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Research Papers

Grave gifts manifest the ritual status of cattle in Neolithic societies of northern Germany

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ABSTRACT

The Neolithic period in NW-Europe marks a time of major transformation in human lifestyle including sedentism, farming, agropastoralism with early animal husbandry and the use of ornamented pottery by "Funnelbeaker" societies. Domestic animals, in particular cattle, served for traction, plowing, and manuring to support agricultural production but also supplied a variety of dietary products including meat, fat, and milk as well as wool. The impact of animal husbandry on improved living conditions in Neolithic societies and in a religious context has been inferred throughout NW-Europe and even earlier in African and Arabian regions by ritual cattle deposits. However, a potential spiritual/religious role of cattle in Neolithic societies is difficult to assess further due to the lack of interpretable Neolithic illustrations. Here, we demonstrate the ritual role of cattle in Neolithic societies from burial gifts preserved in Megalith tombs (3640–2900 BC) of Wangels, NW-Germany, where storage vessels for afterlife alimentary provision of the deceased contained cattle meat and milk products identified by their characteristic lipids but no common aquatic food sources or cereals. Pottery from the latest burial phase only yielded fatty acids which may derive from essential plant oils of Sea Buckthorn (*Hippophae rhamnoides*) that may have served as precious burial gift for medical or for alimentary purposes. The status of cattle as an object of veneration in Neolithic societies is represented by its dominating contribution to grave gifts underlining the esteem cattle received not only in agroeconomical but even further in ritual and religious respect.

1. Introduction

The Neolithic in Europe and the Middle East comprised a period of innovations in farming practices based on emmer or einkorn crops and agropastoralism with early animal husbandry. The domestication of cattle started during the 9th millennium BC in the Fertile Crescent region in the Middle East, while cattle domestication reached Central Europe only about 3000 years later (Scheu et al., 2015). Domesticated cattle were not only employed in more efficient farming activities like plowing and manuring to increase fertility and agricultural production but also supplied a variety of everyday alimentary products including meat, fats, and milk but also other commodities, e.g. horn and wool (Bogaard et al., 2013; Sherratt, 1983). Lipid analysis on pottery vessels indicate that ruminant milk processing took place since the 6th millennium in Eastern and the 5th millennium in Western and Northern Europe (Copley et al., 2005a; Craig et al., 2005; Isaksson and Hallgren, 2012).

In addition to the use of cattle as livestock and nutritional source, cattle held an important position in the religious and/or ritual context of Neolithic cultures, which is manifested by ubiquitous cattle deposits in Central Europe (Kolodziej, 2011; Pollex, 1999). Cattle burials are either connected to human graves or found individually, whereby cattle are usually laid down intact, but also in pieces, and a fire was lit on the cattle bodies. This procedure has been observed in the context of the early Bernburg culture society around 3100 BC (Müller and Schunke, 2014) or the western Globular Amphora culture (GAC) societies (Johannsen and Laursen, 2010; Woidich, 2014). Thus, it has been thought that cattle burials served to worship deceased animals, or cattle were sacrificed to e.g. humans or natural forces (Kolodziej, 2011; Pollex, 1999). The outstanding role of cattle in a ritual context is reported further from other cultures and regions, including archaeological sites from Arabia (McCorriston et al., 2012) and the Sahara (di Lernia, 2006) region of the 7th millennium or from the Viking Age on Iceland (Lucas and McGovern, 2007). Even today, the cow serves an important religious role in

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Hinduism, where it is sacred and worshipped.

In contrast, information on the relevance of deposition of cattle in Megalith tombs of the Funnel Beaker culture societies (FBC) in Northern Germany and Southern Scandinavia, except the stone heap graves from northwest Jutland between 3100 and 2800 BC (Johannsen and Laursen, 2010), is very scarce. However, the high significance of cattle in the subsistence economy in this period is characterised by high ratios of cattle versus other bones in domestic sites (Benecke, 1994; Brozio, 2016; Steffens, 2005). The Megalith tombs in Northern Germany, with a boom in construction around 3400 BC, which declined until 3100 BC and ended around 2800 BC, are mainly characterised by valuable grave goods such as axes, amber objects or highly decorated ceramics (Brozio et al., 2019). The original contents of the ceramic vessels, however, remain mostly unknown. Pottery vessels found in graves and tombs from later periods indicate that luxury and extraordinary goods were added, e.g. wine in amphorae of the Egyptian burial chamber of Tutankhamun (14th cent. BC) (Guasch-Jané et al., 2006), Bronze Age and Iron Age drinking bowls (Sweden) (Isaksson et al., 2010) and frankincense in Medieval pottery vessels from Belgium (Baeten et al., 2014). Thus, grave goods indicate, which resources were highly esteemed in the respective cultures.

