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Fit for purpose? Organic residue analysis and vessel specialisation: the perfectly utilitarian medieval pottery assemblage from West Cotton, Raunds.

Dunne, J[1]., Chapman, A[2]., Blinkhorn, P[3]. and Evershed, R.P[1+].

+corresponding author, *r.p.evershed@bristol.ac.uk*

1. Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol BS8 1TS, UK
2. Archaeologist, MOLA (formerly MOLA (Museum of London Archaeology)), 4 Oat Hill Drive, Northampton, NN3 5AL
3. Archaeological Consultant, 60 Turner Street, Northampton, NN1 4JL UK

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Abstract

The understanding of pottery form and function can provide valuable insights into determining aspects of daily life, including the relationship between food, society and culture, in ancient societies. On a broader scale, it offers longer-term perspectives on craft specialisation, knowledge-exchange, technological innovation and economic development. Organic residue analysis has long contributed to a wide range of archaeological questions but is most notably known for its contribution to elucidating diet and animal management strategies worldwide. Here, we both discuss, and provide an overview on, the potential in examining relationships between form and function using organic residue analysis of pottery assemblages, as vessel attributes such as fabrication, capacity, style and shape are often related to the commodities processed within them. Our subsequent investigation of a medieval pottery assemblage, from West Cotton, Raunds, provides valuable insights into vessel use and specialisation. The two main pottery forms found at the site were highly specialised, with bowls (or cantels) likely being used as measures in grain processing while jars were mainly employed for cooking stews and potages consisting of sheep or cattle carcass meats and, occasionally, leafy vegetables such as cabbages and leeks. The jugs and pitchers did not contain any lipid suggesting they were used solely for holding water or some other aqueous liquid and less commonly used vessels also appear to have had specialised uses, including spouted bowls, likely employed to render fat or clarify butter and an inturned-rim bowl, used for the mixing of tallow and beeswax,

possibly for use as an illuminant, sealant or lubricant. Lipid residue results demonstrate that each vessel type had a defined function and was perfectly specialised to its use, well-adapted for the processing, cooking, storage, serving and transportation of food and liquids, as required by the West Cotton peasant for day-to-day dining.

Introduction

Pottery containers have served a broad range of uses in antiquity, including for the preparation, cooking, serving, storage and transport of food and drink (Shepard 1971; Rice 1987; Orton *et al.* 1993; Rice 1999). These uses can include many kinds of food processing not necessarily linked to cooking per se, for example, salting, pickling, fermentation, grinding, curdling and milling (Hastorf 2016), as well as specialised culinary practices such as brewing (e.g. Michel *et al*. 1992) or preparing dairy products, including cheese (e.g. Salque *et al.* 2013). Non-culinary uses for ceramic vessels include as funerary receptacles (Boast 1995; Edwards *et al.* 1997; Rafferty *et al.* 2015), lamps (Evershed *et al.* 1997; 1999; Mottram *et al.* 1999; Colombini *et al.* 2005; Heron *et al.* 2013; Blinkhorn *et al.* 2017), beehives (Evershed *et al.* 2003), as chamber-pots or urinals (Moorhouse 1978), for cosmetic, medicinal and embalming purposes (Moorhouse 1978; Saliu *et al.* 2011; Facchetti *et al.* 2012; Fraser *et al.* 2012) and in ritual or religious ceremonies (Mathe *et al.* 2007; Le Maguer 2011; Baeten *et al.* 2014). They have also been used in manufacturing roles, including tanning and dyeing (McGovern and Michel 1984; 1985; Karmon and Spanier 1987; Koren 1995; Reese 2010), salt production (Charlton 1969; Horiuchi *et al.* 2011; Weller 2015; Maritan *et al.* 2018), in metallurgy (as crucibles and moulds; Tylecote 1986; Doce 2006), for casting lime (Lilburn 1963; Moorhouse 1978) and are thought to have been used for the manufacture of tar by pyrolysis and/or distillation of pine and birch bark (Heron *et al.* 1991; Regert *et al.* 2003; Lucquin *et al.* 2007; Urem-Kotsou *et al.* 2018). Clearly, the understanding of pottery form and function relating to this multiplicity of uses can therefore provide valuable insights into determining aspects of daily life, including the relationship between food, society and culture in ancient societies. On a broader scale, it offers longer-term perspectives on craft specialisation, knowledge-exchange, technological innovation and economic development (Rodríguez-Alegría and Graff 2012).

Thus, the study of pottery *form or morphology* (the overall shape/profile, rim diameter and component parts such as rims, handles and legs) has always been an important part of ceramic analysis for archaeologists, providing much information on how particular vessels may have been made and used. Various features or forms of pottery vessels, such as shape, capacity and fabric, are often related to potential functions of the vessels and the various commodities processed within them (Shepard 1971; Rice 1987; Smith 1988; Orton *et al.* 1993).

Indeed, as Rice (1987) notes “morphological characteristics - their attributes of shape and technology - are closely related to their suitability for a particular activity.” In broad terms, ethnographic evidence suggests that vessels used for long-term storage tend to be large, and, whereas those used for liquid storage tend to be relatively taller as an aid to pouring, dry goods tend to be stored in short and squat vessels (Fig. 1c). Smaller, narrow jars or jugs (Fig. 1f) with restricted openings were more likely used for short-term storage, transport or the serving of liquids (Rice 1987).

