb Daugava jõe ääres ja seal kaevati 14 × 100 m ning 30 × 70 m suurusel alal. Rauši kalmistu paiknes asulakoha kõrval ja selles tuvastati 169 matust.

Enamasti on Raušis tegemist baltipärase keraamikaga. Proove võeti savinõudest, mis leiti koldekohtadest (1.–5., 7. proov) ja hauapanustena (8.–13. proov) (tabel 1). Uuring keskendus keraamikasse ladestunud lipiidide analüüsile. Võimalusel analüüsiti ka keraamika pinnale ladestunud kõrbekihte (jn 2). Analüüsimeetoditena kasutati massispektromeetria meetodeid: GC-MS ja FID, GC-C-IRMS ning EA-IRMS.

GC-MS-i tulemused võimaldasid tuvastada lipiidide päritolu 14 proovis 20-st. Mitmed proovid (1b, 2a, 3a–b, 4, 5a, 6a, 8a, 10a–b, 12b) sisaldasid täielikku vesikeskkonnale viitavat biomarkerite komplekti, GC-C-IRMS-i tulemused (jn 4) andsid täiendavat infot Raušis tarbitud toiduainete kohta. Nende põhjal saab väita, et lisaks mereveelise päritoluga loomadele tarbiti toiduks nii piima kui ka mäletsejate liha. Samas ei tuvastatud sealihale ja mageveekeskkonna kaladele ning taimedele viitavaid biomarkereid.

EA-IRMS-i (6 kõrbekihi proovi) tulemused korreleeruvad GC-MS-i ja GC-C-IRMS-i tulemustega (jn 5). Kõrbekihtideski on näha kombinatsiooni maismaa ja vesikeskkonna loomadest. Sellegipoolest on ühel proovil (11c) taimsele substantsile viitav madal $\delta^{15}N$ väärtus ja kõrge C/N suhtarv, 48,99, mis näitab pigem süsivesikuterikast (ehk taimset) ainet.

Rauši asulakoha materjal näitab samuti suurt mereveekalade tarbimist. Rauši paikneb Daugava jõe ääres ligipääsuga tuura kudemise rändeteele ja selle kala tarbimine toiduks on igati tõenäoline. Vesikeskkonna biomarkerite domineerimine savinõude lipiidides võib viidata tursa potis valmistamisele, samal ajal kui väiksemaid jõekalu võidi lõkkel küpsetada, kuivatada ja fermentida.

Teine suurem toidugrupp on veis ja piimasaadused. Nendele kahele viitavad ka Raušis leitud loomaluud (jn 7). Samal ajal ei näita sea puudumine selle toiduse puudumist Raušis, sest asulast on leitud rohkelt sealuid. Pigem on tegemist erinevate toiduvalmistusviisidega, mida on täheldatud ka mujal Euroopas: sealiha ilmselt kuivatati ja fermenditi, samas kui veiseliha pigem keedeti.

Üllataval kombel puudus pottides selge viide taimse toidu tarbimisele ja vaid üks kõrbekihi proov viitas taimset päritolu ainele. Kõnealune asjaolu on huvitav, sest siiani on eeldatud, et teravili, eriti pudruna, oli 11.–13. sajandi toidulauaal oluline. Nii Rauši lipiidianalüüsid kui ka Ikšķile (jn 6) inimluude stabiilsed isotoobid aga näitavad, et toidulaud koosnes suuresti loomsest toidust ja kaladest, mitte aga rohketest taimsetest saadustest.

17. sajandi maakasutuskaardid näitavad, et Daugava jõe ja Dole saare pinnas oli peamiselt liivane või vesine niidupealne ning haritavat maad oli jõe ääres vähe (jn 8–9). Õietolmuanalüüsid toetavad seda infot. Inimeste arvukus ja võimalik piirkonna ülerahvastatus 11.–13. sajandil kombinatsioonis halbade pinnasetingimustega võis teraviljakasvatusega võrreldes viia loomakasvatuse ning kalastuse eelistamiseni. Seetõttu võib eeldada, et vajalikuks osutus teravilja import ja teravili ei moodustanud piirkonna põhitoidust.

Praeguse teabe põhjal saame niisiis rääkida pigem proteiinirikka toidulauaga kogukonnast. Taimsed saadused (sh teravili) olid toidulaual pigem marginaalsed lisandid. Lõpliku pildi saamiseks oleks vajalik koguda võrdlusmaterjali kogukondadest, kelle põhitoiduseks olid just nimelt taimsed saadused. Selliseks näiteks sobiks suurepäraselt Tērvete muistis, kust on rohkesti andmeid teraviljade kasutamisest.

Lõpetuseks: kinnitust sai ka eeldus, et liivlaste kalmistutel hauapanustena kasutatud savinõud olid tavalised majapidamisnõud. Viimasele viitavad nii nende visuaalne vaatlus ja kasutusjäljed (jn 3) kui ka lipiidianalüüsitulemused.