2. Archaeological field work and chronology

The investigation area of the Western Oldenburger Graben is located on the Wagrian Peninsula in Northeast Holstein, NW Germany. The relief comprises terrain elevations, depressions, lowlands and wetlands formed by glacial-geological processes during the Weichselian glacial period. Geomorphology is defined by the Oldenburger Graben, a lowland area 23 km long and up to 3 km wide (Fig. 1). After the formation of two fjords during the Holocene sea-level rise, coastline stabilised by a sequential arrangement of cliffs and beach ridges during the Late Mesolithic. The former bays and fjords were cut off from the sea during the Neolithic by sand barriers, promoting the development of inland lagoons (Brozio, 2019, 2016), with Mesolithic and Neolithic settlement activity concentrated along their shores. The settlement site Oldenburg-Dannau LA 77 is located on a WNW – ESE oriented terrain elevation, measuring approximately 280 m long and 125 m wide (Brozio, 2019, 2016).

Except for the western part, the archaeological site is covered with a settlement layer of variable conservation status. Organic materials such as botanical macroremains (Kirleis and Klooβ, 2014) and bones were identified on the former prehistoric riparian zone and the terrain elevation. Settlement features occur as pits and postholes, well structures and rows of stakes, serving to enclose the settlement area between 3087–2927 BC (Brozio, 2019, 2016). Burials within the settlement date to 3960–3806 BC, 3489–3363 BC, and in the riparian zone to the Late Neolithic, 2897–2872 BC. The find material primarily comprises stone artefacts and the ceramic material is mainly composed of highly-fragmented pieces. Overall, only 25% of the vessels exhibit decoration, whereby ornamented vessels tend to be of a finer design (Brozio, 2019, 2016).

The compilation of the findings makes it possible to identify several huts and houses of the Funnel Beaker (FBC) or "Mossby" type (Artursson et al., 2003; Müller, 2013). Based on ^{14}C dates in combination with a seriation of ceramic patterns, a chronological subdivision has been established for the settlement Oldenburg LA 77 (Fig. S1): phase 1, 3270–3110 cal BC; phase 2, 3110–3020 cal BC; phase 3A, 3020–2990 cal BC; and phase 3B, 2990–2920 cal BC (Brozio, 2019, 2016). During the Late Neolithic after 2920 cal BC, the terrain elevation was only used with low intensity. Oldenburg-Dannau is one of the few larger Middle Neolithic settlements of the FBC society in the area that was continuously used over a long period of time.

Megalithic tombs separated spatially from the settlements were also located in the hinterland of the Baltic coast. Up to 15,000 megaliths, characterised by their uprights and capstones, were constructed in northern Germany and southern Scandinavia mainly during the early and middle Neolithic (~3500–3000 a BC) (Müller, 2011). These monumental collective burials are associated not only with the increasing population size, but also with the appearance of social differentiation and symbolizing a status marker (Furholt and Müller, 2011). The megalithic grave Wangels LA 69 is located in the southern moraine tracts bordering the lowland of the Oldenburger Graben on a natural terrain elevation at ca. +22 m a. s. l. The grave chamber is sub-divided into three areas by stone paving and covered by a mound, which was extended to a tumulus in Neolithic time. In addition to stone artefacts and 69 amber objects such as beads shaped like bobbins or double-edged axes, an extensive ceramic inventory – including 57 vessels of the FBC and the Globular Amphora Culture (GAC) was recovered (Fig. S2). The inventory mainly comprises intricately-decorated pieces,

