Organic residue analysis of pottery from two medieval sites in the City of Oxford: a comparative analysis of pottery from the 'Jewish Quarter' at St Aldates and Queen's College site

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1. Introduction

Lipids, the organic solvent soluble components of living organisms, i.e. the fats, waxes and resins of the natural world, are the most frequently recovered compounds from archaeological contexts. They are resistant to decay and are likely to endure at their site of deposition, often for thousands of years, because of their inherent hydrophobicity, making them excellent candidates for use as biomarkers in archaeological research (Evershed, 1993, 2008b). Pottery has become one of the most extensively studied materials for organic residue analysis (Mukherjee *et al.*, 2005) as ceramics, once made, are virtually indestructible and thus are one of the most, if not the most, common artefacts recovered from archaeological sites from the Neolithic period onwards (Tite, 2008). Survival of these residues occurs in three ways; rarely, actual contents are preserved in situ (Charrié-Duhaut *et al.*, 2007) or, more commonly, as surface residues (Evershed, 2008b). The last, most frequent occurrence, is that of absorbed residues preserved within the vessel wall, which have been found to survive in >80% of domestic cooking pottery assemblages worldwide (Evershed, 2008b).

The application of modern analytical techniques enables the identification and characterisation of these sometimes highly degraded remnants of natural commodities used in antiquity (Evershed, 2008b). Often, data obtained from the organic residue analysis of pottery or other organic material provides the only evidence for the processing of animal commodities, aquatic products or plant oils and waxes, particularly at sites exhibiting a paucity of environmental evidence. To date, the use of chemical analyses in the reconstruction of vessel use at sites worldwide has enabled the identification of terrestrial animal fats (Evershed *et al.*, 1997a; Mottram *et al.*, 1999), marine animal fats (Copley *et al.*, 2004; Craig *et al.*, 2007; Cramp and Evershed, 2014; Cramp *et al.*, 2014), plant waxes (Evershed *et al.*, 1991; Dunne *et al.*, 2016), beeswax (Evershed *et al.*, 1997b; Roffet-Salque *et al.*, 2015) and birch bark tar (Charters *et al.*, 1993; Urem-Kotsou *et al.*, 2002). This has increased our understanding of ancient diet and foodways and has provided insights into herding strategies and early agricultural practices. Organic residue analysis has also considerably enhanced our understanding of the technologies involved in the production, repair and use of ancient ceramics (Roffet-Salque *et al.*, 2016).

Preserved animal fats are by far the most commonly observed constituents of lipid residues recovered from archaeological ceramics. This demonstrates their considerable significance to past cultures, not just for their nutritional value but also for diverse uses such as binding media,

illuminants, sealers, lubricants, varnish, adhesives and ritual, medical and cosmetic purposes (Mills and White, 1977; Evershed *et al.*, 1997a).

Today, the high sensitivities of instrumental methods such as gas chromatography and mass spectrometry allow very small amounts of compounds to be detected and identified. Furthermore, higher sensitivity can be achieved using selected ion monitoring (SIM) methods for the detection of specific marine biomarkers (Evershed *et al.*, 2008; Cramp and Evershed, 2014). The advent of gas chromatography-combustion-isotope ratio mass spectrometry in the 1990s introduced the possibility of accessing stable isotope information from individual biomarker structures, opening a range of new avenues for the application of organic residue analysis in archaeology (Evershed *et al.*, 1994; Evershed *et al.*, 1997a).

This stable carbon isotope approach, using GC-C-IRMS, is employed to determine the $\delta^{13}C$ values of the principal fatty acids (C_{16} and C_{18}), ubiquitous in archaeological ceramics. Differences occur in the $\delta^{13}C$ values of these major fatty acids due to the differential routing of dietary carbon and fatty acids during the synthesis of adipose and dairy fats in ruminant animals, thus allowing ruminant milk fatty acids to be distinguished from carcass fats by calculating $\Delta^{13}C$ values ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and plotting that against the $\delta^{13}C$ value of the $C_{16:0}$ fatty acid. Previous research has shown that by plotting $\Delta^{13}C$ values, variations in C_3 versus C_4 plant consumption are removed, thereby emphasizing biosynthetic and metabolic characteristics of the fat source (Dudd and Evershed, 1998; Copley *et al.*, 2003).