Vessels used for cooking appear to display characteristics suited to specific modes of cooking, which likely explains the wide range of shapes used for cooking vessels in antiquity. Broad bowl-shaped pots are generally thought to have been used to cook solid food (Fig. 1b). For example, the wide mouths of cooking pots enable easy access for adding, removing or stirring food, and fast evaporation, making them good for dishes that are intended to thicken liquids. Deep, narrower cooking pots (Fig. 1a) reduce the relative surface area so that liquids evaporate more slowly, making them suitable to cook foods with a high liquid content, such as stews, broths or porridges. Conversely, wide vessels with shallow open bases (Fig. 1d) are more suitable for frying, roasting, sautéing or baking and flat bottomed, long narrow shallow containers, usually semi-rectangular in shape, have been identified as dripping trays (Shepard 1971; Moorhouse 1978; Rice 1987; Mottram *et al.* 1999; Skibo 2013; Villing and Spataro 2015).

Finally, vessels used for serving and eating solid food are more likely to be flat and dish-like (Fig. 1e) whereas more liquid food, such as stews or pottages, served hot, would presumably be served in bowl-shaped vessels. Their shallow height and maximum diameter at the vessel mouth makes them easily accessible to either hands or utensils (Lesure 1998), and the presence of handles would aid in avoiding being burnt by hot food.

However, attributing vessel use purely on functional terms comes with the caveat that ceramic use may often be a matter of deliberate cultural choice, possibly relating to specific social customs or prohibitions, rather than necessarily due to technological choice or specific performance characteristics (see Dunne *et al.* 2018). Moreover, as Woodward (1997) notes, a vessel might have multiple uses over its lifetime, for example, being employed as a storage container, for cooking and serving food, serving as an heirloom/display object and, finally as a cremation urn. Furthermore, once broken, parts of vessels may have been re-used, perhaps as serving utensils or to create lamps. Thus, while the analysis of single forms may be important, where possible, the examination of an entire ceramic assemblage from an archaeological site will help to understand how particular vessel forms may have been used together and their possible relationships within the group (Dunne *et al.* 2018).

Overview – how organic residue analysis provides insights into vessel function

As noted above, organic residue analysis has long contributed to a wide range of archaeological questions but is best known for its contribution to elucidating diet and animal management strategies worldwide (e.g. Copley *et al.* 2003; 2004; 2005a; 2005b; 2005c; Craig *et al.* 2003; 2005; Evershed *et al.* 2008; Outram *et al.* 2009; Dunne *et al.* 2012; Salque *et al.* 2012; Cramp *et al.* 2014a; 2014b; Craig *et al.* 2015; Heron *et al.* 2015; Smyth and Evershed 2015; Debono Spiteri *et al.* 2016; Dunne *et al.* 2017; Ethier *et al.* 2017; Mileto *et al.* 2017; Whelton *et al.* 2018; Cramp *et al.* 2019; Dunne *et al.* 2019). Organic residue analysis of pottery has also produced valuable insights into many ceramic characteristics, including manufacture, incorporating decoration, sealing and repair (Charters *et al.* 1993a; Urem-Kotsou *et al.* 2002; Regert *et al.* 2003; Connan *et al.* 2004; 2013; Knappett *et al.* 2005; Connan *et al.* 2008; Stern *et al.* 2008; Stacey *et al.* 2010), and use, for example, vessel specialisation (Mottram *et al.* 1999; Copley *et al.* 2005a; Cramp *et al.* 2011; Salque *et al.* 2013; Correa-Ascencio *et al.* 2014). Furthermore, quantitative and qualitative investigations of lipid residue profiles has shown different modes of food preparation techniques linked with specific commodities or vessel types, e.g. boiling or roasting (Evershed *et al.* 1995; Raven *et al.* 1997; Cramp *et al.* 2012).

As noted, the style, shape and capacity of vessels, together with modes of manufacture, is often related to the commodities processed within them, thus organic residue analysis can be a valuable technique in examining relationships between vessel form and function. For example, excavations at medieval Causeway Lane, Leicester, revealed two distinct vessel types (lamps and 'dripping dishes') which yielded markedly diverse lipid profiles, suggesting differing uses for the vessels. Compound-specific analyses of the $C_{16:0}$ and $C_{18:0}$ fatty acids revealed the presence of rendered animal fat (tallow), from sheep, goat or cattle, in the lamps, with non-ruminant animal fat (lard) being identified in the 'dripping dishes', providing clear evidence for vessel specialisation (Mottram *et al.* 1999). Further evidence of vessel specialisation was discovered in both amphorae and ollas vessels at ancient Teotihuacan, Central Mexico, which were used to produce an alcoholic beverage from the fermented sap of several species of maguey (*Agavaceae*) plants. The identification of prehistoric alcoholic beverages is highly challenging but a novel proxy, bacteriohopanoids, for the presence of the bacterium *Zymomonas mobilis* used in pulque fermentation, strongly suggested that pulque was produced in these vessels. Furthermore, the finding of coniferous resin in these vessels suggested that the interior surfaces of the vessels were sealed before use to improve storage of liquids (Correa-Ascencio *et al.* 2014).