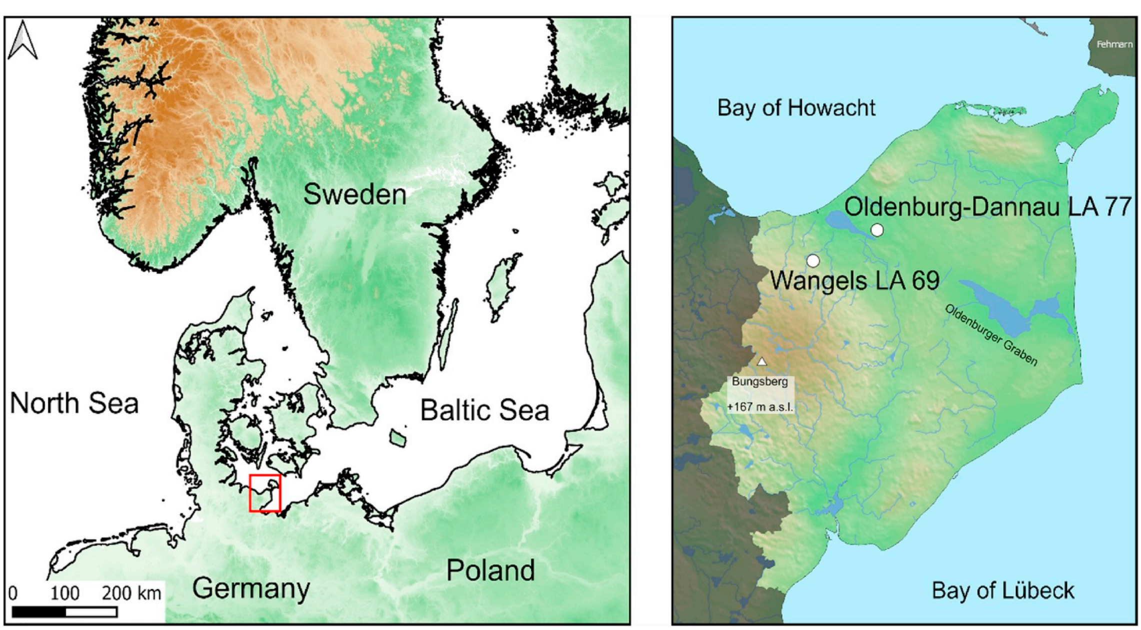

Fig. 1. Map of study area in Northern Europe and location of archaeological sites Wangels LA 69 and Oldenburg-Dannau LA 77 in the Western Oldenburg Graben area on the Baltic coast of Northern Germany.

some of which are preserved in a completely intact and non-fragmented state (Brozio, 2019, 2016).

A fine chronological differentiation of the structure was achieved by a ^{14}C model with 40 out of a total of 51 ^{14}C datings. As a result, seven individual construction and burial phases can be differentiated and classified by absolute chronology (Fig. S3) between 3360 and 1900 cal BC for Wangels: phase 1: Start of use (3640–3360 BC), phase 2: Construction of grave chamber and mound (3360–3280 BC), phase 3: Aggradation of long barrow and establishment of stone circle (3280–3120 BC), phase 4: Burial of a body (3120–3100 BC), phase 5: Burial phase (3120–3000 BC), phase 6/7: Secondary burial phase (3000–1900 BC).

Seriation of the ceramics in combination with scientific dating and stratigraphic information enable the distinction of three ceramic phases integrated in the absolute-chronological phase model. A differentiation of the burials in two Funnel Beaker utilization phases and a Globular Amphora secondary burial phase (phase 7) is feasible. A unique phenomenon is the deposition of a vessel under one of the orthostats before the construction of the chamber, interpreted as a votive or a building sacrifice.

In conclusion, the beginning of the site's use is placed between 3640–3360 BC, followed by the period from 3360–3280 BC, when the construction of the grave chamber and the first mound in the form of a round mound took place. The enlargement of the round mound of the passage grave to a long barrow with a surrounding stone kerb dates between 3280 and 3120 cal BC. A more than 400-year frequentation span of the feature lasting to within the outgoing Late Neolithic around 1900 BC is verified by the ^{14}C model.

3. Material and methods

3.1. Lipid analysis

Organic residue analysis were conducted on 33 pottery vessels excavated from two Neolithic sites Wangels LA 69 and Oldenburg-Dannau LA 77 in Northern Germany following previously published extraction protocols (Evershed et al., 2008b). Briefly, from intact pots a 4 cm^2 piece was cut and from sherds an equivalent sample size was obtained. Before further crushing and grinding, surfaces were carefully abraded to remove exogenous contaminations. 3–4 g of crushed potsherds were extracted by ultrasonication with dichloromethane:methanol (2:1 v/v, 3 × 5 ml). All supernatants were combined and filtered through $NaSO_4$ to remove water and clay particles. Solvents were evaporated to dryness under a gentle steam of nitrogen (N_2) to obtain total lipid extracts (TLE). An aliquot of each sample was derivatized by using *N,O*-bis(trimethylsilyl)trifluoroacetamide and pyridine (70 °C, 60 min) and analysed by high-temperature gas chromatography-mass spectrometry (HTGC-MS).

A second aliquot (~2g) of surface-cleaned and powdered sherd was extracted using direct-acidification-methanol extraction to obtain fatty acids methyl esters (FAME) for GC-combustion-isotope ratio mass spectrometry (GC-C-IRMS) analysis (Correa-Ascencio and Evershed, 2014). Briefly, powdered sherds were treated with 5 ml H_2SO_4-methanol (4% v/v) and heated for 4 h at 70 °C. Subsequently, 2 ml water (HPLC-grade) was added and lipids were extracted thrice with 3 ml *n*-hexane and transferred into a clean vial. Combined *n*-hexane extracts were blown down under a gentle stream of N_2. An aliquot of the extract was separated over aluminium oxide with *n*-hexane:dichloromethane (95:5, v/v) to recover the neutral fraction and *n*-hexane:dichloromethane (1:2, v/v) to obtain FAMEs.

