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Dietary Practices of the Gauja Livs: Lipid Residue Analyses of the Turaida Hillfort and Pūteļi Cemetery Pottery Material

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ABSTRACT

This study reports the first comprehensive data on the dietary aspects of Gauja Livs in the 11th–12th century CE. This region is presently lacking in bioarchaeological material (human bones and ancient plant remains), which is typically used for decoding the ancient diet. To tackle this problem pottery fragments from Turaida hillfort and Pūteļi cemetery were studied using Lipid Residue Analysis. Samples included both pottery clay matrix and burnt foodcrusts. The main goal of the study was to obtain direct information on the food substances consumed by the Gauja Livs, based on the pottery material from Turaida hillfort and from the local cemetery to reassess existing assumptions about their dietary practices both in mundane and ritual contexts. The lipid residue results revealed the main food groups consumed by the community contained terrestrial animal and aquatic products, but also provided insights into a potential mixing of different foodstuffs. Some of the expected foodstuffs were not found in or on the analysed pottery, leaving the possibility for a hypothetical use of cooking practices that might have excluded ceramic vessels. This research also gives preliminary indications of gender-based dietary patterns if assessed in context with other studies from the eastern Baltic Sea region in the pre-medieval and early medieval period.

1. Introduction

The regions along the Daugava and Gauja rivers (Figure 1) experienced significant changes in the 10th century. They were settled by the Livs and were established as important trade routes. Beginning with the second half of the 11th century, the trade routes to the East and West brought prosperity to the Liv people (Ciglis *et al.*, 2001, pp.16 and 18; Šnē, 2000, p.143).

Archaeobotanical material from Daugava Liv sites was first comprehensively analysed in connection with the general overview of cultivated plant development in Latvia; however, this did not include Gauja Livs (Rasiņš *et al.*, 1983). Since then, several archaeobotanical case studies have been conducted which directly or indirectly touch upon other regions during the Late Iron Age period (Brown, 2019; Kalniņa *et al.*, 2019; Banerjea *et al.*, 2017; Stivriņš *et al.*, 2014; Zariņa, 2015). The Gauja Liv region lacks both archaeobotanical material and corresponding analyses (see section 2.3 in this article). The only analysis of the Liv diet that uses modern investigation methods has been conducted on the Daugava Livs (Gunnarssone *et al.*, 2020). The current conception of the Late Iron Age presents an agrarian society (crops and livestock) whose food procurement practices are largely similar to those of people from the beginning of the medieval period (Brown, 2019, p.127).

This article focuses on a site-specific Lipid Residue Analysis (LRA) that was undertaken in order to investigate the validity of our current state of knowledge based on available zooarchaeological and archaeobotanical records. Our findings provide the first biomolecular insights into the culture and the dietary habits of the Gauja Livs and create comparative material for future analyses. While scholars

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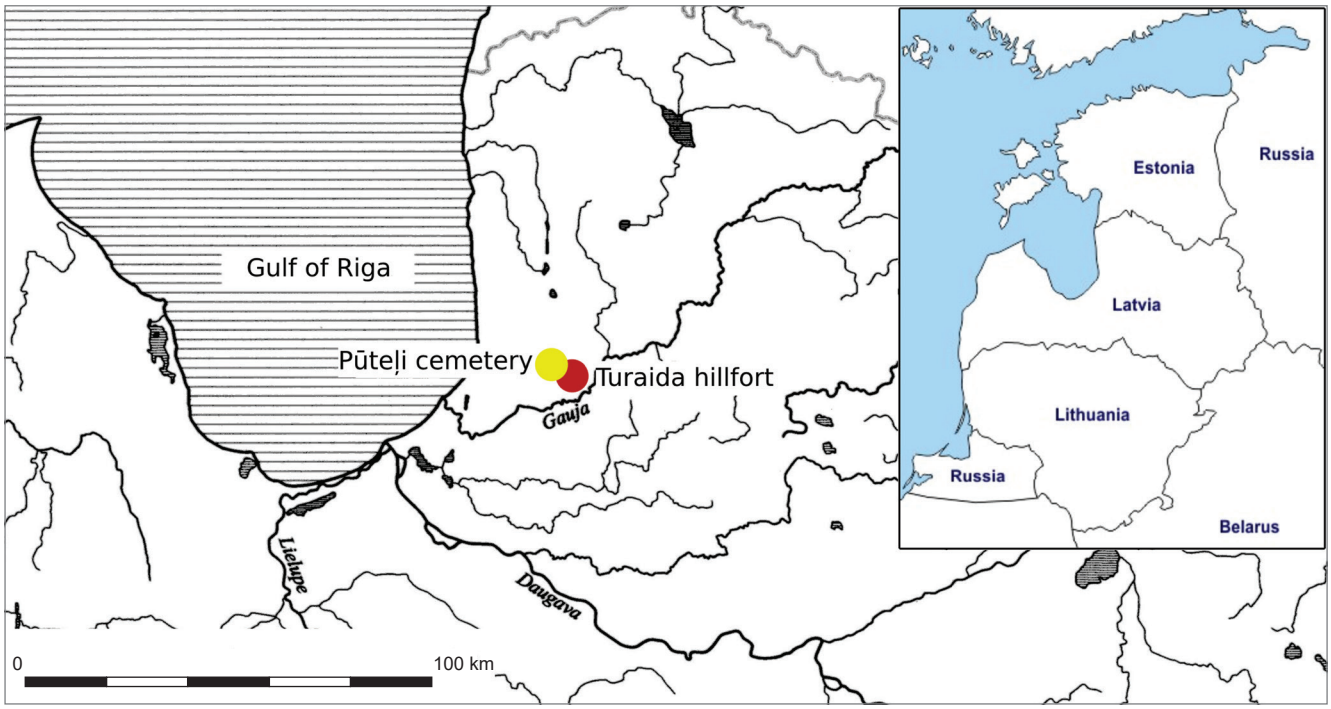

Figure 1. Map with Turaida hillfort (red) and Pūteļi cemetery (yellow). In the upper right corner is the geographic location of Latvia.

increasingly accept that Late Iron Age people in the Baltics expressed local regional variations in their economies, only in some cases did this also include differences in their dietary patterns (Oras *et al.*, 2018; Aguraiuja-Lätti and Lõugas, 2019; Bliujiene *et al.*, 2018; Pētersone-Gordina, 2022).

2. Material

2.1 Sites of study

To study the dietary aspects of Gauja Livs sampling was carried out at two sites – Turaida hillfort and Pūteļi cemetery. Both sites provided different contexts for the interpretation of selected sherds, but they also came with their own specific limitations.

2.1.1 Turaida hillfort

Turaida hillfort (Figure 1) was chosen for our research as the only archeologically-studied site in the whole Guja region which contained an intensive culture layer. Other excavated settlements or hillforts in the Gauja region have yielded either no or very sparse archaeological material (Ciglis, 2001). Turaida provides a well-preserved archaeological context for directly contextualising the sample material. Also, it is one of the rare sites to be directly mentioned in written records (Indriķis, 1993, pp.51 and 81).

Turaida is one of the most extensively excavated medieval sites in Latvia. Archaeological field research was conducted here from 1976 to 1999 and the excavated material is presently held at the Turaida Museum Reserve. Archaeologists differentiate two inhabitation periods – an earlier phase relating to the Late Iron Age hillfort (from the beginning of the 11th century to 1212), and a later phase starting with the construction of the medieval stone/brick castle (from 1214 to the 18th century).