2. Aims and objectives

The objective of this investigation was to determine whether organic residues were preserved in pottery vessels from phase 3 and 4 of an archaeological site at St Aldates, Oxford. The site is thought to have been located within a medieval 'Jewish Quarter'. Evidence for this included the exceptional animal bone assemblage where it was noted "a significant shift in the species represented on the site, with birds accounting for a third of the skeletal material recovered. This increase came at the expense of domestic cattle and pigs, which both occurred about half as frequently when compared with earlier phase". It was decided to carry out organic residue analysis to determine which commodities were processed in the vessels and, indeed, whether a 'Jewish' signal could be identified. For the purposes of comparison, it was agreed that organic residue analysis would be carried out on a contemporaneous assemblage from the City of Oxford. Pottery was thus selected from a site at Queen's College, Oxford. This site originates from the Late Saxon period and comprises a road/street with cellar and other pits with evidence

for smithing and smelting as well as domestic rubbish. The pits/quarries of the medieval pre-college phases (i.e. contemporary with the Jewish phase at St Aldates) contained predominately domestic refuse with some slag, probably largely residual. These vessels were late 11th - late 13th century vessels and from pre-college contexts so should not correlate to restricted high-status diets.

Furthermore, comparison was also made to potsherds from phase 1 and 2 of the St Aldates site (n=8) and phase 3 and 4 (*n*=2) previously analysed by Lucy Cramp and Helen Whelton from the University of Bristol.

Analytical methods

Lipid analysis and interpretations were performed using established protocols described in detail in earlier publications (Correa-Ascencio and Evershed, 2014). All solvents used were HPLC grade (Rathburn) and the reagents were analytical grade (typically > 98% of purity). Briefly, ~2 g of potsherd were sampled and surfaces cleaned with a modelling drill to remove exogenous lipids. The cleaned sherd powder was crushed in a solvent-washed mortar and pestle and weighed into a furnaced culture tube (I). An internal standard was added (40 µg *n*-tetratriacontane; Sigma Aldrich Company Ltd) together with 5 mL of H_2SO_4/MeOH 2 - 4% ($\delta^{13}C$ measured) and the culture tubes were placed on a heating block for 1 hour at 70 °C, mixing every 10 minutes. Once cooled, the methanolic acid was transferred to test tubes and centrifuged at 2500 rpm for 10 minutes. The supernatant was then decanted into another furnaced culture tube (II) and 2 mL of DCM extracted double distilled water was added. In order to recover any lipids not fully solubilised by the methanol solution, 2 x 3 mL of hexane was added to the extracted potsherds contained in the original culture tubes, mixed well and transferred to culture tube II. The extraction was transferred to a clean, furnaced 3.5 mm vial and blown down to dryness. Following this, 2 x 2 mL hexane was added directly to the H_2SO_4/ MeOH solution in culture tube II and whirlimixed to extract the remaining residues, then transferred to the 3.5mL vials and blown down until a full vial of hexane remained. Aliquots of the TLE's were derivatised using *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) containing 1 % trimethylchlorosilane (TMCS; Sigma Aldrich Company Ltd.; 40 µL; 70°C, 1 h), excess BSTFA was removed under nitrogen and the derivatised TLE was dissolved in hexane prior to GC, GC-MS and GC-C-IRMS.

Firstly, the samples underwent high-temperature gas chromatography using a gas chromatograph (GC) fitted with a high temperature non-polar column (DB1-HT; 100%

dimethylpolysiloxane, 15 m x 0·32 mm i.d., 0.1 μm film thickness). The carrier gas was helium and the temperature programme comprised a 50°C isothermal hold followed by an increase to 350° at a rate of 10° min^{-1} followed by a 10 min isothermal hold. A procedural blank (no sample) was prepared and analysed alongside every batch of samples. Further compound identification was accomplished using gas chromatography-mass spectrometry (GC-MS). FAMEs were then introduced by autosampler onto a GC-MS fitted with a non-polar column (100% dimethyl polysiloxane stationary phase; 60 m x 0.25 mm i.d., 0·1 μm film thickness). The instrument was a ThermoFinnigan single quadrupole TraceMS run in EI mode (electron energy 70 eV, scan time of 0·6 s). Samples were run in full scan mode (*m/z* 50–650) and the temperature programme comprised an isothermal hold at 50°C for 2 min, ramping to 300°C at 10°C min^{-1}, followed by an isothermal hold at 300°C (15 min). Data acquisition and processing were carried out using the HP Chemstation software (Rev. B.03.02 (341), Agilent Technologies). Peaks were identified on the basis of their mass spectra and gas chromatography (GC) retention times, by comparison with the NIST mass spectral library (version 2.0).