3.2. High-temperature gas chromatography-mass spectrometry (HTGC-MS)

HTGC-MS for TLE measurements were performed using an Agilent 7890A GC equipped with a Phenomenex ZB-1HT (10 m × 0.25 mm × 0.25 μm) column connected to a Phenomenex ZB-5HT Inferno (5 m × 0.25 mm × 0.25 μm) column coupled to an Agilent 5975B mass spectrometer. The oven temperature was held at 80 °C for 2 min, after which the temperature was raised to 400 °C at 8 °C/min and held for 1 min. The MS was operated at an electron energy of 70 eV, scanning at a rate of 1 scan per second for the range of *m/z* 50–750 Da in full scan mode.

GC-MS analysis on FAMEs were performed using an Agilent 7890A GC equipped with an Agilent DB-5 (30 m × 0.25 mm) column coupled to an Agilent 5975B mass spectrometer. GC oven temperature was set to 40 °C and held for 2 min then ramped to 240 °C at 15 °C/min and held isothermal for 15 min. The MS was operated at an electron energy of 70 eV scanning at a rate of 1 scan per second for the range of m/z 50–750 Da in full scan mode. In a second run, the samples were run in SIM mode, scanning the ions *m/z* 105, 262, 290, 318, 346 to detect APAAs. Peak identifications were performed using NIST14 mass spectral database, published mass spectra and retention time.

3.3. Gas chromatography-combustion-isotope ratio mass spectrometry for $\delta^{13}C$ analysis (GC-C-IRMS)

GC-C-IRMS analyses was performed using a Thermo Delta V Plus isotope ratio mass spectrometer coupled to a Thermo Fisher Trace 1310 GC. Samples were diluted in *n*-hexane and 1 μl was injected onto an Agilent DB-5 (30 m × 0.25 mm × 0.25 μm) column in split mode with a split ratio of 50:1. The temperature program was 2 min isothermal at 40 °C followed by an increase of 12 °C/min to 250 °C and 7 °C min at 250 °C isothermal. The combustion reactor consisted of a NiO tube filled with CuO, NiO and Pt wires and was maintained at 850 °C. The ion intensities of m/z 44, 45, and 46 were monitored and the $^{13}C/^{12}C$ ratios of each sample peak were automatically computed by comparison with a standard reference of known isotopic composition. Each sample was run in duplicate. External standards were run every 8 samples. Instrument precision and accuracy of FAME isotope standard analyses were better than 0.5‰. $\delta^{13}C$ values of samples were corrected for carbon atom addition during methylation using mass balance equations.

4. Results and discussion

Here, we present evidence of cattle employed in ritual context based on organic remains detected in Neolithic pottery vessels from Northern Germany. A total of 33 pottery sherds from the Megalith tomb Wangels LA 69 (n = 15) and the adjacent domestic dwelling site Oldenburg LA 77 (n = 18) in Northern Germany (Fig. 1) were solvent extracted and analysed by gas chromatography-mass spectrometry (GC-MS) and gas chromatography combustion isotope ratio mass spectrometry (GC-C-IRMS). Both sites are located in a nearshore landscape characterised by fjords and lagoons in the Oldenburger Graben (Fig. 1) (Brozio et al., 2014). For the Megalith grave Wangels seven individual construction and burial phases have been defined (see SI Appendix) dating from 3640–1900 BC, which comprised partially intact and highly decorated ceramic artefacts of the Funnel Beaker Culture (FBC) and the Globular Amphora Culture (GAC). In contrast, in the adjacent settlement Oldenburg (3270–2920 BC) strongly fragmented and undecorated ceramics were found, which were interpreted as daily consumers goods (Filipović et al., 2019).

Of the 33 potsherds, 28 (84%) yielded sufficient (>5 μg/g) lipid concentration in the range from 5.9 to 9661.5 μg/g sherd with mean value of 600.8 μg/g (Tables S1 and S2), which is concentration considered appropriate for further interpretation (Evershed, 2008). The sherds with concentrations <5 μg/g should be interpreted with caution as they may contain substantial proportions of contaminants. However, no modern contaminants such as squalene from human skin have been detected. Analysis of ceramic-bound organic residues by GC-MS allows subdivision of specimens into two broad categories (Fig. 2). The first category is dominated by palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids combined with abundant triacylglycerols (C_{42} to C_{54}), which derive from degraded animal fat (Fig. 2a). The ratio of both fatty acids expressed as P/S ratio has been used to distinguish between animal fats and plant origin, since plant oils produce up to 3 to 4 times greater amounts of palmitic acid and animal fats more stearic acid (Copley et al., 2005b). Most samples have low P/S values < 2. In addition, we identified branched pentadecanoic and heptadecanoic fatty acid, occurring as iso- and anteiso-isomers, which derive from bacteria living in the rumen of the milk-producing species cattle, goat and sheep (Dudd and Evershed, 1998). The second category shows a dominance of C_{16} over C_{18} fatty acids with a P/S ratio of up to 3.3, combined with a higher proportion of unsaturated fatty acids ($C_{16:1}$ and $C_{18:1}$) and high relative abundance of $C_{12:0}$ and $C_{14:0}$ homologues, a distribution diagnostic for plant oils (Copley et al., 2001) (Fig. 2b). Most fresh plant oils from e.g. poppy, safflower, hemp and wheat germ are dominated by unsaturated fatty acids such as $C_{18:1}$, $C_{18:2}$ or even $C_{18:3}$ (Bozan and Temelli, 2008; Orsavova et al., 2015). Under common conditions of preservation, polyunsaturated compounds get destroyed or survive in just minor quantities in archaeological samples due to oxidation and microbial mineralization. Therefore, enhanced amounts of the $C_{16:1}$ fatty acid as detected here are rarely found in archaeological vessel.