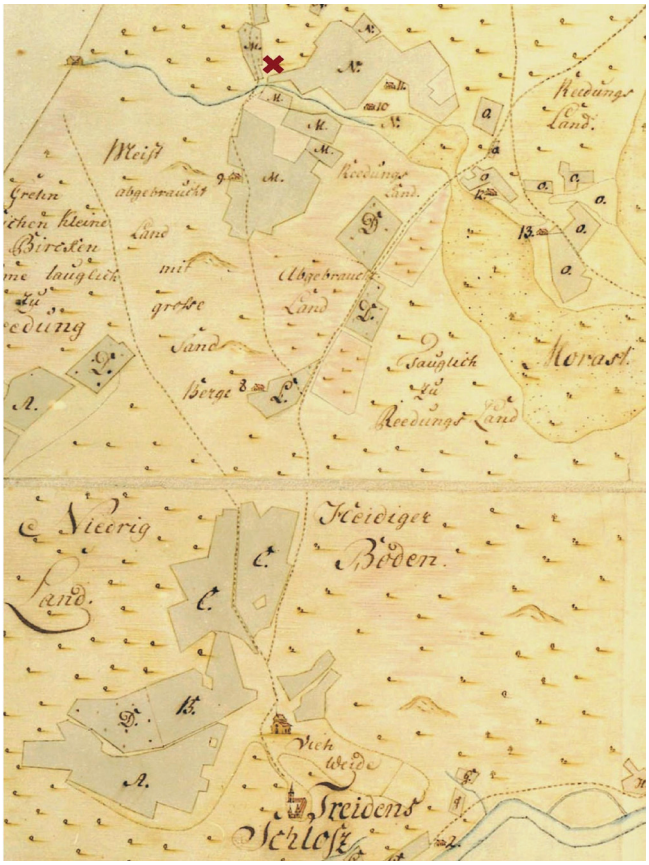

Figure 2. Land map of Turaida manor from 1683. Approximate placement of Pūteļi cemetery marked by "X". Source: Turaida Museum Reserve.

Figure 3. Restored Baltic ware pot form Pūteļi burial No 33, with the sampled sherd (front and back view). Source: National History Museum of Latvia. Photo by A. Gunnarssone.

The Livs, which built the original Turaida wooden hillfort, settled the area at the end of the 10th or at the beginning of the 11th century (Graudonis, 2003, p.26; Dumpe, 2019, p.18; Ciglis; 2015, pp.28–29). The construction of the stone castle began in 1214, two years after the wooden hillfort was burned down. The archaeological material of the two periods was separated by a 20 cm thick clay layer, placed during the construction of the stone castle (Graudonis, 2003, p.49; Jansons, 2007, p.11).

2.1.2 Pūteļi cemetery

Pūteļi cemetery was chosen as the second site of study as the most probable burial site of Turaida inhabitants. Pūteļi is the nearest known Liv cemetery to Turaida hillfort (3.3 km distance). A land survey map from 1683 shows a direct road connecting both places (Figure 2). Based on the finds, the cemetery was used at the same time period as the hillfort, represented the same material culture, and contained individuals with particularly lavish sets of grave goods.

Livs are the only Late Iron Age culture in Latvia that placed household vessels (Figure 3) in burials with the deceased (Gunnarssone *et al.*, 2020, p.58). The different deposition contexts (a living site versus a burial site) means that the sherds could suffer different post deposition effects, allowing us to compare and contrast the analyses' results for a more precise interpretation. The selection of sherds from the grave goods also provided the possibility to link the samples with individual households, as well as to a more precise point in time.

Originally, Pūteļi might have consisted of around 100 barrows with inhumation burials (Ciglis 2015, p.29). It was first studied in 1873 by Jakob Carl Georg von Sievers. At present, the excavated material is housed at the Archaeological Department of the University of Tartu. In 1896, the 10th Russia Archaeological Congress carried out a model excavation at the site, investigating 25 ancient barrows (Graudonis, 2003, p.31). Later, the area of the cemetery was intensively looted and used for farming.

Unfortunately, in the 19th century archaeologists still considered antiques their private property (Graudonis, 2003, p.31). Only a small part of the Archaeological Congress artefact collection and fragmentary documentation is stored in the National History Museum of Latvia. Several artefacts (45 objects) are also held in Berlin. Based on typological dating of the known artefacts, Pūteļi cemetery is considered to represent the 11th–13th century (Ciglis, 2015, p.22), but so far there have been no radiocarbon dates from the site.

2.2. Material selection

The Turaida hillfort pottery assemblage is in quite good condition, as characterised by the number of identifiable sherds. The rim sherds are profiled and sometimes include ornamentation. Given the identifying features, the sherds could be separated as belonging to particular vessels (Gunnarssone, 2019, pp.35–38), thus avoiding repeated sampling of one and the same vessel. The Baltic ware pots in Turaida have visually distinct stylistic features, which indicate local production (see shoulder ornamentation in Figure 3). The sherd selection also took into account the preservation of foodcrust. Presently there is no single answer for determining the precise mixture of ingredients or distinguishing subsequent cooking events in a sample. However, it is reasonable to assume that the foodcrusts contain fewer and later cooking events versus the clay matrix which represents a long-term accumulation of foodstuffs (Miller *et al.*, 2020).

Three sherds were selected from the Turaida hillfort (pre-medieval) context. Two of those were taken from the Liv wooden building in area R-Z II, dated by dendrochronology to the 11th–12th century (Graudonis, 2003, p.26). One sherd was taken from between the 9th and 11th buttress, within the same cultural layer as other 11th–12th century finds (Graudonis, 2003, p.26). This layer was separated from later construction by an intentionally placed 20 cm thick layer of clay, which also served to greatly reduce the possibility of contamination from later deposits.

The sample selection from Pūteļi cemetery posed problems in terms of establishing reliable contexts for each vessel. Only five vessels could have their origin reliably traced to a specific burial and they were selected for LRA,

Figure 4. Burial goods from Pūteļi cemetery, grave No 25 (one spearhead with silver inlay was not available for photography). Source: National History Museum of Latvia. Photo by A. Gunnarssone.

Table 1. Overview of samples analysed and overall lipid preservation in each sample.

Site	Sample context	Sex (based on burial goods)	Collection no	Sample type	Sample code	Sample masse used in AE (g)	Lipid concentration (ug/g^{-1})
Puteļi cemetery	burial nr.1.	male	64856	Ci	PUT-1	0.9	140.7
Puteļi cemetery	burial nr.23.	female	64867	Ci	PUT-2	1.16	2009.0
Puteļi cemetery	burial nr.25.	male	64869	Ci	PUT-3	1.02	54.1
Puteļi cemetery	burial nr.33.	unknown	65146	Ci	PUT-4	0.88	2376.1
Puteļi cemetery	burial nr.39b	unknown	64872	Ci	PUT-5	1.15	110.1
Turaida castle	between 9th and 11th butress		3	Ci	TUR-1	0.8	2228.0
Turaida castle	R-Z II trench, level 11		4	Fi	TUR-2a	0.0204	1177.9
Turaida castle	R-Z II trench, level 11		4	Ci	TUR-2b	0.81	8163.4
Turaida castle	R-Z II trench, level 11		5	Fi	TUR-3a	0.023	646.4
Turaida castle	R-Z II trench, level 11		5	Ci	TUR-3b	0.91	136.8

*Ci – ceramic powder (interior), Fi – food crust interior, Fe – food crust exterior.

burials: No 1, No 23, No 25, No 33 and No 39b. None of the available vessels contained preserved foodcrusts. The burial pottery can be typologically dated from the end of the 11th to the first half of the 13th century CE. Sampling permissions were obtained from the archive holders.

In Pūteļi cemetery only one burial (No 1) contained a deteriorated human bone fragment. Without the possibility for osteological or biomolecular analyses, the burials were assigned the sex of the deceased as expressed by their grave goods. Based on grave goods stored in the museum (Figure 4), two burials were assigned as male (No 1, No. 25), one as female (No 23) and in two cases the sex remained unknown (No 33, No 39b) (Table 1). This approach does not imply that Livs had only two social gender categories. It might have been a more complex concept, but the present material does not allow for a data-based discussion of this question.

2.3. Contextualising material

Unfortunately, during the excavations in Turaida archaeologists did not take **soil samples** from the Liv culture layer. There is also a lack of any other archaeobotanical data (pollen, biological microremains, *etc.*) for the whole Gauja region. The only direct information on the procurement of plant-based food in Turaida comes from written sources – The Livonian Chronicle of Henry.