Carbon isotope analyses by GC-C-IRMS were also carried out using a GC Agilent Technologies 7890A coupled to an Isoprime 100 (EI, 70eV, three faraday cup collectors *m/z* 44, 45 and 46) via an IsoprimeGC5 combustion interface with a CuO and silver wool reactor maintained at 850°C.

3. Results

Lipid analysis and interpretations were performed using established protocols described in detail in earlier publications (e.g. Dudd and Evershed, 1998; Correa-Ascencio and Evershed, 2014). A total of thirty sherds were sampled, fifteen from the St Aldates Jewish Quarter phases 3 and 4 and the remaining fifteen from Queen's College site. The lipid recovery rate from both sites was 67% (*n*=10 each). The mean lipid concentration from the sherds (Table 1) was 11.4 mg g^{-1}, with a maximum lipid concentration of 45.5 mg g^{-1} (OXF021). Many of the potsherds contained very high concentrations of lipids (e.g. OXF003, 42.0 mg g^{-1}, OXF006, 29.9 mg g^{-1} and OXF025, 36.4 mg g^{-1}), demonstrating excellent preservation. Interestingly, the maximum concentration of absorbed lipid observed in an archaeological potsherd to date is 17.8 mg g^{-1} (Copley *et al.*, 2005c). This likely indicates that these were vessels which were subjected to sustained use in the processing of high lipid-yielding commodities.

Table 1. Laboratory number, site, context number, phase, fabric, vessel part, form, lipid concentrations (µg g^{-1}), total lipid concentration in extract (µg), $\delta^{13}C$ and $\Delta^{13}C$ values, and attributions of pottery lipid residues from two Oxford sites.

Laboratory Number	Site	Context number	Phase	Fabric	Part	Form	Lipid concentration (ug g-1)	Total lipid in extract (ug)	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	Attribution
OXF001	OXQUPG15	1745	1a (Late 11th/12th century)	Cotswold-type Ware	Rim	Jar	26982.5	66646.7	-29.6	-30.9	-1.3	Ruminant adipose
OXF003	OXQUPG15	1341	2a (13th/14th century)	Cotswold-type Ware	Rim	Jar	42008.4	99980.0	-30.2	-31.7	-1.4	Ruminant adipose
OXF006	OXQUPG15	1279	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	29886.4	66646.7	-29.7	-31.0	-1.2	Ruminant adipose
OXF007	OXQUPG15	1335	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	10683.4	18161.8	-27.5	-29.8	-2.3	Ruminant adipose
OXF008	OXQUPG15	1335	2a (13th/14th century)	Medieval Oxford Ware	Body	-	22412.6	49980.0	-28.2	-29.9	-1.7	Ruminant adipose
OXF010	OXQUPG15	1508	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	14403.5	49980.0	-28.2	-29.0	-0.7	Ruminant/non-ruminant adipose
OXF011	OXQUPG15	1335	2a (13th/14th century)	Cotswold-type Ware	Rim	Jar	20756.4	36323.6	-29.3	-30.8	-1.5	Ruminant adipose
OXF012	OXQUPG15	1335	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	1730.1	4307.8	-28.1	-28.9	-0.9	Ruminant/non-ruminant adipose
OXF013	OXQUPG15	1995	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	3104.2	9716.1	-27.2	-27.1	0.1	Ruminant/non-ruminant adipose
OXF014	OXQUPG15	1995	2a (13th/14th century)	Medieval Oxford Ware	Rim	Jar	19690.6	57102.9	-28.7	-30.1	-1.5	Ruminant adipose
OXF019	OXSTAD16	1167	3 (Late 11th/12th century)	Medieval Oxford Ware	Rim, body	Jar	286.3	967.6	-29.5	-30.9	-1.4	Ruminant adipose
OXF020	OXSTAD16	1076	3 (Late 11th/12th century)	Medieval Oxford Ware	Rim	Jar	9861.7	26626.7	-29.7	-31.3	-1.6	Ruminant adipose
OXF021	OXSTAD16	1076	3 (Late 11th/12th century)	Medieval Oxford Ware	Rim	Jar	45492.6	133293.3	-28.2	-30.0	-1.8	Ruminant adipose
OXF023	OXSTAD16	1083	3 (Late 11th/12th century)	Medieval Oxford Ware	Rim	Jar	26334.7	66626.7	-29.3	-31.2	-1.9	Ruminant adipose
OXF024	OXSTAD16	4008	4 (13th/14th century)	Medieval Oxford Ware	Rim	Jar	10528.2	28531.4	-28.7	-30.3	-1.6	Ruminant adipose
OXF025	OXSTAD16	4008	4 (13th/14th century)	Medieval Oxford Ware	Rim	Jar	36408.0	66626.7	-29.0	-31.1	-2.2	Ruminant adipose
OXF026	OXSTAD16	4008	4 (13th/14th century)	Medieval Oxford Ware	Rim	Jar	4560.1	14774.8	-29.1	-31.3	-2.2	Ruminant adipose
OXF028	OXSTAD16	4047	4 (13th/14th century)	Medieval Oxford Ware	Rim	Jar	419.7	1099.6	-29.2	-31.5	-2.3	Ruminant adipose
OXF029	OXSTAD16	4047	4 (13th/14th century)	Medieval Oxford Ware	Body	-	601.8	1275.8	-29.0	-34.1	-5.2	Dairy fat
OXF030	OXSTAD16	4047	4 (13th/14th century)	Medieval Oxford Ware	Rim	Jar	13354.3	36323.6	-29.9	-31.3	-1.5	Ruminant adipose