Exceptionally high proportions of palmitic ($C_{16:0}$) and palmitoleic acid ($C_{16:1}^{cis\Delta 9}$) occur in sea buckthorn (*Hippophae rhamnoides*) berry and pulp oils, contributing 50%–80% of the total fatty acids (Dulf, 2012; Fatima et al., 2012; Yang and Kallio, 2001). These compounds are known as major constituent of human skin fat, leading to application of pulp oil for cosmetic and healing purposes (Fatima et al., 2012; Yang and Kallio, 2001; Zeb, 2004). Rare reports of abundant C_{16} fatty acids in tropical to subtropical plants include macadamia nuts with $C_{16:0} + C_{16:1}$ contributing between 20 and 40% of total fatty acids (Aquino-Bolaños et al., 2017; Maguire et al., 2004) or durian fruit with $C_{16:0} + C_{16:1}$ contributing between 30 and 40% of total fatty acids (Amid et al., 2012; Berry, 1981; Ho and Bhat, 2015). Amongst Zanthoxylium species, only *Zanthoxylum armatum* contain up to 20% C_{16} fatty acids, whereas *Zanthoxylum bungeanum* C_{16} fatty acid proportions did not exceed 10% (Hou et al., 2019). All of these C_{16} fatty acid enriched plants were reported from warmer climates and can be excluded to have inhabit the coastal regions along the Baltic Sea.

A variety of C_{16} fatty acids is further known to occur in non-plant sources, e.g. fish liver oils and in seal bone (Ackman, 1967; Heron et al., 2015; Keinänen et al., 2017; Özogul and Özogul, 2007), where they comprise between 15 and 25% of total fatty acids. The latter two aquatic sources can be excluded as potential origin as firstly, the diagnostic aquatic biomarkers (Evershed et al., 2008a; Hansel et al., 2011, 2004) isoprenoidal, long-chain unsaturated,ω-(o-alkylphenyl) alkanoic fatty acids (APAA), or dihydroxy fatty acids were lacking, secondly, the carbon isotope signatures of the $C_{16:0}$ fatty acid did not correspond with a marine source, although both locations are close to the sea (Fig. 3), and thirdly the relative proportions of C_{16} fatty acids are too low.

Sea buckthorn, on the other hand, is nowadays a common widespread growing plant at the coast of northern Germany and is used as healing agent and cosmetic thus explaining their use as precious grave gift. Further source-specific lipids such as animal sterols and phytosterols and their derivates (cholesterol, 7-ketocholesterol, β-sitosterol, stigmasterol) occurred in subordinate amount or traces, which can be explained by the rapid degradation due to oxidation during deposition and/or firing of the vessels (Hammann et al., 2018). In potsherds ($n = 33$) of the burial site Wangels, 73% revealed an origin from animal fats, whereas in contrast the domestic site Oldenburg yielded 61% samples derived from plant sources.

Further corroboration of animal fat origin in ceramic sherds was achieved by determination of carbon stable isotope ($\delta^{13}C$) values of the two major fatty acid methyl esters derivatives ($C_{16:0}$ and $C_{18:0}$) (Fig. 3). Differences in $\delta^{13}C$ values of fatty acids occur due to specific metabolic routes for ruminant and non-ruminant animals (Copley et al., 2003). To diminish local environmental or climatic influence or variation in food source (C_3 *vs*. C_4 plants), a $\Delta^{13}C$ ($=\delta^{13}C_{18:0}$ - $\delta^{13}C_{16:0}$) value is employed to differentiate food source or processing (Copley et al., 2003). For source allocation of animal fats, $\delta^{13}C$ results obtained from archaeological specimens have been compared with those from modern reference fats (Copley et al., 2003; Craig et al., 2011; Dudd and Evershed, 1998). By comparison of the $\Delta^{13}C$ values of the 18 animal fat residues with the modern reference animal fats, a predominance of ruminant fats (73%) over dairy products (27%) is observed for specimens from the Megalith tomb of Wangels (Fig. 3). Contrary, pottery sherds from the domestic site Oldenburg contain preferentially dairy fats (71%). The ruminant fats are interpreted as of cattle meat origin, since archaeozoological findings of ruminant species from the coeval Oldenburg site are derived predominantly, about 40%, from cattle (Filipović et al., 2019). The animal bones of the Oldenburg LA 77 site are currently being investigated. A first sample showed 41% cattle, followed by pigs with 33%. Fatty acids derived from porcine meat could not be detected in the burial gift vessels although porcine bone, contributed one third of bones found in the Oldenburg domestic site, the remaining being of cattle origin, this underlining that the spiritual esteem devoted to husbandry animals was selectively placed on cattle. Since decorated beakers were mainly found intact and no evidence for exposure to cooking was observed, they were presumably produced solely for the burial rite and filled with high-quality cattle meat as grave good in a ceremonial ritual. The appreciation of cattle fat as precious burial gift is explained by the fact that slaughter and sacrifice of animals is terminal, whereas sustainable utilization is achieved by milking.