Across broad scales, comparative analysis of a number of defined vessel types (e.g. bowls, jars, dishes) can be used to determine the possible function of each specific vessel type, in order to evaluate wider patterns in vessel use and to trace diversification and specialisation of vessel use, using intra-, inter-site and regional comparisons. A case in point was the lipid residue analysis of three categories of vessels, bowls, jars and 'saucepan pots', from the British Iron Age sites of Danebury Hillfort, Yarnton Cresswell Field, Maiden Castle and Stanwick, to investigate which particular commodities may have been processed in each container and also establish whether any of these particular vessel types were specialised in processing specific foodstuffs. The study revealed that at the sites where jars were most common, then these were used to process dairy products whilst at sites where 'saucepan pots' predominated, these were preferentially associated with dairy products (Copley *et al.* 2005a). A further example of a comparative study of a range of vessel types, from a centre of pottery manufacture, provided valuable insights into pottery use. Kimpe *et al.*, (2004) examined possible relationships between form and function of a group of vessels from Late Roman to early Byzantine (fifth to seventh century AD) pottery workshops in Sagalassos, Turkey. The investigation of cooking pots, amphora, jars, *dolia* and *unguenturia*, using a range of analytical techniques, identified quantitative and qualitative differences between the lipid residues, which confirmed likely differences in use. Firstly, the presence of diterpenes, including dehydroabietic acid, abietic acid and isopimaric acid, in almost all the vessels, except the cooking pots and some *dolia*, indicates that the non-cooking pots were sealed with a *Pinus* resin before use. This was likely to render the inside of storage (jars or *dolia*) or transport/trade vessels (amphorae, *unguenturia*) less porous. The cooking pots contained higher abundances of lipids, dominated by the stearic acid and saturated triacylglycerols (TAGs), suggesting these were mainly used to cook animal products. Jars and *unguentaria* contained higher concentrations of oleic and linoleic acid, implying that more vegetable products were stored in these pots, whereas amphorae and *dolia* show a mixed content of animal and vegetable products (Kimpe *et al.* 2004). Certainly, amphorae are known to have been used for transporting olive oil, wine and fish products (Peacock and Williams 1991) and it is possible that the small, less common *unguentaria*, the only vessel not made at the site, were used as a container for some rare and expensive plant-derived oil (Kimpe *et al.* 2004). Lastly, Grooved Ware, from sites in southern England and

Scotland, was analysed to determine the range and level of pig exploitation in the Late Neolithic. Pottery from broadly contemporaneous Neolithic pottery styles (Round Based, Peterborough and Impressed Ware) was investigated as a comparison. Interestingly, Grooved Ware vessels were found to yield more 'pig' lipid residues than other prehistoric pottery types. There was also a clear association between pottery from ceremonial sites and the exploitation of pigs, suggesting that pork consumption may have been a part of specific ritual practices (Mukherjee *et al.* 2007; Mukherjee *et al.* 2008).

Organic residue analysis of specific vessel types, namely perforated pottery sherds, found across sites in the region of Kuyavia, Poland, occupied by the first Central European farmers (LBK, *Linearbandkeramik*), were applied to test the hypothesis, derived from ethnographic analogies, that such sieves were used as cheese-strainers (Bogucki 1984; Salque *et al.* 2013). Significantly, the identification of dairy products in these 'sieve' vessels, and associated bowls, strongly suggested the process of cheese-making in prehistoric Europe, similarly to other archaeological contexts (Gouin 1990). Other vessels from the same sites, i.e. cooking pots, were used to process ruminant meat and collared flasks were shown to be waterproofed with beeswax. This identification of particular foodstuffs in these different vessel types provides the first evidence for Early Neolithic specialisation in pottery use (Salque *et al.* 2013). Another instance of vessel specialisation was found in large numbers of wide-mouthed, narrow bottomed pottery containers, notable for the grooves which covered half of the internal surface, found on rural sites across Ancient Greece (Evershed *et al.* 2003). These combed ware vessels were thought by some to have been used as beehives, although it had previously been argued that they were too small for this purpose. Chemical and isotopic analyses showed a number of vessels contained *n*-alkanes, *n*-alkanols and long-chain palmitic acid wax esters in the C_{40}-C_{52} carbon number range together with long-chain hydroxypalmitic acid wax esters, indicative of the presence of beeswax. (Heron *et al.* 1994; Regert *et al.* 2001; Evershed *et al.* 2003; Roffet-Salque *et al.* 2015). Furthermore, compound-specific isotope anlysis of the *n*-alkanes and *n*-alkanols compared very closely to the reference beeswax. Interestingly, ethnographic evidence from several Mediterranean countries suggests similar beehives are still in use today (Evershed *et al.* 2003). In addition, Cramp *et al.*, (2011) investigated the possible function of Roman *mortarium*, found in Britain from the Late Iron Age, by comparing lipid residues extracted from mortarium at six British sites and cooking vessels from four British Iron Age and two Romano-British sites. The mortaria were discovered to have been used to process products of both plant and animal origin, predominantly ruminant carcass products. Interestingly, plant-derived residues, comprising long-chain odd-carbon numbered *n*-alkanes, even-carbon numbered *n*-alkanols, plant sterols, mid-chain ketones and wax esters, were observed in high frequency in the mortaria (60-90%) although they were also present in Iron Age and Roman cooking vessels, albeit in smaller numbers. Overall, the lipid concentrations were lower in the mortaria, perhaps reflecting their use as multi purpose ‘mixing-bowls’ for resource preparation involving animal and plant products. Certainly, heat is known to help the liberation and transfer of lipids from commodities processed in the pots into the ceramic matrix (Charters *et al.* 1993b; Evershed 2008). However, it is not known whether this processing of plant and animal products was for culinary or non-culinary practices, such as cosmetic or medicinal purposes.

Furthermore, organic residue analysis can also provide insights into settlement organisation, especially with regard to spatial use. For instance, spatial variability in the quantity, forms and condition of pottery at a site can be used to interpret patterns of activity, leading to understanding of how particular areas within a site, or even sites themselves, may have been used (Woodward 2002; Biagetti *et al.* 2004). Organic residue analysis can further refine this understanding by revealing areas of food preparation, cooking or storage, specific patterns which may not be readily apparent from ceramic distribution patterns alone. For example, GC-MS and bulk isotope analysis was used to examine the cemented matrix of slab-lined pits in Artic Norway, (Heron *et al.* 2010), originally identified as graves or turf houses (Simonsen 1982). The presence of ω-(o-alkylphenyl) alkanoic acids, α,ω-dicarboxylic acids and dihydroxy fatty acids and isoprenoid fatty acids suggests that these features were used for large-scale processing and heating of marine mammals, including walrus, seal and whale blubber, to extract oil (Heron *et al.* 2010). Residue analysis of Late Neolithic pottery at Durrington Walls found that different foodstuffs, that is, dairy and meat products, were consumed in domestic and monumental areas of the site. Furthermore, pottery vessels, differentiated by size, were used for the cooking of particular food groups (Craig *et al.* 2015). However, an alternative interpretation argues that the vessels were used for non-food purposes, that is, in the production of tallow, possibly to aid in transporting the megaliths to Stonehenge, by means of ‘greased’ sleds (Shillito 2019).