To date, analysis of the total lipid extracts (TLEs, *n*=30) from the two Oxford sites, using GC and GC-MS, demonstrated that 20 sherds contained sufficient concentrations (>5µg g^{-1}) of lipids that can be reliably interpreted (Evershed, 2008a). These extracts comprised lipid profiles which demonstrated free fatty acids, palmitic (C_{16}) and stearic (C_{18}), typical of a degraded animal fat (Figure 1a, b and c), were the most abundant components (e.g. Evershed *et al.*, 1997a; Berstan *et al.*, 2008).

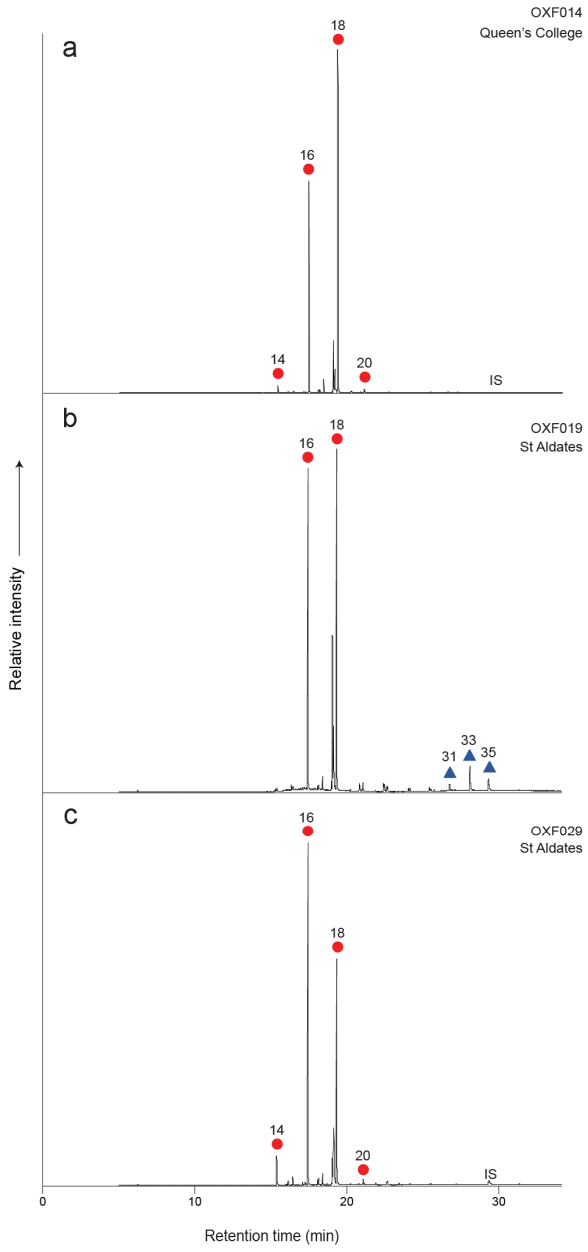

Figure 1. Gas chromatograms of trimethylsilylated FAMEs from pottery extracts a) OXF014 from Queen's College, b) OXF019 and c) OXF029 from St. Aldates. Circles, *n*-alkanoic acids (fatty acids, FA); triangles, mid-chain ketones; IS, internal standard, C_{34} *n*-tetratriacontane.

Significantly, in vessel OXF019; Figure 1b), odd carbon number ketones were present ($C_{31:0}$, $C_{33:0}$ and $C_{35:0}$, blue triangles). Experimental analysis has shown these ketones, found in a monomodal distribution, originate from the pyrolysis of acyl lipids and ketonic decarboxylation reactions which occur in unglazed ceramic vessels during cooking, when the temperature exceeds 300° C. These ketones are thought to accumulate gradually with repeated use (Evershed *et al.*, 1995; Raven *et al.*, 1997), suggesting that this vessel was used as a cooking pot.