$\delta^{13}C$ values of the archaeological samples with plant origin (Fig. 3) to a large extent possess values comparable to modern C_3 vegetable oils (Spangenberg and Ogrinc, 2001; Steele et al., 2010; Woodbury et al., 1998) and plot close to the 1:1 line in the $\delta^{13}C_{16}$ *vs.* $\delta^{13}C_{18}$ discrimination diagram. This parity is characteristic for vegetable oils due to the fatty acids biosynthesis in plant cells (Spangenberg and Ogrinc, 2001). The higher proportion of dairy products and plant oils in the utility vessels from the Oldenburg settlement is in keeping with the common plant spectrum used for subsistence farming based on cereals like barley and einkorn, gathered plants and weeds (Filipović et al., 2019; Kirleis et al., 2012) for this period and contrast sharply with the exclusivity of cattle meat in the burial gifts. However, the presence of cereals in the ceramic is uncertain as no cereal-specific biomarkers like alkylresorcinols or long-chain alkyl lipids have been found. This is ascribed to the substantially lower concentrations of lipids in plants than in animal products (Colonese et al., 2017; Hammann and Cramp, 2018). The presumed consumption of sea buckthorn, which is widespread on the coast of the Baltic Sea, could have been a healthy dietary supplement due to its active ingredients such as antioxidants, carotenoids, unsaturated fatty acids and vitamin C (Zielińska and Nowak, 2017).

By comparing our results from the coeval Oldenburg domestic site and Wangels ritual burial sites with earlier studies on ceramics from the Baltic Sea region, a transformation in diet over time becomes evident. High proportions of aquatic biomarkers were identified in Late Mesolithic/Early Neolithic potteries from coastal sites in Germany, Denmark and South Sweden, indicating that early farming had not been induced yet (Craig et al., 2011; Papakosta et al., 2019). These studies revealed the utilization of ceramic pots from hunter-gatherer sites in marine or freshwater resource but not terrestrial food (animals and plants) processing. The absence of aquatic biomarkers, despite availability of animal and plant resources in our study of younger Neolithic samples is corroborated by isotope data from human remains suggesting a trend from more aquatic to more terrestrial food consumption in the Mesolithic-Neolithic transition (Fischer et al., 2007; Terberger et al., 2018).

5. Conclusion

Food residues recovered from Neolithic (3600–2900 BC) delicately designed pottery recovered from a Funnel Beaker Megalith tomb contrasted compositionally from those found in an adjacent domestic