Finally, studying the regions of accumulation of lipids in a vessel can provide insights into the possible function of vessels. Previous work on determining the spatial distribution of lipids in pottery vessels suggested that most of the cooking vessels analysed showed a pattern of greater lipid concentrations in the upper bodies of vessels and much lower amounts in their bases (Charters *et al.* 1993b; Charters 1996; Evershed 2008). Further experimental work on different modes of cooking, i.e boiling vs roasting, showed that lipid accumulation in vessels, following boiling of foodstuffs in water, leads to preferential deposition of lipid in the upper body and rim areas of vessels. However, experimental roasting of meat in an oven demonstrated that liquified fat mostly accumulated in the base of the vessel, although fat was observed to splatter up the sides of the vessel. This pattern of lipid distribution differed from that of boiling foodstuffs in that greater amounts of lipid were present in the base and lower body of the vessel. Surprisingly, following roasting, high concentrations of lipid were still present in the upper bodies of vessels, likely resulting from spitting or splashing of meat fat up the sides of vessels during cooking, together with capillary action through the vessel fabric (Evershed 2008).

Form and function – medieval pottery

The investigation of medieval pottery has traditionally focused on a combination of factors, including use-wear analysis, such as the amount and position of wear marks and the presence of sooting to suggest vessels used for cooking, i.e. were in direct contact with fire, together with surviving documentary records and manuscript illustrations (Moorhouse 1978; 1986; McCarthy and Brooks 1988; Blinkhorn 1998-1999). Here, organic residue analysis of the entire ‘suite’ of vessels used by the medieval peasant at the site of West Cotton, Northamptonshire, over a period of around 500 years, provided a unique opportunity to determine both what foodstuffs were processed in the vessels and whether different vessel types from the site had specific functions. Notably, the pottery assemblage is remarkably consistent in form throughout the medieval period and does not display any typological development.

The West Cotton project

Full details of the The Raunds Area Project (Fig. 2) have been described previously (Chapman 2010; Dunne *et al.* 2019) so a short overview will be given here. The project aim was to investigate the development and subsequent expansion of medieval villages in middle England, involving a major landscape survey, large-scale excavations, documentary studies and environmental investigations which encompassed four medieval parishes, Raunds, Ringstead, Hargrave and Stanwick in Northamptonshire (Chapman 2010). There were three deserted medieval settlements within the Raunds area and the investigation of one of these, West Cotton, situated at the edge of the floodplain in the Nene Valley, was a major feature of the project. The settlement at West Cotton consisted of three phases, the first being a planned Saxon settlement (covering the period AD 950 to 1100). This included a late Saxon timber hall with ancillary buildings, and an associated watermill, arranged within a series of regular one-acre plots. Nearby was a second similar holding, with dependent peasants. In the Norman period (*c.* AD 1100 and 1250), the site comprised a small stone-built Norman manor house with a two-storey hall, dovecote and detached kitchen/bakehouse and garderobe. During the period AD 1250 to 1450, the economic base of the village changed to an emphasis on crop processing and storage. Later, the old manor house was replaced by peasant tenements, while the manor was relocated to the east, marking the end of direct farming of the manorial demesne (*c.* mid-thirteenth century). Finally, the new manor was converted to tenements, becoming a full peasant hamlet. The tenements were progressively abandoned throughout the fourteenth century, and by the mid-fifteenth century the settlement was uninhabited and given over to pasture closes (Figs. 2 and 3: Dunne *et al.* 2019).

The West Cotton pottery assemblage

The ceramic assemblage from West Cotton, comprising mainly Anglo-Saxon and medieval pottery, totalled 107643 potsherds (823.5kg). The vessels were mostly incomplete, suggesting that the assemblage represents only a fraction of the pottery used at the site. This suggests medieval pottery was used in large quantities, playing an important role in medieval cooking due to its ability to both withstand, and retain, sustained heat for prolonged periods (Blinkhorn 1998-1999). Late Saxon ware comprised mainly St Neots type (also found in later deposits, up to twelfth-century contexts), with Stamford ware and Cotswolds-type Oolitic wares making up the rest of the assemblage. By far the bulk of the pottery from medieval contexts comprised generally undecorated and unglazed, shell-tempered coarsewares (seen as a continuation of the St Neots-type ware tradition) from various local sources, with Lyveden/Stanion glazed wares, Potterspury wares and Brill/Boarstal types comprising the majority of the glazed material (Blinkhorn 2010; Dunne *et al.* 2019). The range of vessel types found at West Cotton was very limited, with only jars, bowls, pitchers and (rare) Top Hat vessels being present (Fig. 3). Jars were undoubtedly the most dominant vessel in each medieval phase, comprising at least three-quarters of the assemblage (Figs. 3 and 4). Jars took two main forms, a slightly baggy type, with nearly vertical body walls and the rim diameter being narrower than that of the base, and a more elegant shouldered variety, with the rim diameter being generally greater than the base diameter (Blinkhorn 1998-1999; 2010). Bowls, in two main forms, were the second most common vessel, comprising either wide shallow pans with near-vertical sides and deeper versions with open sides. Also present were three rare St Neots ware spouted bowls (Figs. 3 and 4). Jugs/pitchers (Figs. 3 and 4) were not common although they did comprise a variety of shapes and sizes. Of the common vessel forms a total of 25 jars (55 potsherds), 28 bowls

(33 potsherds), 5 jugs and pitchers (9 potsherds), and 8 Top Hat vessels (12 potsherds) together with 4 inturned rim bowls (5 potsherds), 3 spouted bowls (5 potsherds), 2 dishes (2 potsherds) and 1 oval shallow dish (2 potsherds) were analysed (Table 2).