Interestingly, two of the lipid profiles (OXF007 and OXF008) from the Queen's College assemblage displayed an unusual lipid distribution, comprising the unsaturated fatty acids $C_{20:1}$, $C_{22:1}$ and $C_{24:1}$, with the $C_{22:1}$ being most dominant (Figure 2). Radish oil (and other oil of the Brassicacea) contains high abundances of $C_{22:1\Delta13}$, and to a lesser extent $C_{20:1\Delta11}$ and $C_{24:1\Delta15}$. This particular distribution was identified in ancient radish propagules from the site of Qasr Ibrim, Egypt (Bland, 1999). Furthermore, Brassicaceae (*Cruciferae*) seed oil (most likely radish oil, *Raphanus sativus*) was identified, through its degradation products, as an illuminant in lamps found at the site (Copley *et al.*, 2005d). This was confirmed by the huge numbers of radish seeds surviving in deposits at the site.

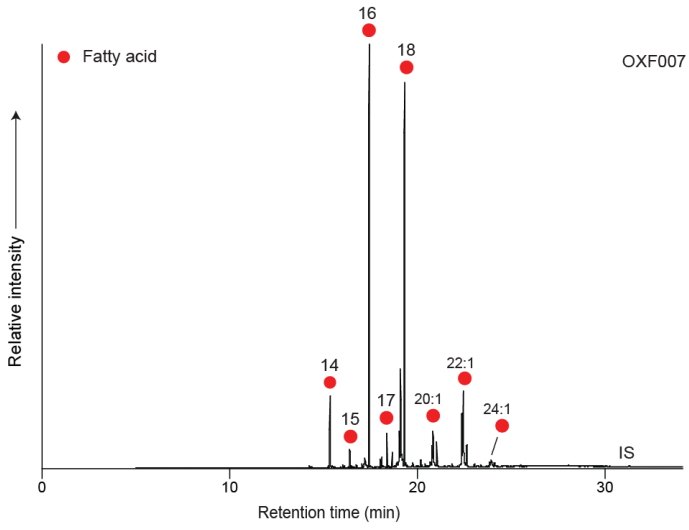

Figure 2. Gas chromatogram of trimethylsilylated FAMEs from pottery extracts a) OXF007 from Queen's College, Oxford. Circles, *n*-alkanoic acids (fatty acids, FA); IS, internal standard, C_{34} *n*-tetratriacontane.

Analysis of modern seeds from six *Brassica* species (*B. napus, B. juncea, B. carinata, B. oleracea, B. nigra and B. rapa*) confirm that the eicosanoic ($C_{22:0}$), and erucic ($C_{22:1}$) acids are among the seven major fatty acids found in these species. In fact, the erucic acid is present at only 1.16 % in *B. rapa* but at concentrations ranging from 31.27 % to 46.19 % in the other *Brassica* seeds (Sharafi *et al.*, 2015). This suggests that seed oil from *Brassica* species may have been used in the cooking of the ruminant carcass products in this vessel.