The **animal bone** material found in the Turaida hillfort supplies direct evidence of livestock farming along the Gauja River. During the excavations, the archaeologists noted the origins of bone material found in the hillfort and the mediaeval layers separately (Graudonis, 1981, p.44). Regrettably, afterwards, all the bone material was mixed together. Hence, it is impracticable to re-evaluate the animal bone remains attributable to the 11th–12th century by the number of individuals or the processing traces left on the bones.

This study of the Gauja Liv diet does not include **human bone stable isotope analyses**. The main reason is the lack of Late Iron Age human bone material for the Gauja region. The few preserved bones are not available for destructive sampling. While the possibility of unearthing new material always exists, all the known Guaja Liv cemeteries have been heavily looted to the point where any new material would lack basic context.

Considering the scarcity of ecofacts and fragmentary nature of the human skeletal remains, pottery deposited as burial goods or from a settlement context is the best representative material for decoding the diet of the Gauja Livs.

3. Methods

3.1 Lipid extraction

Sampling of pottery took place at the Archaeology Laboratory, University of Tartu. Samples of foodcrust, ca. 20–30 mg, 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 1 mm (approx.) layer to avoid any direct contamination, and then drilling into the sherd to remove ca 1.5 g of ceramic powder. The sherds were returned to the collections.

Lipid samples were separated directly from ca 1 g of ceramic powder or ca 20 mg of foodcrust using an acid-catalysed methylation procedure with methanol (MeOH) and sulphuric acid (H_2SO_4) followed by heating on a heating block at 70 °C for 4 hours (Craig *et al.*, 2013; Heron *et al.*, 2015). After heating, lipids were extracted with n-hexane (3×2 ml) and dried under a gentle stream of nitrogen at 37 °C. Samples were dissolved in 90 ml of n-hexane with the addition of 10 µg of internal standard C36 (n-hexatriacontane).

3.2 Biomarker and isotopic analysis

For estimating general preservation and quantity of lipids, gas chromatography (GC) with a flame ionisation detector

Table 2. GC-MS and GC-C-IRMS analysis results of the Pūteļi cemetery and Turaida castle samples. (Cn:x) – carboxilic acids with carbon length n and number of unsaturation x. FA – fatty acid, APAA – ω-(o-alkylphenyl) alkanoic acids, phy – phytanic acid, K – ketones.

Site	Sample code	Sat. FA range	Main FA(s)	Unsat. FA	Branched-chain FAs	Dicarb. acids	APFAs	Isopre-noids	n-alkanes	Chol. der.	Abietic acid	Other terpenes	Ketones	Other compounds/ comments	δ13C C16:0	δ13C C18:0	Δ13C(C18:0-C16:0)
Puteļi cemetery	PUT_1	C12-26	C16	C16:1, C18:1	C12-13, C15-17	C8-12, C16, C18			C19-22		yes	phenanthrene	5K12 6K12 2K13 6K14 7K15 2K15 3K15 14K27 4K29 16K31 17K35	phthalates	–27.80	–30.05	–2.25
Puteļi cemetery	PUT_2	C10-28	C18	C18:1, C18:2, C22:1	C16	C8-10, C12, C14	C18	phy	C19, C22		yes	Phenanthrene, naphthalene		β-Amyrin (trace), phthalates	–28.91	–33.23	–4.32
Puteļi cemetery	PUT_3	C14-24	C16	C16:1, C18:1	C13-14				C19-22		yes	phenanthrene	2K15	phthalates	–25.77	–28.30	–2.53
Puteļi cemetery	PUT_4	C12-26	C16, C18	C16:1, C18:1, C18:2, C22:1, C 24:1		C8-10, C12-14, C16, C18	C18	phy	C19-20 (trace)		yes	phenanthrene, naphthalene		phthalates	–28.02	–31.63	–3.61
Puteļi cemetery	PUT_5	C14-22	C16	C22:1					C15-23		yes	phenanthrene, naphthalene, retene		phthalates	–28.75	–27.93	0.82
Turaida castle	TUR-1	C12-24	C18	C16:1, C18:1, C22:1	C13-14	C8-14, C16-17	C16-20	phy		yes	yes	phenanthrene		phthalates	–26.76	–29.57	–2.81
Turaida castle	TUR-2a	C14-24	C18	C16:1, C18:1, C18:2	C14		C16-20	phy							–28.76	–31.68	–2.92
Turaida castle	TUR-2b	C10-26	C18	C16:1, C18:1, C18:2, C22:1		C7-14	C16-22	phy		yes	yes	phenanthrene		phthalates	–28.53	–31.44	–2.91
Turaida castle	TUR-3a	C14-20	C16	C18:1			C16-20	phy							–26.79	–29.08	–2.29
Turaida castle	TUR-3b	C12-24	C16, C18	C16:1, C18:1, C18:2, C22:1	C14, C20	C9-13	C16-20	phy	C15-17 (trace)		yes	phenanthrene, naphthalene		phthalates	–26.45	–28.69	–2.24

(FID) was employed at the Institute of Chemistry (University of Tartu). An Agilent 7890 A Series gas chromatograph and DB5-MS (5%-phenyl)-methylpolysiloxane column (30m×0.25 mm×0.25 µm) was used. Injected sample size was 1 µl. The splitless injector was used at 300 °C with helium 6.0 carrier gas at a constant flow rate of 3 ml min^{-1} (33.033 psi). The temperature was set at 70 °C for 2 min, with a gradient of 15 °C/min up to 325 °C and the latter maintained for 15 min with a total run time of 34 min. FID was kept at 300 °C with a hydrogen flow of 30 ml min^{-1}, and air flow of 400 ml min^{-1}.

Gas chromatography-mass spectrometry (GC-MS) analysis for detecting different lipid components was conducted at the Archemy laboratory, 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 ionisation energy was 70 eV and spectra were obtained by scanning between m/z 50 and 800 amu. The temperature programme was set as follows: 50 °C for 2 min, thereafter a gradient of 10 °C/min up to 325 °C and kept there for 14.5 min with the total run time of 44.5 min. Compounds were identified with Agilent ChemStation and MassHunter (10.2) software using the NIST 14 mass spectral library as a reference database.

Gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) analysis was conducted at the York BioArCh laboratory. The analysis used acid-extracted samples to estimate the $^{13}C/^{12}C$ ratio in the two most-abundant fatty acids ($C_{16:0}$ and $C_{18:0}$). The samples were analysed using an Isoprime 100 (Isoprime, Cheadle, UK) linked with an Agilent 7890B Series Gas Chromatograph (Agilent Technologies, Cheadle, Cheshire, UK) with Isoprime GC5 interface (Isoprime Cheadle, UK). All samples were diluted with hexane and subsequently 1 µl of each sample was injected into a DB-5MS UI fused-silica column (PN 122-5562UI; 60 m×250 µm×0.25 µm; J&W Scientific technologies, Folsom, CA, USA). The Split/Splitless injector was operated in Splitless mode. 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 20 min. Ultra-high-purity-grade helium with a flow rate of 2 ml/min was used as the carrier gas. Eluted products were combusted to CO_2 and ionised 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 IonOS Software (Isoprime, Cheadle, UK), and were based on comparisons with a repeatedly measured standard reference gas (CO_2). The results from the analysis are reported in parts per mille (‰) relative to an international standard (V-PDB). A batch of samples was calibrated using a calibration curve (average R2=0.999 in one batch) based on expected vs. measured $\delta^{13}C$ values of n-alkanes and n-alkanoic acid esters international standards (Indiana A6 and F8-3 mixture). The accuracy of the instrument was determined on n-alkanoic acid ester standards of known isotopic composition (Indiana standard F8-3, 4 measurements). The mean ±S.D. values of these were –29.87±0.09‰ and –23.22±0.16‰ 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. Precision was determined on a laboratory standard mixture that was injected regularly between samples (42 measurements). The mean ±SD values of n-alkanoic acid esters were –30.51±0.09‰ for the methyl ester of $C_{16:0}$ and –26.19±0.11‰ for the methyl ester of $C_{18:0}$. Values were corrected subsequent to analysis to account for the methylation of the carboxyl group, which occurs during acid extraction using a mass balance formula. 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. Each sample was measured at least twice, whilst the standard deviation provided takes into account the propagation of uncertainties between the replicate measurement of: (i) the sample, (ii) the methylated standard, and (iii) the $C_{16:0}$ and $C_{18:0}$ fatty acids standard measured offline.