Summary of lipid residue results

A total of 123 potsherds from 76 reconstructed vessels were examined using analytical procedures described in the material and methods section (Dudd and Evershed 1998; Copley *et al.* 2003; Correa-Ascencio and Evershed 2014; Dunne *et al.* 2019). Many of these vessels comprised full or partial profiles, suggesting that the potsherds were found in their primary deposit. Total lipid extracts (TLEs), with sufficient concentrations (>5µg g^{-1}) of lipids that can be reliably interpreted (Evershed 2008), were recovered from *c*. 58% of the potsherds (*n*=71), although it should be noted that many of these contained very low concentrations of lipid; mean for sherds yielding animal products was 0.4 mg g^{-1}, with a maximum lipid concentration of 4.8 mg g^{-1} (Table 1).

Analysis of the TLE’s from the West Cotton assemblage, with sufficient concentrations of lipid (*n*=30), revealed that the free fatty acids, palmitic ($C_{16;0}$) and stearic ($C_{18:0}$) were the most abundant components. The majority of the extracts comprise a higher abundance of the $C_{18:0}$ fatty acid (stearic acid) than the $C_{16:0}$ (palmitic acid) component, suggestive of a degraded animal fat (Evershed *et al.* 2002). Also present was a series of biomarkers denoting leafy vegetable processing, probably cabbage (*Brassica*) and leek, in several vessels. Compounds indicative of a beeswax origin, including long-chain alcohols, *n*-alkanes and fatty acyl wax esters in the carbon range C_{40} to C_{54} (Regert *et al.* 2001; Roffet-Salque *et al.* 2015), were also identified.

In summary, dairy product processing at West Cotton accounted for 27% of vessels. Butter and cheese were one of the mainstays of the medieval peasants diet and sometimes described as ‘white meats’ of the poor (Adamson 2004). However, it is ruminant carcass products, i.e. cattle or sheep, which dominant the assemblage at 60% of vessels, suggesting that they were used as ‘stewpots’ to cook beef or mutton, with the occasional addition of leafy vegetables (Dunne *et al.* 2019).

Relationships between West Cotton vessel forms and function

Jars

As discussed, the bulk of the pottery found in West Cotton medieval contexts comprised unglazed, shell-tempered coarsewares, with a limited range of vessel types, jars, bowls, pitchers and (rare) Top Hat vessels. Measurement of a sample of 20 jars (by far the commonest vessel) demonstrated that there appears to be three main sizes, with capacities of approximately 4, 7 and 20 litres (Blinkhorn 1998-1999). Many of the sherds were smoked and burnt on the exterior, and, functionally, the wide, everted rim forms of the jars would have been suitable for lids and the straight sides mean that adding or extracting cooked food and cleaning the jars would have been straightforward. Finally, a substantial group were located behind the manorial kitchen range, suggesting they were part of a kitchen midden deposit (Fig. 5a, plan of Manor House).

Significantly, the jars and 'Top Hat' vessels contain much higher lipid concentrations than the jugs or bowls, confirming their use as cooking pots (Table 2 and Fig. 6). The range of lipid concentrations for jar sherds is greater than that for the sherds of 'top hat' vessels (trace to 4840, 22 to 3869, and trace to 1840; and 168 to 1793, 149 to 428, and 269 to 1194 μg g^{-1}, for the rim, body and base sherds of jars and 'top hat' vessels, respectively, (Table 2 and Fig. 6) and, overall, is broader than for other vessel types. This suggests that jars may have had a wider repertoire of uses than 'top hat' vessels (Charters *et al.* 1993b). Regardless of this, both vessel types were primarily used to process ruminant carcass products, likely indicating they were used to prepare the pottages and stews which were the mainstay of the medieval diet (see Fig. 7a, b and d, Dunne *et al.* 2019).

Top Hat vessels

Interestingly, the form of the Top Hat vessels, the smoking and burning on the exterior and the fact that the majority yield lipid residues (7 out of 8 vessels) does confirm that they may also have been specialist cooking vessels. In the deposits, they occur in quantity in association with the kitchen, in a possible kitchen midden (Fig. 5a, plan of Manor House), but not within an assemblage probably associated with the barn and processing building, adding credence to this interpretation (Blinkhorn 2010). Although the volumes of the Top Hat vessels appear extremely large compared to modern cooking vessels (ranging from 1.8 to 18.8 litres), ethnographic studies indicate that such large cooking pots are not unusual in peasant societies. In the 1950's, villagers at Atany, Hungary, were still using traditional pottery cooking vessels of the same fabric, form and manufacture as the pottery of the medieval period (Fel and Hofer 1988). Each pot in the household was used only for the heating of one specific foodstuff, with the vessel volume depending on the function of the pot in the kitchen and the size of the family. The largest pots were generally used for the heating of water, milk (for cheese manufacture) or the soups and stews which formed the major part of the diet.

The mean lipid concentration for the sherds of each vessel type reveals that the spouted bowls displayed the highest mean lipid concentration (2785 μg g^{-1}, Table 2 and Fig. 6) while the bowls presented the lowest (2, 9 and 26 μg g^{-1} for Lyveden A, Shelly ware and Potterspury ware, respectively). The lipid concentration range for vessel types, that is, the lowest and highest values for sherds of that vessel type, varies considerably (Table 2 and Fig. 6). For example, with bowls the range is relatively narrow (< 1 to 47 μg g^{-1}), indicating that the amount of absorbed lipid remains consistent across the sherds of individual bowls. Conversely, the lipid concentration range for jars is much broader (1 to 4840 μg g^{-1}), implying that jars had widely varying uses (Charters *et al.* 1993b; Charters 1996).