GC-C-IRMS analyses were carried out on 20 samples (Table 1 and Figure 3) to determine the $\delta^{13}C$ values of the major fatty acids, $C_{16:0}$ and $C_{18:0}$, and ascertain the source of the lipids extracted. The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids for both sites are plotted onto a scatter plot along with the reference animal fat ellipses (Figure 3a, c and e, St Aldates phase 1 and 2, St Aldates phase 3 and 4 and Queens College, respectively). It has been established that when an extract from a vessel plots directly within an ellipse, for example, ruminant dairy, ruminant adipose or non-ruminant adipose, then it can attributed to that particular source. If it plots just outside then it can be described as predominantly of that particular origin. However, it should be noted that extracts commonly plot between reference animal fat ellipses and along the theoretical mixing curves, suggesting either the mixing of animal fats contemporaneously or during the lifetime of use of the vessel (Mukherjee, 2004; Mukherjee *et al.*, 2005).

In the Queen's College assemblage, vessel numbers OXF001, OXF003, OXF006 and OXF011 plot within the reference ellipse for ruminant adipose fats (Figure 3e), suggesting these vessels were solely used to process carcass products from cattle, sheep or goat. The remaining vessels, OXF007, OXF008, OXF010, OXF012, OXF013 and OXF014 plot between the ruminant adipose and non-ruminant adipose ellipses indicative of some mixing of animal products from ruminants (cattle, sheep and goat) and non-ruminants (pig), in varying degrees. Interestingly, no processing of dairy products is indicated at this site.

Lipid residue results from the St Aldates phases 1 and 2 show that one vessel, SN40, plots within the dairy product ellipse (Figure 3a), confirming it was used solely to process dairy products, such as milk, cream, butter or cheese. Two vessels, SN34 and SN35, plot just within the ruminant adipose ellipse and the remainder, SN31, SN32, SN33, SN37 and SN40, plot between the ruminant adipose and non-ruminant adipose ellipses indicative of some mixing of animal products from ruminants (cattle, sheep and goat) and non-ruminants (pig), in varying degrees.

Significantly, the majority of vessels from the St Aldates Jewish Quarter phases 3 and 4 (OXF019, OXF020, OXF023, OXF025, OXF026, OXF028, OXF029 and OXF030) plot directly within the ruminant adipose ellipse (Figure 3c), suggesting these vessels were solely used to process carcass products from cattle, sheep or goat. One vessel plots on the border of the ellipse (OXF024) and one just outside, suggestive of some mixing with animal fats of a non-ruminant origin, although likely in very minor quantities. These may be porcine products, but, significantly, bird bones account for a third of the faunal assemblage in this period, so these data may suggest the processing of bird products with the ruminant products. One vessel, OXF029, plots within the dairy product ellipse, confirming it was used solely to process dairy products, such as milk, cream, butter and cheese. Please note two samples from phase 3 and 4, analysed previously by H. Whelton and L. Cramp, are included in this dataset (coloured light blue in figure 3).

Ruminant dairy fats are differentiated from ruminant adipose fats when they display $\Delta^{13}C$ values of less than -3.1 ‰ (Dunne *et al.*, 2012; Salque, 2012). Lipid residue results for the early St Aldates phase 1 and 2 and the later St Aldates phase 3 and 4 show that one lipid residue from each phase (SN40, Figure 3b and OXF029, Figure 3d, respectively) plots in the ruminant dairy region with $\Delta^{13}C$ values of -6.6 ‰ and -5.2 ‰, confirming the use of secondary products, such as milk, butter and cheese, in both phases, albeit at a very minor level. A further vessel SN39, with a $\Delta^{13}C$ value of -3.4 ‰, from phase 1 and 2, plots in the ruminant dairy region, although some mixing with other carcass products in this vessel may be indicated. Significantly, all other vessels from St Aldates phase 3 and 4 plot firmly within the ruminant carcass products region.