4. Results

4.1. Lipid quantification and characterisation

Analysed sample volumes and preservation of lipids identified with GC-FID as per gram of ceramic powder or foodcrust is reported in Table 1. The preservation of lipids was exceptionally good, within the range of 54.1 to 8163.4 mg/g^{-1}. The detailed overview of lipid analysis with GC-MS and GC-C-IRMS are provided in Table 2.

4.2 Biomarker profiles

Relying on the biomarker-based GC-MS analysis (Table 2) it was possible to identify the tentative origin of lipids in the Turaida hillfort samples, whereas the Pūteļi cemetery samples remained somewhat ambiguous. All the samples from Turaida hillfort included full aquatic biomarkers: ω-(o-alkylphenyl) alkanoic acids (APAAs) with carbon atoms ranging from C_{16} to $C_{20/22}$ formed during the heating of polyunsaturated fatty acids of aquatic organisms, together with one of the isoprenoid fatty acids (phytanic, pristanic, and 4,8,12-trimethyltridecanoic (TMTD), whereas in this batch only phytanic acid was detected) (Hansel *et al.*, 2004; Craig *et al.*, 2007). In two samples (TUR-1 and 2b), cholesterol or its derivatives as biomarkers for animal products (either aquatic or terrestrial) were present, although later secondary contamination from human handling cannot be excluded either.

The identification of Pūteļi cemetery samples using the GC-MS data remained somewhat vaguer. Partial aquatic biomarkers (APAA in C_{18} fatty acid together with phytanic acid) were detected in two Pūteļi samples, PUT-2 and 4,

which all in all had a rather similar lipid profile. However, this biomarker profile might also indicate potential ruminant carcass fats, hence not necessarily relating to aquatic products, whereas this distinction can be made with the further analysis of phytanic acid diastereomers (*cf.* Lucquin, 2016) not conducted in this study. The PUT-2 sample also included traces of β-amyrin, a widely-occurring plant triterpene, which has been associated with the use of Viburnum berry in ceramics (Bondetti *et al.*, 2019); however, being a low abundance peak, environmental contamination from sediment cannot be entirely excluded.

Two samples (PUT-1 and 3) displayed a rather similar lipid profile, characterised by notably evident short/mid-chain n-alkanes, mostly in the range of 19–22, yet without any clear odd over even domination, or higher abundance of long-chain fatty acids (>C20). Therefore, the lipid profiles of these two samples do not seem to fit with that of typical plant wax (*cf.* Bush and McInerney, 2013; Égüez *et al.*, 2022; Evershed *et al.*, 1991; Patalano *et al.*, 2021). PUT-3 showed a considerably higher palmitic acid peak, which despite being widely debated (Whelton *et al.*, 2021), has been sometimes suggested as an indicator of plant substance (Dunne *et al.*, 2016). However, no other plant biomarkers like stigmasterol, sitosterols, campesterol or alike were identified in either of these samples. One potential explanation fitting with the n-alkane profile, at least partially, would be that of aquatic plant or sediment origin (Ficken *et al.*, 2000; Wang and Liu, 2012), yet the high abundance of even-number n-alkanes in our samples contradicts this interpretation as well. Short-/mid-chain n-alkanes have been also related to sediment samples deriving from biomass burning (heating-based degradation or incomplete combustion of biomass at higher temperatures ca 400 and 500 °C (*cf.* Eckmeier and Wiesenberg, 2009) or microbial degradation (Brittingham *et al.*, 2017), whereas similarly to our samples in both of these scenarios there is also no odd- over even-number alkane distribution. Thus, the n-alkanes detected in PUT-1 and 3 samples might be the result of initial archaeological (some kind of site-specific biomass burning practices) or secondary collection curatorial (related to storage and microbial growth) origin contamination (Whelton *et al.*, 2021). PUT-1 included a considerable amount of ketones as well, whereas PUT-3 only one mid-chain example. Although ketones have been identified in plants as well (*cf.* Evershed *et al.*, 1991), the long-chain ketones have been related to the heating of triacylglycerols (*cf.* Evershed *et al.*, 1995; Raven *et al.*, 1997). As we are missing the full higher plant-related biomolecular profile combining wax esters, n-alkanes, and long-chain n-alcohols, the explanation of burnt biomass seems the most likely, although not entirely conclusive, in the case of these two samples. The origin of samples PUT 4–5 remained unclear based on GC-MS biomarker analysis.

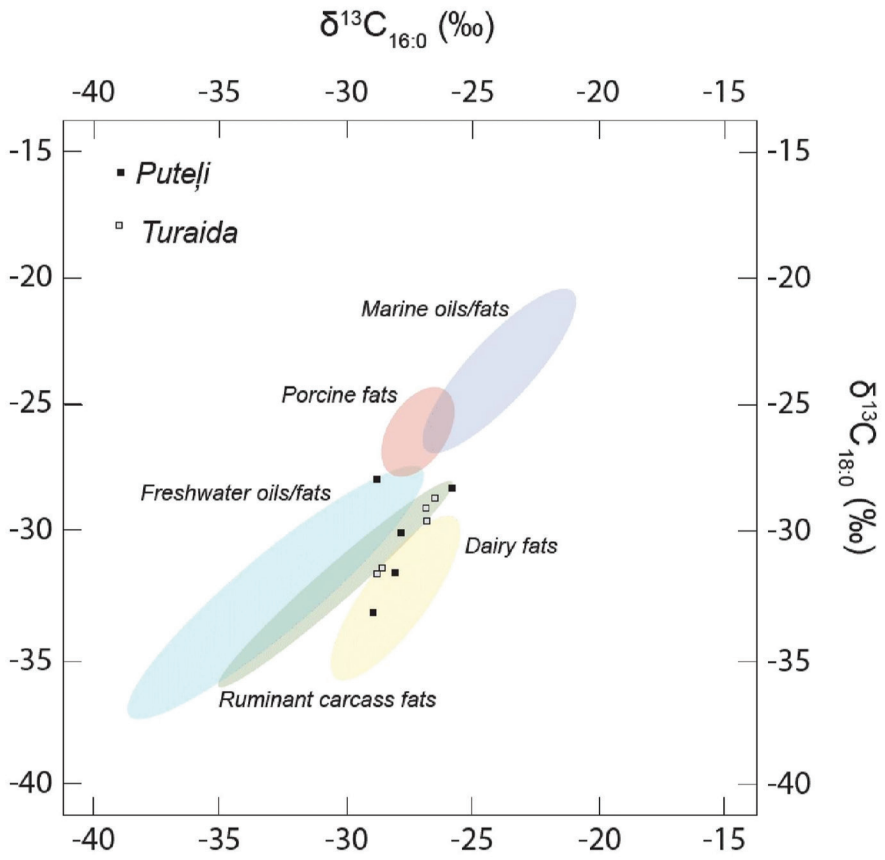

Figure 5. Single compound stable isotope analysis (GC-C-IRMS results) of Pūteļi cemetery and Turaida hillfort samples (plotted on eastern Baltic reference data based on Courel *et al.*, 2020, with 95% confidence ranges). Note that all Turaida hillfort samples included full aquatic biomarkers.