Jugs and pitchers

The jugs and pitchers analysed (5 vessels, 9 sherds, Table 2), comprising two Brill jugs, two Shelly ware pitchers and a Nuneaton A ware jug, did not contain any lipid (Table 2 and Fig. 6), suggesting they were used solely for holding water or some other aqueous liquid (McCarthy and Brooks 1988). Interestingly, spatial analysis shows that the three main glazed jugs in use at the site, Lyveden/Stanion 'B' ware (dumpy, wide-based pitchers, Figs. 3 and 4), Potterspury ware (large, globular pitchers) and Brill/Boarstall ware (smaller, elegant balaster jugs), were found in different proportions in the kitchen and hall middens. The dominance of Lyveden/Stanion 'B' and Potterspury ware in the kitchen midden suggests that these jugs were used for transporting liquids from the kitchen into the hall where they were decanted into the smaller, more refined Brill/Boarstall jugs for consumption at the table (Fig. 5b, plan of medieval tenements). Certainly, a disproportionately higher number of Brill/Boarstall sherds were found in the hall midden (Blinkhorn 1998-1999). Of course, glazed jugs would have been a more efficient container of liquid than the porous shelly coarseware.

Bowls

Shelly ware bowls have always been regarded as having been used for skimming milk, largely due to their wide shallow shape (Blinkhorn 1998-1999). However, these vessels either contain no, or very low, concentrations of lipid, making this unlikely (Table 2 and Fig. 6). In fact, eight of the nine Lyveden A ware and the three Late Medieval Reduced ware bowls did not contain any lipid, and of the fourteen Shelly ware bowls analysed, ten contained no lipid and the remaining four (RP9, RP10, RP31 and RP47) held very low concentrations of lipid (Table 2, < 50 μg g^{-1} sherd). Significantly, their location in the archaeological deposits (Fig. 5a, plan of Manor House) suggests a somewhat different use. Spatial analysis of the pottery demonstrated that the kitchen midden, which produced many of the cylindrical jar rims sherds, did not contain any bowl sherds, but, conversely, a dump of pottery in a ditch to the rear of a barn and grain processing building (malthouse) yielded a large number of bowl sherds but no cylindrical jar sherds (Blinkhorn 1998-1999; 2010). This is further borne out by statistical analysis of the pottery assemblages in individual tenements (Fig. 5b). Tenement B yards show a definite drop in the proportion of jars in use between the phase 2/0 (AD 1225-1250) and phase 2/2 (AD 1250-1300) and a large increase in the proportion of bowls during the second phase, when the tenement contained a bakehouse along with the processing room (Blinkhorn 2010). Their association with the bakehouse correlates well with the suggestion that bowls have a specialised use not related to cooking but were rather used to measure standard amounts of grain, meal and/or flour. Analysis of vessel capacities of the West Cotton Shelly ware bowls suggests three favoured sizes, one at 2 litres, a second in the region 3.5-4.0 litres and a third between 6 and 8 litres (Blinkhorn 1998-1999). Significantly, the standard medieval dry measure for grain, flour and meal, the bushel, was approximately 35.2 litres (Zupko 1968). This had a smaller unit of 2 quarts, known as the *pottle*, which measured 1.9 litres. Medieval documents frequently refer to specific capacities of earthenware pots, including the pint, quart, pottle, gallon and bushel, the quart, pottle and gallon being the most common. Customers are known to have ordered specific sizes and shapes of vessels from potters, using these measures (Moorhouse 1981). The most common West Cotton bowl sizes of 2, 3.5-4 and 6-8 litres correlate with capacities of 1, 2 and 4 pottles, which were around 1.9, 3.8 and 7.6 litres or half a gallon, one and two gallons (Blinkhorn 2010). This suggests that the potters made these vessels in these three volume units (as standard sizes) or vessels of those specific capacities were favoured by the people at West Cotton. Documents refer to a type of medieval measuring device known as a Cantel, which was a round, shallow vessel specifically used for measuring oats, malt or meal (Zupko 1968). Furthermore, a sixteenth-century illustration from the York Baker's Company Ordinances shows meal being measured in such a vessel (Brears 1987). Flour would be poured into the cantel, then swiped across with a wooden batten (the 'strike') to obtain an exact bowlful. In summary, the lipid residue results from the bowls, in combination with the documentary and archaeological evidence, i.e. their location in a dump of pottery in a ditch to the rear of a barn and grain processing building, strongly suggests that the West Cotton bowls were used as cantels to measure standard amounts of grain, meal and/or flour. Significantly, the bowls remained remarkably consistent in form throughout the medieval period, suggesting they were indeed perfectly functional and fit for purpose.

Potterspury bowls

In contrast, the Potterspury bowls (RP44, rim and base sherds and RP41, base sherd) both yielded lipids typical of a degraded animal fat profile, including triacylglycerols, their degradation products, di- and monoacylglycerols and free fatty acids. Lipids indicative of a leaf wax origin were present in the rim sherd from RP44, including nonacosane, nonacosan-15-one, nonacosan-15-ol, hexacosanol and hentriacontane and all bar the latter of these compounds were also detected in the base sherd of the vessel. The same compounds were observed in the base sherd of RP41 but in lower relative abundance (Table 1 and Fig. 6). This suggests these two bowls were used to process both animal and plant foodstuffs, likely *Brassica*, probably in the form of soups and stews. Two Potterspury jars (RP63 and RP68) were also analysed, one of which, RP68, was sampled at the rim, body and base of the vessel, but neither yielded lipids (Fig. 6). Thus, in contrast to the Lyveden A and Shelly coarseware vessels, the Potterspury jars contained no lipid whereas the bowls comprised lipid profiles indicative of plant and animal product processing. This suggests a different use for vessels of the same form but separate ware types.