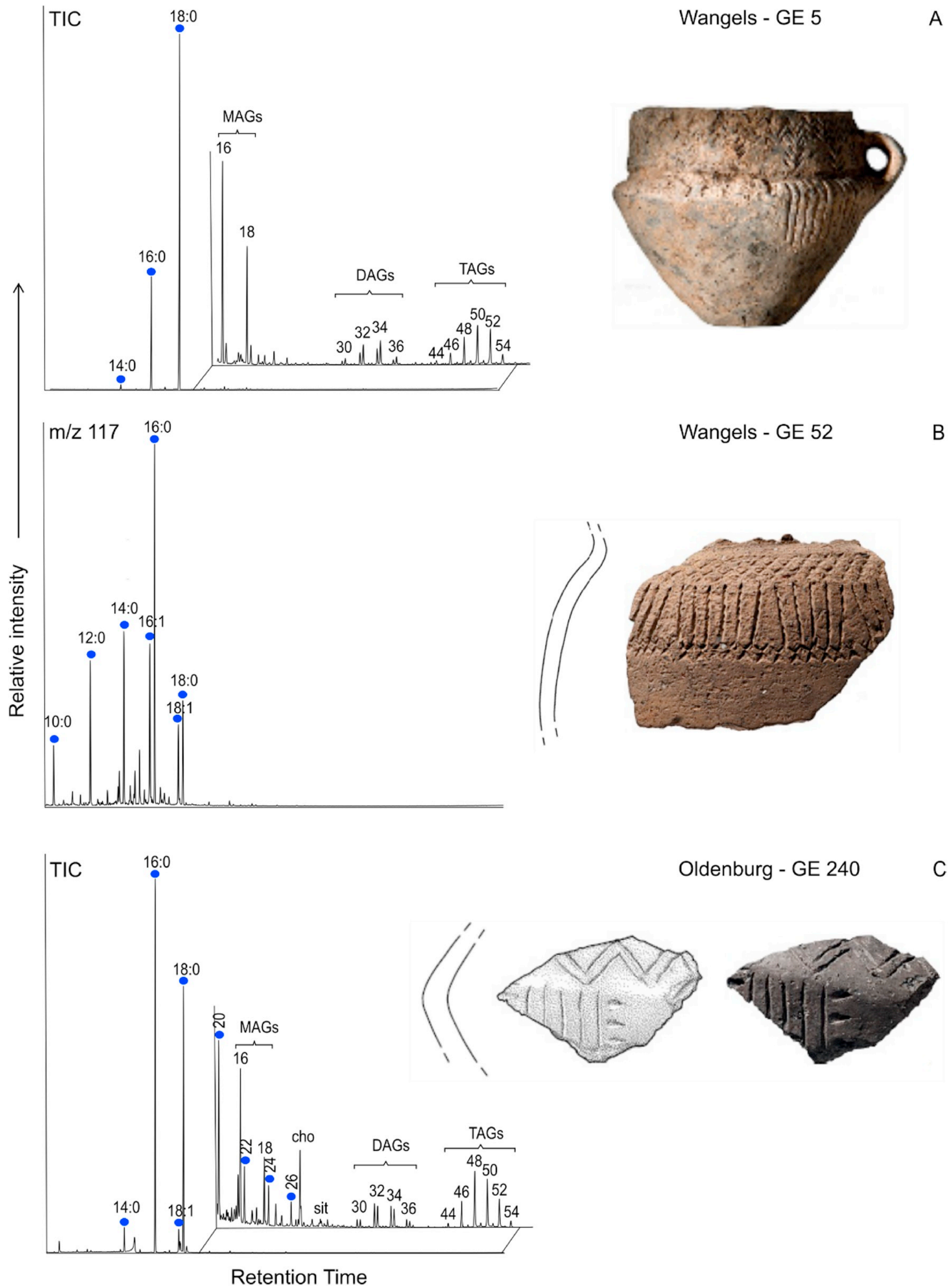

Fig. 2. Partial ion chromatograms of lipid extracts from three representative pottery vessels. **A**: Pottery vessel from burial site Wangels showing a molecular distribution indicative for degraded animal fats. **B**: Pottery sherd from Wangels containing plant oils as revealed by abundant unsaturated fatty acids. **C**: Ceramic fragment from domestic site Oldenburg containing degraded animal fat with minor amounts of the plant/vegetable biomarkers phytosterols and C_{20} to C_{26} long-chain fatty acids. Blue circle with x:y: free fatty acids with x carbon atoms and y degrees of unsaturation; MAGs: monoacylglycerols; DAGs: diacylglycerols, TAGs: triacylglycerols; cho: cholesterol; sit: sitosterol. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