4.3 Compound specific isotope results

GC-C-IRMS results measured from the $C_{16:0}$ and $C_{18:0}$ fatty acids (Figure 5) provide further information on the origin of food sources processed in Pūteļi cemetery and Turaida hillfort vessels. The isotopic measurements show a wider variety of food substances in the dataset. Turaida hillfort sample isotopes plot into the ruminant carcass fats region, with a good overlap of foodcrust and ceramic powder measurements from the same vessel.

The two Pūteļi cemetery samples with range of n-alkanes (PUT-1 and 3) both plot to the ruminant range. Without any aquatic biomarker indication, it seems most likely that indeed ruminant carcass fats were cooked in these vessels. Two samples, PUT-2 and 4, clearly plot in the dairy range with their depleted $C_{16:0}$ and $C_{18:0}$ values, and Δ13C value >–3.3‰ (Copley *et al.*, 2003). Sample PUT-5 plots between the porcine (omnivorous) and freshwater range.

5. Discussion

5.1 The frequent and the abundant

Lipid residue data shows three products that dominated in the Gauja Liv diet – aquatic, ruminant and dairy (Table 1, Figure 5). Aquatic biomarkers were present in all Turaida samples (Table 1). The overlap of foodcrust and ceramic powder results of the same vessels (TUR-2(a,b) and TUR-3(a,b)) indicates that vessels from Turaida were frequently used to process aquatic organisms. The GC-C-IRMS analysis did not show clear signs of lipids from marine origins and most likely they were of freshwater origins (Figure 5). In most cases it can be assumed to have been fish (as the most common resource) but other aquatic animals cannot be ruled out.

The isotopic measurements reveal a wider variety of food substances that were cooked together or intermittently with freshwater organisms. Isotopes from Turaida hillfort plot into the region for ruminant carcass fats. As the biomarker-based results gave evidence for aquatic fats for all Turaida vessels, two scenarios of contemporaneous or subsequent cooking events are possible:

1. Mixing of freshwater fish and dairy resulting in the mid-range ruminant-like isotopic values (*cf.* similar tendencies with plant in Hendy *et al.*, 2018);
2. Mixing of aquatic substances (indicated by biomarker data) with ruminant carcass fats (based on isotopic data).

The archaeological bone material from Turaida confirms that **large-stock animals** (cattle) were the most common source of meat at the site (Figure 6). After cattle and pigs, the third most common species were small-stock animals (sheep and goats). The lipid values of both large and small stock animals would plot in the range of ruminant carcass fats.

Two Pūteļi cemetery samples (PUT-1 and 3) plot in the ruminant range in their compound specific isotopic results. Unlike the Turaida samples these did not have indications of aquatic biomarkers, suggesting the processing of unmixed ruminant-like products. However, the biomarker profile of these two samples displayed short/mid-chain n-alkanes, most likely resulting from some type of site-specific biomass burning practices. The exact impact of this theoretical event on the lipid results currently remains open and needs further investigation. Yet, here it is worth pointing out that isotopic values of ruminants may also result from the mixing of higher proportions of plants (cereals) and dairy (Hendy *et al.*, 2018). Yet missing any clear biomarker profiles for cereals in these samples, this interpretation does not seem to be valid.

Keeping cattle and sheep/goats at the site would also result in the availability of milk. Seasonally, **dairy** would be a relatively abundant product. Even with the relatively small sample set, two Pūteļi cemetery samples (PUT-2 and 4) plot in the dairy range of compound specific isotopic results. The biomarker profiles for both of these samples contained APAA-C_{18} together with phytanic acid that might be interpreted as a partial aquatic biomarker or originate from ruminant carcass fats, although recent studies looking at APAA-C_{18} isomers have also shown

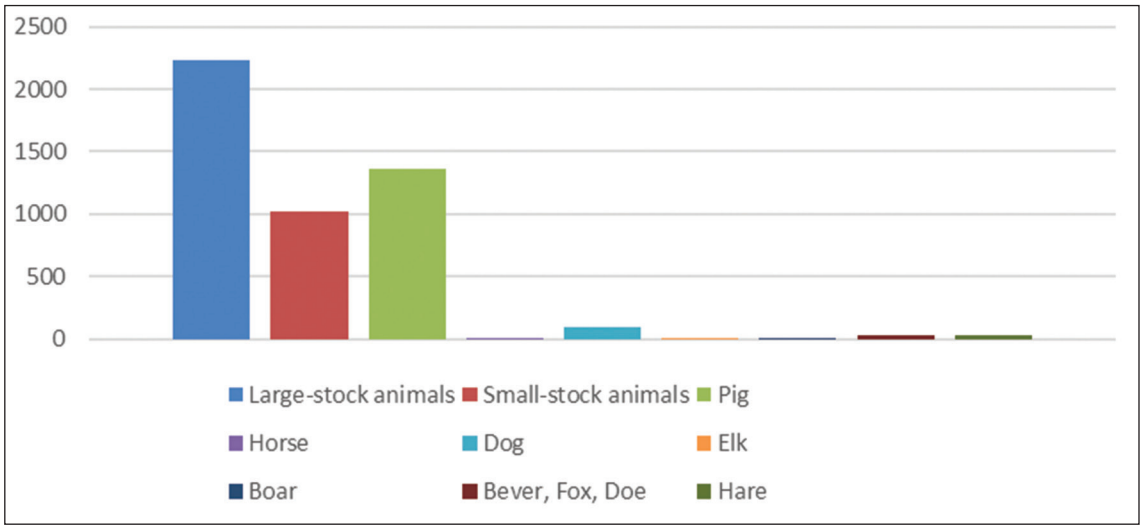

Figure 6. Total number of animal bones found in Turaida hillfort, Late Iron Age layers (Graudonis, 2003, p.44).

the possibility of having plants with this profile (Bondetti *et al.*, 2021). Unfortunately, these specific analyses were not carried out in this study. Hence, the PUT-2 and PUT-4 residues were dairy based, but possible mixing with other products in contemporaneous or subsequent cooking events is possible.

5.2 The lacking

According to the archaeological animal bone remains, **pork** should have been present in the lipid residues, as the second most abundant animal bone material was from suids (Figure 6). The lipid residue results do not give clear evidence for pork consumption. The only sample that is relatively close to the porcine isotopic ellipse and could be connected to porcine fats is PUT-5: located between the porcine (omnivorous) and freshwater range, but lacking any aquatic biomarkers. It is both possible that this is a regional deviation in the porcine fat isotopic values based on environmental factors or the feed practices of suids. Or that the temperature was too low (or the heating period short) for aquatic biomarkers to be preserved, as most aquatic biomarkers only form during prolonged heating in above 270 °C (Hansel *et al.*, 2004).

The general pattern concerning pork matches previous analyses of Daugava Liv pottery material (Gunnarssone *et al.*, 2020, p.60). The absence can be hypothetically explained by the culinary custom of smoking pig meat, as pork is more practically beneficial to smoke than beef (Spry-Marqués, 2017, p.153). Similar selective processing practices have also been reported elsewhere (Mottram *et al.*, 1999). If the butchered pig meat was predominantly smoked, the resulting smoked produce would later require only short-term heating, or be consumed cold.

The second aspect is the mixing factor. Several analysed samples display a potential mixing of multiple product groups. If porcine fat residues would have been mixed with aquatic or ruminant fats, the resulting isotope measurements might fall outside the suid isotopic ranges.

The second group conspicuously missing from the lipid results are the cultivated crops. The Liv diet, according to lipid residue and human bone isotopic analyses, leans towards a protein rich diet (Gunnarssone *et al.* 2020, p.65). However, the absence of cultivated plants in the lipid residues is unexpected given that historic records of the time depict an agrarian society. The Chronicle of Henry mentions the presence of cultivated fields on two occasions when discussing the Livs of Turaida. It states that the people of Turaida *had ... done a lot of evil to Kaupo [local king] ... taking away his fields...* (Indriķis, 1993, p.81) and that ... *the Turaida Livs wanted to sacrifice him [bishop] to their gods, because his sown fields gave a better harvest than their own fields, which, flooded by rain, were destroyed.* (Indriķis, 1993, p.51). It is possible that these were more general statements but, it seems unlikely given that the author does not juxtapose the cultivated Christian land versus the wild barbarian lands.