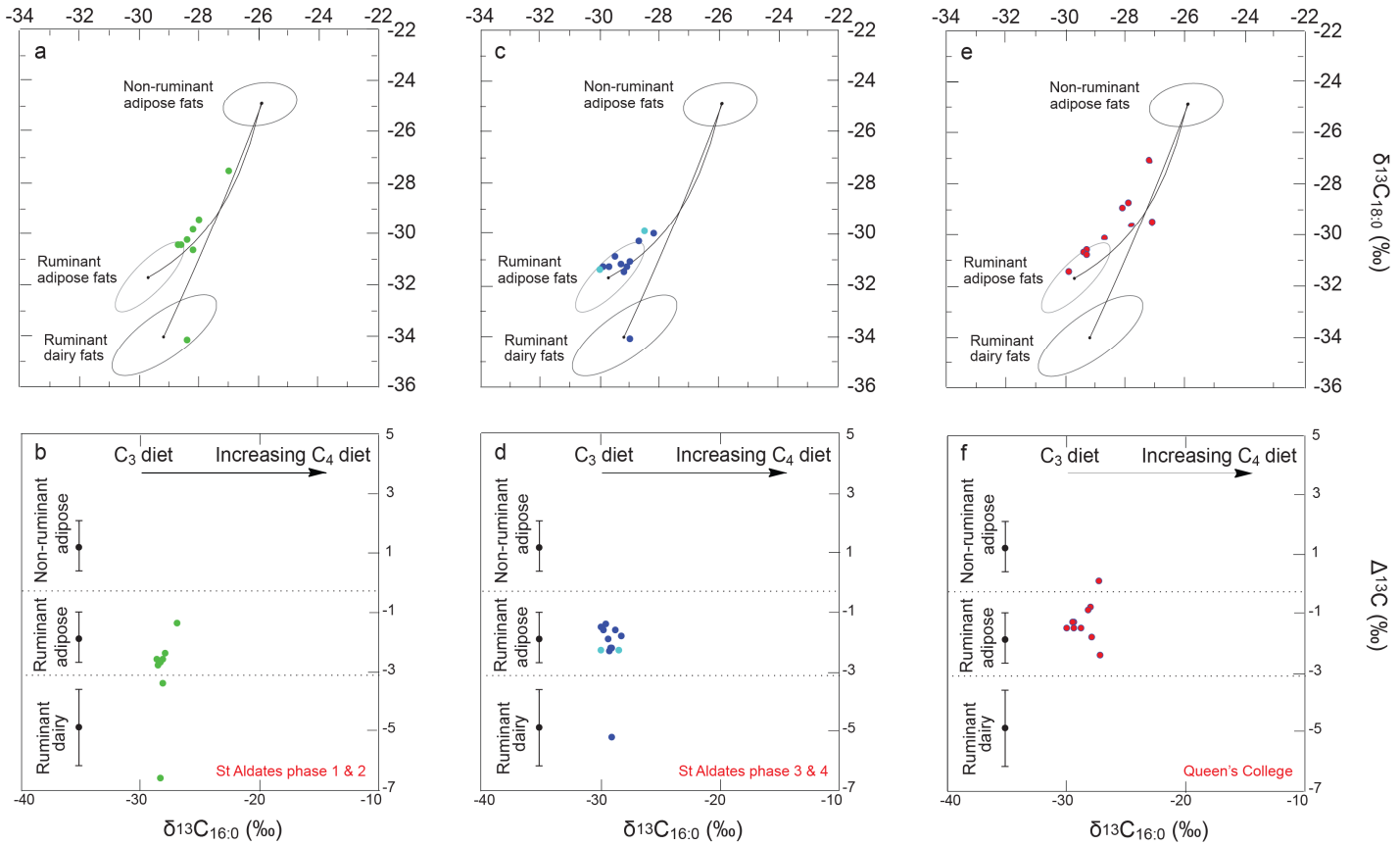

Figure 3. Graphs showing: **a, c** and **e**. $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids for archaeological fats extracted from St Aldates ceramics phases 1 and 2, St Aldates ceramics phases 3 and 4 and Queen's College, respectively. Note: the data points coloured light blue in plots c and d were analysed previously by H.Whelton and L. Cramp. The three fields correspond to the P = 0.684 confidence ellipses for animals raised on a strict C_3 diet in Britain (Copley et al., 2003). Each data point represents an individual vessel. **b, d** and **f** show the $\Delta^{13}C$ ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) values from the same potsherds. The ranges shown here represent the mean ± 1 s.d. of the $\Delta^{13}C$ values for a global database comprising modern reference animal fats from Africa (Dunne *et al.*, 2012), UK (animals raised on a pure C3 diet) (Dudd and Evershed, 1998), Kazakhstan (Outram *et al.*, 2009), Switzerland (Spangenberg *et al.*, 2006) and the Near East (Gregg *et al.*, 2009), published elsewhere.