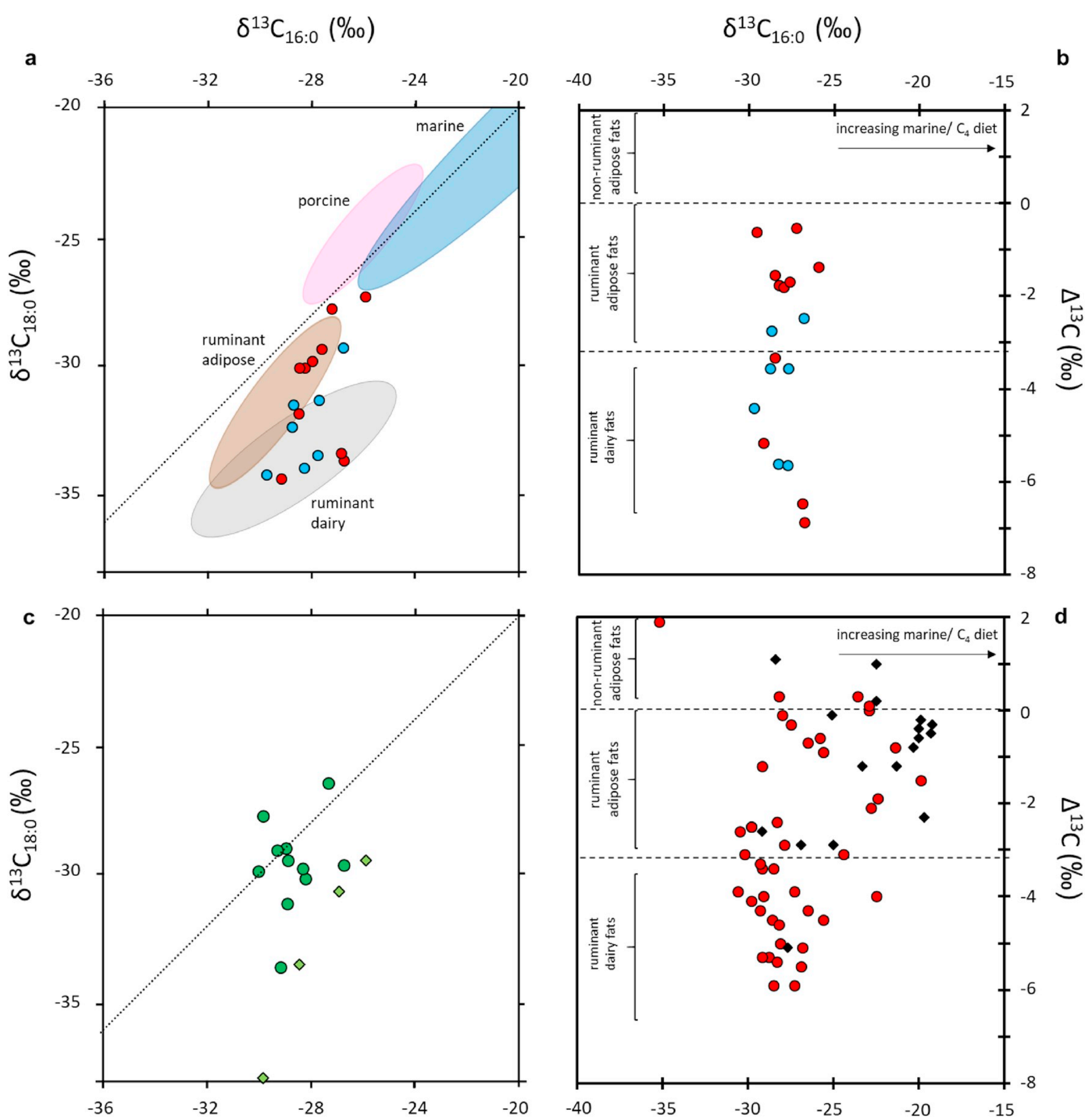

Fig. 3. Stable carbon isotope composition of individual fatty acids in lipid residues of animal origin from Neolithic pottery vessels of the Megalith tomb Wangels (red) and domestic site Oldenburg (blue) (**a**, **b**). Modern $\delta^{13}C$ reference values in **a** are according to Craig et al. (2011). $\delta^{13}C_{16}$ and $\delta^{13}C_{18}$ values of plant origin from Wangels (green circle) and Oldenburg (green square) (**c**). Distribution of $\delta^{13}C$ values reported for C_{16} and C_{18} fatty acids of Mesolithic age from Northern Germany (Craig et al., 2011) attributed to terrestrial (red dots) and marine (black squares) food sources. A shift from Mesolithic, more marine influenced to fully terrestrial Neolithic diet is evident if compared with **b**. Ranges for $\Delta^{13}C$ values in **b** and **d** are based on a global database comprising modern animal reference fats from the United Kingdom, Switzerland, the Near East, Africa, and Kazakhstan (Dudd and Evershed, 1998; Dunne et al., 2012; Gregg et al., 2009; Outram et al., 2009; Spangenberg et al., 2006). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

dwelling site on the shores of the south-western Baltic, NW-Germany. Burial gift aliments held extraordinary and precious products to serve the buried ancestors during afterlife. Molecular biomarkers and their respective carbon isotope signatures identified a specific plant essential oil and cattle meat or dairy products. Amongst aliments from three different burial phases, the youngest only (3000–2900 BC) yielded the plant oil, possibly produced from sea buckthorn (*Hippophae rhamnoides*) and stored in specific vessels of the globular amphora type, exclusively. All remaining grave goods comprised either ruminant meat or milk, consistent with predominant cattle husbandry, corroborated by bone findings in coeval adjacent domestic sites. Here, food residues from pottery used in everyday cooking revealed a mixed composition of dominantly plant and milk origin but only subordinate or no meat. With no porcine burial gifts identified but porcine bone contributing one third of animal bone findings in dwelling sites we note that although pork made up a portion of Middle Neolithic meat diet, it lacks in grave aliments and conclude that domestic pigs possessed no spiritual attribute in the Neolithic spiritual world. Burial gifts of animal origin exclusively consisted of cattle products indicating that these animals not only served as food source but also played an important role in the ritual sphere in Neolithic societies. In particular this underlines the importance of cattle in the spiritual perception of the Globular Amphora Culture, known for its cattle burials. For the Funnel Beaker culture, in which the importance of cattle is also evident through depositions in settlements and enclosures, we for the first time demonstrate by organic residue analysis that high-quality meat products were used as grave goods and/or sacrifices in the context of megalithic tombs.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2020.105122.

Author contributions

LS designed research, JW and LS conducted organic chemical and isotope analysis, JPB and JM contributed archaeological investigations, including dating chronology. LS and JW wrote the paper with contributions and discussion by JPB and JM.

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