The most common cultivated plants in the related Daugava Liv society (Ciglis, 2001, pp.10–15; Šnē, 2000, pp.144–145) are barley, wheat, oats and rye, with an addition of beans, peas and turnips (Rasiņš *et al.*, 1983, Tables 3 and 5.). Due to their high carbohydrate and low lipid content the detection of plants via LRA is complicated. However, several recent studies have managed to identify plant substances through LRA (Dolbunova *et al.*, 2022, pp.4–9; Murakami *et al.*, 2022, pp.8–11; Courel *et al.*, 2021, p.7; Papakosta *et al.*, 2019, p.148; Colonese *et al.*, 2017, pp.3–4; Oras *et al.*, 2017, p.129; Bondetti *et al.*, 2021). So far, plant biomarkers have been absent not only in the Gauja Liv vessel residue analyses, but also in the Daugava Liv vessel residue analyses (Gunnarssone *et al.*, 2020, pp.61–64). The role plants played in the protein rich Liv diet is a question that needs further research and analytical development as the present data tends to be contradictory.

The use of **gathered plants**, such as hazelnuts, wild strawberries and raspberries, to supplement the diet, is known in many Late Iron Age hillforts (Rasiņš *et al.*, 1983, pp.154–169; Sillasoo, 1992; Tvauri, 2016, p.39; Valk, 1994, p.388). Even in Turaida, during the excavations, hazelnuts were found in the R-Z II building. Sadly, the leading archaeologist did not take note of this find (Jemelijanovs, 2023). Most of the wild berries and nuts would have been eaten uncooked and thus not appear in the pots as lipid residues. However, a trace element associated with Viburnum berries was found in one of the samples. Whilst Viburnum berries can be consumed raw, cooking would have removed their naturally sour taste (PFAF, 2009). The low abundance leaves a possibility for this to be a contamination. However, it would also seem probable that these berries were never used in large amounts.

The lack of **honey** in the Lipid Residue Analysis has been noted when discussing other cultures (Dolbunova, 2022, p.4). For Livs, honey was an important resource for food, drink and trade (Indriķis, 1993, p.53). The absence of indications for it in LRA might be due to the type of vessel used for storage. Raw honey that is stored in an unglazed pot is likely to permeate into the pot's pores and crystallise, leading to fractures in the clay matrix. For this reason, long-term storage might have been done in wooden containers as seen in ethnography (Bīlenšteins, 2007, p.103). Archaeological excavations of a Liv 12th–13th century building in Riga unearthed a spruce bark vessel covered in birch bark that contained honeycombs. A few streets away a similar vessel filled with wax was obtained (Ciglis, 2001, p.37). Hence, it can be presumed that honey and wax might not have been commonly stored in ceramic containers and it should not be expected to be present in LRA of pottery.

5.3 Food in burial context

During sample selection, special attention was given to contextual information. Although the sample set was much too small for any overarching conclusions, it should be noted that the isotopic measurements of the two vessels placed in male burials contained residues plotting in the ruminant adipose regions. The one vessel from a female burial, however, contained residues that plot in the range of dairy. This now is

the third known site which displays more depleted $\delta^{13}C$ values for vessels placed in female burials than for ones placed in male burials. The same pattern of depleted $\delta^{13}C$ values in female burial vessels has been noted in the study of the 12th–13th century CE Kukruse cemetery (Oras *et al.*, 2018, p.99), and observed in the analyses of the 11th–13th century CE Rauši cemetery (Gunnarssone *et al.*, 2020, Figure 4).

The possibility of the vessels placed in graves having a direct relation to the buried individual's diet can only be assessed by comparative bone collagen stable isotope analyses. In Latvia there is only one known published dataset of dietary stable isotope analyses of human bone collagen from the Iron Age. The 9th–10th century CE burials in Lejasbitēni cemetery showed significantly higher $\delta^{15}N$ values in male remains than female remains (Pētersone-Gordina *et al.*, 2022, p.7). A similar analysis in Kukruse cemetery (Estonia) also displayed higher $\delta^{15}N$ values in male remains than female remains (Oras *et al.*, 2018, p.96). Both seem to indicate a higher protein intake for male individuals.

Two studies of human bone collagen show higher protein intake for the male population in the Late Iron Age. With the addition of this study, there are now three sample sets showing pots placed in male burials as also having a greater likelihood of being used to process organisms of a higher trophic level. Although none of these studies have large sample sets, a tentative pattern seems to be appearing.

However, we emphasise that vessels were placed in burials by the deceased's relatives not by the buried individual. If further studies will follow the outlined trend, the connection of the artefact to the individual's diet would raise a whole new set of questions concerning the cooking practices. It would imply that female and male food was cooked separately often enough to result in distinct lipid profiles in the cooking ware. Theoretically this could have occurred during gender-specific tasks that happened some distance from the home. For example, extended fishing trips for males, or cattle herding for females. Or pots that were used to solely process milk were preferentially placed in female burials. However, this is still only a tentative pattern, covering three distinct groups of people which might all have had different subsistence and cultural customs. We still lack substantial data for any definitive conclusions.

6. Conclusions

This study of Gauja Liv dietary aspects using Lipid Residue Analysis shows the predominance of an animal-based diet during the Late Iron Age. The lipid GC-MS and GC-C-IRMS analyses established the main bases of the diet as: freshwater organisms, ruminant carcass fats and dairy. These food groups most likely represent freshwater fish, beef, mutton and milk products. Notably all the samples from Turaida hillfort contained full aquatic biomarkers and almost half of the Pūteļi cemetery samples contained partial aquatic biomarkers, although this lipid profile can also be related to other food substances.

The study suggests that some mixing of different foodstuffs occurred as either contemporaneous or as subsequent cooking events as shown by the contrasting compound specific isotope results and the biomarker profiles. The most direct evidence was for the mixing of freshwater organisms with ruminant carcass fats.

Several food groups, like porcine fats, honey and plant substances, which are known from the archaeological material and historic sources, were not identified through LRA. The absence of these food groups might be a result of the sample set size or different food processing strategies. Although the archaeological material confirms a notable rearing of pigs, only one sample had isotopic values that could potentially be linked to omnivores. This paper proposes that pork might have been predominantly treated by smoking, and hence removing the need for long-term processing in a pot and reducing the amount of detectable lipid residue.

More problematic and elusive are cultivated crops. Historical written sources attest that Turaida Livs did cultivate cereals, but this study was not able to pick up any traces of cultivated crops. Cereal detection using LRA is challenging, but has been done in similar studies. The absence of plant products in the lipid residues might be due to the small sample set that excludes products which were less common in the Liv diet, or the result of the analytical resolution obtained in this study. More research is needed concerning these questions.

The approach of selecting two sample sets from two typologically different sites – burial and living – has shown itself as beneficial. The inclusion of samples from the living site allowed for a more confident discussion of the diet in broad terms, while the samples from the burial site provided some indications for possible studies of gender-based diet in the future.

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References

AGURAIUJA-LÄTTI, Ü., and LÕUGAS, L., 2019. Stable isotope evidence for medieval diet in urban and rural northern Estonia. *Journal of Archaeological Science: Reports,* 26, 101901.

BANERJEA R.Y., BADURA M., KALĒJS U., CERINA A., GOS K., HAMILTON-DYER S., MALTBY M., SEETAH K., and PLUSKOWSKI, A., 2017. A multi-proxy, diachronic and spatial perspective on the urban

activities within an indigenous community in medieval Riga, Latvia. *Quaternary International*, 460, 3–21.

BĪLENŠTEINS, A., 2007. *Latviešu koka iedzīves priekšmeti. Latviešu koka iedzīves priekšmeti.* Riga: Jumava.