Specialist vessels

Interestingly, although the Shelly ware bowls generally contain either no, or very low levels of lipid, differing distribution patterns and lipid concentrations were seen in the three St Neots ware spouted bowls. It has previously been suggested that the sockets were not spouts, but were for the insertion of wooden handles to allow the vessels to be used as frying pans (Blinkhorn 2010). Lipid concentrations from these sherds were exceptionally high (3868 and 3695; 3326; 2686 and 348 $\mu g\ g^{-1}$ for RP72 rim and base, RP93 spout and RP94 rim and base respectively), greatly exceeding those seen in other bowls studied (Table 1 and Fig. 6). Of these, vessels RP72 and RP94 were used to process dairy products and RP93, with a $\Delta^{13}C$ value of -3.0 ‰, plots close to the border between ruminant dairy and ruminant adipose values (Table 1 and Fig. 7c), suggesting some mixing of these fats, either contemporaneously or during the lifetime use of the vessel. This hints at possible vessel specialisation with spouted bowls being used to render fat or clarify butter, with the socket used as a spout for pouring off part of the liquid.

Significantly, the spout sherd (RP93) contained a very high abundance of lipid (3326 μg g^{-1}), confirming sustained contact with a fat source.

The remaining four St Neots ware bowls were also of a specialised type, namely 'inturned-rim' bowls. Of these, three contained either no, or trace, amounts of lipid (RP1, RP23 and RP26 at 0, 0 and 21 μg g^{-1}, respectively) but a base and rim sherd from vessel RP73 yielded high concentrations of lipid at 2821 and 2731 μg g^{-1}, respectively (Table 1 and Fig. 6). Interestingly, the base sherd comprised a typical lipid distribution indicative of a beeswax origin, including long-chain alcohols, *n*-alkanes and fatty acyl wax esters in the carbon range C_{40} to C_{54} (Regert *et al.* 2001; Roffet-Salque *et al.* 2015). However, the rim sherd contained mainly free fatty acids, including $C_{15:0}$ and $C_{17:0}$ odd-carbon numbered fatty acids, known bacterial markers which result from microbial activity in the rumen, suggestive of a degraded animal fat, possibly tallow. This was confirmed by the $\Delta^{13}C$ value of -1.7 ‰, indicative of the processing of ruminant adipose products (Fig. 7f). Long chain *n*-alkanes, alcohols, and wax esters, deriving from beeswax, were also present in low abundances. Thus, the rim sherd of RP73 contains predominantly degraded animal fat and the base sherd comprises mainly beeswax. It is not possible to determine whether beeswax and the animal products were used as a mixture or whether they were used in the vessel on separate occasions. However, beeswax was a valuable commodity in medieval times and, as Crane (1983) notes, cheaper animal fats, such as tallow, were often added to eke out beeswax when making candles for domestic use. Tallow is obtained through skimming the fat from the top of vats where animal carcasses, commonly beef and mutton, are boiled. The high numbers of sheep in the faunal assemblage at West Cotton suggests that the likely source of the tallow was mutton, known to be particularly valued for its qualities of 'gloss and hardness'. Samuel Pepys (17th Century) noted that candles made solely from tallow have a putrid stench and emit offensive smoke, whereas beeswax candles produce a much brighter light than tallow, and, in practical terms, a mixture of tallow and beeswax would also improve the smell. Certainly, the dimensions of this vessel suggest that it would be ideal for the dipping of a wick, and it may be that this inturned-rim bowl was filled with a fat and wax mixture and, with the addition of a wick, may have been used as a lamp. RP73 has a totally blackened outer surface, indicating heating over a fire, which may have resulted from the heating of the vessel each time fat and wax were added to refuel the vessel. Alternatively, beeswax may have been mixed with animal fat to alter the properties of the fat for a specific purpose, perhaps for use as a sealant, lubricant or polish, although a culinary use cannot be excluded. Vessel RP73 was excavated from the area of the earliest watermill so a possible lubricant or sealant may have been associated with the activities of the mill. Significantly, rim, body and base sherds from vessel RP78, a Shelly ware jar, also contained the same mixture of lipids as RP73, namely beeswax and degraded animal fat (Fig. 6). Concentrations were also extremely high at 4840, 3869 and 284 μg g^{-1}, respectively. Both vessels are of a similar date (AD 1150-1225) and RP78 was also excavated from a context associated with the mill.

Discussion and conclusion

The invention of ceramic containers has long been regarded as a crucial step in human technological progress. This development changed the nature of food preparation in a fundamental manner, allowing the processing of previously otherwise unpalatable or even toxic foods, rendering them edible and unlocking their nutritional potential. For example, thermally resistant ceramic vessels likely facilitated the prolonged boiling of grains and seeds that previously needed long periods of soaking or cooking and would also improve the ‘shelf life’ of foods. Pottery vessels would also have allowed the prolonged boiling of milk to produce cheese and meats and vegetables to make stews.

Thus, the examination of form and function, to help in understanding the possible uses for pottery containers, may provide valuable insights into the complex human choices involved in the selection, preparation and consumption of foodstuffs. In broader terms, relationships between food, society and culture and the social and technological choices made by ancient people, can also be examined. Any study of pottery function begins with the premise, as Braun (1983) notes, that pots are tools and, as such, are designed to be used for a purpose. Such containers may have been fashioned (or adopted) to serve technological, social or ideological functions, and, indeed, combinations of these, but their primary purpose, both prehistorically and through ethnographic analogy, has always been in processing, cooking, storing, serving or transporting food and liquids (Schiffer and Skibo 1987; Brown 1989; Hayden 1995; Hoopes and Barnett 1995; Hayden 1998; Rice 1999; 2006; Dunne *et al.* 2018).