3.3 Discussion and conclusion

The objective of this investigation was firstly to determine whether organic residues were preserved in potsherds from the phase 3 and 4 of medieval St Aldates and a comparative assemblage from Queen's College, Oxford. Lipid residue results were also compared with pottery from St Aldates phase 1 and 2, analysed previously.

The area around St Aldates is known to be the Jewish quarter or Jewry during the 12th and 13th centuries. Furthermore, the exceptional faunal assemblage, comprising a high proportion of bird bones, and a remarkable drop in pig bones, suggest a possible Jewish habitation. Other finds from the site also may be significant. Consequently, it was decided to determine which commodities were processed in the vessels and, indeed, whether a 'Jewish' signal could be identified. There is extensive regulation and detail regarding animal consumption within the Jewish faith, but, in brief, in terms of the mammal species allowed, they need to have both cloven hooves and chew their cud (that is, be ruminants). Animals that only meet one characteristic (such as pig) are not permitted. Aquatic species with both fins and scales are allowed as are certain bird species, including chicken, geese and duck (Valenzuela-Lamas *et al.*, 2014).

The results, determined from GC, GC-MS and GC-C-IRMS analyses, demonstrate that six of the eight lipid residues from the earlier non-Jewish phases (1 and 2) at St Aldates were predominantly used to process ruminant products (cattle, sheep or goat) but with the addition of some non-ruminant products (pig). Two vessels were used to process dairy products (milk, butter or cheese). In these phases, animal bones comprised 40% domestic cattle, 40% caprine and 20% pig.

The presence of the unsaturated fatty acids $C_{20:1}$, $C_{22:1}$ and $C_{24:1}$ suggests that seed oil from *Brassica* species may have been used in the cooking of the ruminant carcass products in two vessels from St Aldates phase 1 and 2.

In contrast, nine of the twelve pottery samples from St Aldates phase 3 and 4 vessels were used solely to process ruminant carcass products, with a very minor amount of mixing of animal products in ta further wo potsherds. This could originate from non-ruminant products (pig) or possibly from birds, such as chicken, geese or duck. This data strongly suggests possible vessel specialisation, in that they were only used to process ruminant products, confirming a possible Jewish origin. One vessel was used solely to process dairy products, which is consistent with

the known Jewish prohibition against the mixing of meat and milk. The lipid results correlate well with data from the faunal assemblage which notes a high proportion of bird bone (one third of the assemblage) from species which are considered *kosher* (permitted), including domestic fowl (*Gallus gallus*) and geese (*Anser* sp.). This is at the expense of cattle and pig, which occur half as frequently in phase 3. In phase 4, pig bones drop to 5% of the assemblage.

Lipid residue results from the contemporaneous site at Queen's College show that four vessels were used to process solely ruminant carcass products with the remainder being used to process both ruminant and non-ruminant products, whether contemporaneously or over the lifetime of use of the vessel. No information on the faunal assemblage from this site was available.

In summary, this data provides strong evidence that, at both the earlier St Aldates phases 1 and 2, and the contemporaneous site of Queen's College, vessels were being used to process both ruminant and non-ruminant (porcine) products. In contrast, during the 'Jewish' phase, it seems that non-ruminant (pig) processing was either very minor, or effectively, non-existent.

A further question raised by this study is the near absence of dairy products found in the vessels. This is in contrast to lipid residue studies of prehistoric pottery in Britain (Copley *et al.*, 2003; Copley *et al.*, 2005a; Copley *et al.*, 2005b; Copley *et al.*, 2005c) and late Saxon to early medieval pottery from West Cotton, Northamptonshire (Dudd and Evershed, 1998), where dairy products are shown to play a significant part in local subsistence strategies. This absence may be because dairy products were processed in different types of vessels (e.g. wooden bowls) or were perhaps not produced in individual households but rather purchased ready-made from sellers of butter and cheese. Certainly, dairy products, sometimes referred to as 'white meats' of the poor, are thought to have been mainstays of the medieval peasant's diet (Adamson, 2004).

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