BLIUJIENĖ, A. MATULAITIENĖ, I., GARBARAS, A., ŠAPOLAITĖ, J., EŽERINSKIS, Ž., ULOZAITĖ R., and BRAČIULIENĖ, R., 2018. Dietary aspects of the West Lithuanian people during the Late Roman and Early Migration periods with reference to household and funerary pottery. *Praehistorische Zeitschrift*, 93(1), 144–165.

BONDETTI, M., CHIRKOVA, S.S., LUCQUIN, A., MEADOWS, J., LOZOVSKAYA, O., DOLBUNOVA, E., JORDAN, P., and CRAIG, O.E., 2019. Fruits, fish and the introduction of pottery in the Eastern European plain: Lipid residue analysis of ceramic vessels from Zamostje 2. *Quaternary International*, 541(10), 104–114.

BONDETTI, M., SCOTT, E., COUREL, B., LUCQUIN, A., SHODA, S., LUNDY, J., LABRA-ODDE, C., DRIEU, L., and CRAIG, O.E., 2021. Investigating the formation and diagnostic value of ω-(o-alkylphenyl) alkanoic acids in ancient pottery. *Archeometry*, 63(3) 594–608.

BRITTINGHAM, A., HREN, M.T., and HARTMAN, G., 2017. Microbial alteration of the hydrogen and carbon isotopic composition of n-alkanes in sediments. *Organic Geochemistry*, 107, 1–8.

BROWN, A., 2019. Vegetation Change in Livonia: the Palynological Data. In: A.G. Pluskowski, ed. *Environment, Colonization and the Baltic Crusader States.* Terra Sacra I, Turnhout: Brepols, pp. 106–135.

BUSH, R.T., and MCINERNEY, F.A., 2013. Leaf wax n-alkane distributions in and across modern plants: Implications for paleoecology and chemotaxonomy. *Geochimica et Cosmochimica Acta*, 117, 161–179.

CIGLIS, J., 2015. Baltu un Baltijas somu kultūras mijiedarbība Gaujas lejteces reģionā līdz 13. gadsimta sākumam. In: I. Stašulāne, ed. B*altu un Baltijas somu senlietas Turaidas muzejrezervāta krājumā*. Riga: Zinātne, pp. 11– 50.

CIGLIS, J., ZIRNE, S., and ŽEIERE, I., 2001. *Lībieši senatnē. Livs in the antiquity*. Riga: NIMS.

COLONESE, A.C., HENDY, J., LUCQUIN, A., SPELLER, C.F., COLLINS, M.J., CARRER, F., GUBLER, R., KÜHN, M., FISCHER, R., and CRAIG, O.E., 2017. New criteria for the molecular identification of cereal grains associated with archaeological artefacts. *Scientific Reports*, 7, 6633.

COPLEY, M.S., BERSTAN, R., DUDD, S.N., DOCHERTY, G., MUKHERJEE, A.J., STRAKER, V., PAYNE, S., and EVERSHED, R.P., 2003. Direct chemical evidence for widespread dairying in prehistoric Britain. *Proceedings of the National Academy of Sciences,* 100(4), 1524–1529.

COUREL, B., MEADOWS, J., CARRETERO, L.G., LUCQUIN, A., MCLAUGHLIN, R., BONDETTI, M., ANDREEV, K., SKOROBOGATOV, A., SMOLYANINOV, R., SURKOV, A., VYBORNOV, A.A., DOLBUNOVA, E., HERON, C.P., and CRAIG, O.E., 2021. The use of early pottery by hunter-gatherers of the Eastern European forest-steppe. *Quaternary Science Reviews*, 269, 1–12.

CRAIG, O.E., FORSTER, M., ANDERSEN, S.H., KOCH, E., CROMBE, P., MILNER, N.J., STERN, B., BAILEY, G.N., and HERON, C.P., 2007. Molecular and isotopic demonstration of the processing of aquatic products in Northern European prehistoric pottery. *Archaeometry*, 49(1), 135–152.

CRAIG, O.E., SAUL, H., LUCQUIN, A., NISHIDA, Y., TACHÉ, K., CLARKE, L., THOMPSON, A., ALTOFT, D.T., UCHIYAMA, J., AJIMOTO, M., GIBBS, K., ISAKSSON, S., HERON, C.P., and JORDAN, P., 2013. Earliest evidence for the use of pottery. *Nature*, 496, 351–354.

DOLBUNOVA, E., LUCQUIN, A., T. ROWAN MCLAUGHLIN, R.T., BONDETTI, M., COUREL B., ORAS E., PIEZONKA, H., ROBSON, H.K., TALBOT, H., ADAMCZAK, K., ANDREEV, K., ASHEICHYK, V., CHARNIAUSKI, M., CZEKAJ-ZASTAWNY, A., EZEPENKO, I., GRECHKINA, T., GUNNARSSONE, A., GUSENTSOVA, T.M., HASKEVYCH, D., IVANISCHEVA, M., KABACIŃSKI, J., KARMANOV, V., KOSORUKOVA, N., KOSTYLEVA, E., KRIISKA, A., KUKAWKA, S., LOZOVSKAYA, O., MAZURKEVICH, A., NEDOMOLKINA, N., PILIČIAUSKAS, G., SINITSYNA, G., SKOROBOGATOV, A., SMOLYANINOV, R.V., SURKOV, A., TKACHOV, O., TKACHOVA, M., TSYBRIJ, A., TSYBRIJ, V., VYBORNOV, A.A., WAWRUSIEWICZ, A., YUDIN, A.I., MEADOWS, J., HERON, C., and CRAIG, O.E., 2022. The transmission of pottery technology among prehistoric European hunter-gatherers. *Nature Human Behaviour*, 7, 1–13.

DUMPE, B., 2019. Bezripas keramika. In: I. Stašulāne, ed. *Turaidas pils 10.–19. gs. keramikas trauki*. Riga: Zinātne, pp. 14–19.

DUNNE, J., MERCURI, A.M., EVERSHED, R.P., BRUNI S., and LERNIA, S., 2016. Earliest direct evidence of plant processing in prehistoric Saharan pottery. *Nature Plants*, 3, 16194.

ECKMEIER, E., and WIESENBERG, G.L.B., 2009. Short-chain n-alkanes (C16–20) in ancient soil are useful molecular markers for prehistoric biomass burning. *Journal of Archaeological Science*, 36(7), 1590–1596.

ÉGÜEZ, N., MALLOL, C., and MAKAREWICZ, C.A., 2022. n-Alkanes and their carbon isotopes (δ13C) reveal seasonal foddering and long-term corralling of pastoralist livestock in eastern Mongolia. *Journal of Archaeological Science*, 147, 105666.

EVERSHED, R.P., HERON, C., and GOAD, L.J., 1991. Epicuticular wax components preserved in potsherds as chemical indicators of leafy vegetables in ancient diets. *Antiquity*, 65(248), 540–544.

EVERSHED, R.P., STOTT, A.W., RAVEN, A., DUDD, S.N., CHARTERS, S., and LEYDEN, A., 1995. Formation of long-chain ketones in ancient pottery vessels by pyrolysis of acyl lipids. *Tetrahedron Letters*, 36(48), 8875–8878.

FICKEN, K.J., LI, B., SWAIN, D.L., and EGLINTON, G., 2000. An n-alkane proxy for the sedimentary input of submerged/floating freshwater aquatic macrophytes. *Organic Geochemistry*, 31(7–8), 745–749.

GRAUDONIS, J., 2003. *Turaidas pils I*. Riga: Jāņasēta.

GUNNARSSONE, A., 2019. Agrā ripas keramika. In: I. Stašulāne, ed. *Turaidas pils 10.–19. Gadsimta keramikas trauki*. Riga: Zinātne, pp. 31–35.

GUNNARSSONE, A., ORAS, E., TALBOT, H.M., ILVES, K., and LEGZDIŅA, D., 2020. Cooking for the Living and the Dead: Lipid Analyses of Rauši Settlement and Cemetery Pottery from the 11th–13th Century. *Estonian Journal of Archaeology*, 24(1), 45–69.

HANSEL, F.A., COPLEY, M.S., MADUREIRA, L.A.S., and EVERSHED, R.P., 2004. Thermally produced ω-(o-alkylphenyl) alkanoic acids provide evidence for the processing of marine products in archaeological pottery vessels. *Tetrahedron Letters*, 45(14), 2999–3002.

HENDY, J., COLONESE, A.C., FRANZ, I., FERNANDES, R., FISCHER, R., ORTON, D., LUCQUIN, A., SPINDLER, L., ANVARI, J., STROUD, E., BIEHL, P.F., SPELLER, C., BOIVIN, N., MACKIE, M., JERSIE-CHRISTENSEN, R.R., OLSEN, J.V., COLLINS, M.J., CRAIG, O.E., and ROSENSTOCK, E., 2018. Ancient proteins from ceramic vessels at Çatalhöyük West reveal the hidden cuisine of early farmers. *Nature Communications*, 9, 4064.

HERON, C., CRAIG, O.E., LUQUIN, A., STEELE, V.J., THOMPSON, A., and PILIČIAUSKAS, G., 2015. Cooking fish and drinking milk? Patterns in pottery use in the southeastern Baltic, 3300–2400 cal BC. *Journal of Archaeological Science*, 63, 33–43.

INDRIĶIS, 1993. *Indriķa Hronika.* Tulkojis Ā. Feldhūns. Riga: Zinātne.

JANSONS, G., 2007. *Turaidas pils ahitektūra 13.–17. gadsimts*. Riga: Latvijas vēstures institūta apgāds.

JEMELIJANOVS, E., 2023. Interviewed by Alise Gunnarssone. 10th January, Turaida.

KALNIŅA, L., CERIŅA, A., KIZIKS, K., STANKEVIČA, K., PUJĀTE, A., and DRUČKA, A., 2019. Evidence of human impact and vegetation change during the Late Iron Age and Medieval Livonian Period at Some Sites Along the Lower Course of River Daugava. In: A.G. Pluskowski, ed. *Ecologies of Crusading, Colonization and Religious Conversion in the Medieval Baltic*. Terra Sacra II, Turnhout: Brepols, pp. 129–145.

LUCQUIN, A., COLONESE, A.C., FARRELL, T.F.G., and CRAIG, O.E., 2016. Utilising phytanic acid diastereomers for the characterisation of archaeological lipid residues in pottery samples. *Tetrahedron Letters*, 57(6), 703–707.

MILLER, M.J., WHELTON, H.L., SWIFT, J.A., MALINE, S., HAMMANN, S., CRAMP, L.J.E., MCCLEARY, A., TAYLOR, G., VACCA, K., BECKS, F., EVERSHED, R.P., and HASTORF, C.A., 2020. Interpreting ancient food practices: stable isotope and molecular analyses of visible and absorbed residues from a year-long cooking experiment. *Science Reports*, 10, 13704.

MOTTRAM, H.R., DUDD, S.N., LAWRENCE, G.J., STOTT, A.W., and EVERSHED, R.P., 1999. New chromatographic, mass spectrometric

and stable isotope approaches to the classification of degraded animal fats preserved in archaeological pottery. *Journal of Chromatography A*, 833(2), 209–221.

MURAKAMI, N., ONGGARULY, A., RAKHIMZHANOVA, S., STANDALL, E.A., TALBOT, H.M., LUCQUIN, A., SUZUKI, M., KARIMAGAMBETOV, A., NUSKABAY, A., NAM, S.W., CRAIG, O.E., and SHODA, S., 2022. Lipid residues in ancient pastoralist pottery from Kazakhstan reveal regional differences in cooking practices. *Frontiers in Ecology and Evolution*, 10, 1–16.

ORAS, E., HIGHAM, T.F.G., CRAMP, L.J.E., and BULL, I.D., 2017. Archaeological science and object biography: a Roman bronze lamp from Kavastu bog (Estonia). *Antiquity*, 91(355), 124–138.

ORASA, E., TÕRVA, M., JONUKSC, T., MALVEA, M., RADINID, A., ISAKSSONE, S., GLEDHILLF, A., KEKIŠEVB, O., VAHURB, S., and LEITOB, I., 2018. Social food here and hereafter: Multiproxy analysis of gender-specific food consumption in conversion period inhumation cemetery at Kukruse, NE-Estonia. *Journal of Archaeological Science*, 97, 90–101.

PAPAKOSTAA, V., ORAS, E., and ISAKSSONA, S., 2019. Early pottery use across the Baltic – A comparative lipid residue study on Ertebølle and Narva ceramics from coastal hunter-gatherer sites in southern Scandinavia, northern Germany and Estonia. *Journal of Archaeological Science*, 24, 142–151.

PATALANO, R., ROBERTS, P., BOIVIN, N., PETRAGLIA, M.D., and MERCADER, J., 2021. Plant wax biomarkers in human evolutionary studies. *Evolutionary Anthropology: Issues, News, and Reviews*, 30(6), 385–398.

PĒTERSONE-GORDINA, E., GERHARDS, G., VILCĀNE, A., MILLARD, A.R., MOORE, J., ĶIMSIS, J., and RANKA, R., 2022. Diet and social status in the Lejasbitēni Iron Age population from Latvia. *Journal of Archaeological Science: Reports*, 44, 103519).

PFAF, 2009. *Viburnum opulus – L.* [online]. PFAF. [viewed 30/03/2023]. Available from: https://pfaf.org/user/Plant. aspx?Latin Name=Viburnum+opulus

RASIŅŠ, A., and TAURIŅA, M., 1983. Pārskats par Latvijas PSR arheoloģiskajos izrakumos konstatētajām kultūraugu un nezāļu sēklām. *Arheoloģija un Etnogrāfija*, 14, 152–175.

RAVEN, A.M., VAN BERGEN, P.F., STOTT, A.W., DUDD, S.N., and EVERSHED, R.P., 1997. Formation of Long-Chain Ketones in Archaeological Pottery Vessels by Pyrolysis of Acyl Lipids. *Journal of Analytical and Applied Pyrolysis*, 40/41, 267–285.

SILLASOO, Ü., 1992. *Taimeleiud Tartu Küütri tn. 1992.* Manuscript deposited in the Institute of History and Archaeology of the University of Tartu.

ŠNĒ, A., 2000. Vara un vadonība Lībiešu sabiedrībās aizvēstures beigās. In: I. Gorenko, ed. *Cauri gadsimtiem*. Riga: NIMS, pp. 141–147.

SPRYMARQUÉS, P., 2017. *Pig/Pork: Archaeology, Zoology and Edibility*. Croydon: Bloomsbury Sigma.

STIVRINS, N., BROWN, A., REITALU, T., VESKI, S., HEINSALU, A., BANERJEA, R.Y., and ELMI, K., 2015. Landscape change in central Latvia since the Iron Age: multi-proxy analysis of the vegetation impact of conflict, colonization and economic expansion during the last 2,000 years. *Vegetation History and Archaeobotany*, 24, 377–391.

TVAURI, A., and VANHANEN, S., 2016. The Find of Pre-Viking Age Charred Grains from Fort-Settlement in Tartu. *Estonian Journal of Archaeology*, 20(1), 33–53.

VALK, H., 1994. The end of excavation at the Late Iron-Age settlement of Aindu. *Tatü*, 43(4), 386–389.

WANG, Z., and LIU, W., 2012. Carbon chain length distribution in n-alkyl lipids: A process for evaluating source inputs to Lakee Qinghai. *Organic Geochemistry*, 50, 36–43.

WHELTON, H.L., HAMMANN, S., CRAMP, L.J.E., DUNNE, J., ROFFET-SALQUE, M., and EVERSHED, R.P., 2021. A call for caution in the analysis of lipids and other small biomolecules from archaeological contexts. *Journal of Archaeological Science*, 132, 105397.

ZARIŅA, G., 2015. *Ikšķiles 13.–15. gadsimta iedzīvotāji.* Riga: Zinātne.