Here, we investigated the medieval pottery assemblage from West Cotton, where a combination of lipid residue analysis, documentary evidence, ethnographic analogy and spatial analysis of pottery excavated from activity/use areas at the site demonstrates that each vessel used at the site had a defined function. The two main pottery forms were highly specialised, with bowls (or cantels) being used as measures in grain processing while jars were mainly employed for cooking stews and potages consisting of sheep or cattle carcass meats and, occasionally, vegetables such as cabbages and leeks (Dunne *et al.* 2019). Furthermore, less commonly used vessels also appear to have had specialised uses, including spouted bowls, likely employed to render fat or clarify butter and an inturned-rim bowl, used for the mixing of tallow and beeswax, possibly for use as an illuminant, sealant or lubricant. The jugs and pitchers did not contain any lipid suggesting they were used solely for holding water or some other aqueous liquid and, notably, spatial analysis suggested the larger Lyveden/Stanion 'B' and Potterspury jugs were used for transporting liquids from the kitchen into the hall where they were decanted into the smaller, more refined Brill/Boarstall jugs for consumption at the table.

It is interesting that, as far back as 1978, Moorhouse noted that the "limited range of common forms produced by the medieval potter, the 'cooking-pot', 'jug' and 'bowl', … created a subconscious assumption that medieval pottery had a very limited range of uses". Clearly, our findings contradict this and, indeed, demonstrate that here the medieval potter created a 'perfectly functional' suite of vessels, well-adapted for the processing, cooking, storage, serving and transportation of food and liquids, as required by the West Cotton peasant for day-to-day dining. The medieval potter was clearly aware of the importance of the performance characteristics of the vessels he or she produced, and it is noteworthy that there do not seem to have been any technological changes/improvements to the pottery over time, suggesting that the material performance of the vessels was perfectly satisfactory.

Material and methods

The pottery investigated in this study comprises a group of 'reconstructed' vessels from West Cotton. These are vessels for which, in most cases, full or partial profiles were available, suggesting that the potsherds were extracted from their primary deposit. Of the 73 vessels analysed, 22% were sampled at three points from the profile, rim, body and base and a further 21% were sampled from the body and rim. The remainder (58%) were mostly bowls and were only sampled from the body.

Lipid analysis and interpretations were performed using established protocols described in detail in earlier publications (Charters *et al.* 1993b; Dudd and Evershed 1998; Copley *et al.* 2003). Briefly, ~2 g of potsherd were sampled and surfaces cleaned with a modelling drill to remove any exogenous lipids. The sherds were then ground to a powder, an internal standard added and solvent extracted by ultrasonication (chloroform/methanol 2:1 *v/v*, 30 min, 2x10ml). The solvent was evaporated under a gentle stream of nitrogen to obtain the total lipid extract

(TLE). Aliquots of the TLE were trimethylsilylated (*N*,*O*-bis(trimethylsilyl)trifluoroacetamide 80 µL, 70° C, 60 min), and submitted to analysis by GC and GC/MS.

Further aliquots of the TLE were treated with NaOH/H_2O (9:1 *w/v*) in methanol (5% *v/v*, 70°C, 1 h). Following neutralization, lipids were extracted into chloroform and the excess solvent evaporated under a gentle stream of nitrogen. Fatty acid methyl esters (FAMEs) were prepared by reaction with BF_3-methanol (14% *w/v*, 70°C, 1 h). The FAMEs were extracted with chloroform and the solvent removed under nitrogen. The FAMEs were re-dissolved into hexane for analysis by GC and GC-C-IRMS.

GC analyses were performed on a Hewlett-Packard 5890A gas chromatograph, coupled to an Opus V PC using HP Chemstation software which provided instrument control, data acquisition and post-run data-processing facilities. Samples were introduced by on-column injection into a 60 cm x 0.53 mm (i.d.) retention gap (deactivated polyimide clad fused-silica capillary; Phase Separations, U.K.) connected to the analytical column via a lightweight glass-lined stainless-steel union of 0.8 mm i.d. (S.G.E.). the column used was a polyimide clad 12 m x 0.22 mm i.d. fused-silica capillary, coated with BP-1 stationary phase (immobilised dimethyl polysiloxane, OV-1 equivalent, 0.1 µm film thickness; S.G.E.). The carrier gas was helium and the temperature programme comprised a 2 min 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.

GC/MS analyses were performed using a Finnigan 4500 quadrupole mass spectrometer (Finnigan MAT GmbH, Bremen, Germany) directly coupled to a Carlo Erba 5160 Mega series GC with on-column injection. Operating conditions were as follows: ion source, 170°C; emission current, 400 µA and electron energy, 70 eV. The GC-MS interface was maintained at a temperature of 350°C. Spectra were recorded over the range *m/z* 50-850 every 1.5 s. Data were acquired and processed using an INCOS data system.

Carbon isotope analyses by GC-C-IRMS were carried out using a Varian 3500 gas chromatograph (Varian Associates Inc., Walnut Creek, CA) attached to a Finnigan MAT Delta-S isotope ratio mass spectrometer (Finnigan MAT GmbH, Bremen, Germany) *via* a modified Finnigan MAT combustion interface. The GC column used was a 25 m x 0.32 mm i.d. polyimide-clad fused silica capillary column coated with HP5 (5% diphenylpolysiloxane 95% dimethylpolysiloxane) stationary phase of film thickness 0.33 pm. Helium was used as carrier gas and the samples were dissolved in an appropriate volume of hexane. The reactor temperature was 860°C, and the mass spectrometer source pressure was 9 x 10^{-5} Pa. Gas chromatography temperature programming was from 70 to 150°C at 10°C min^{-1}, and then from 150 to 290°C at 5°C min^{-1} following a 2 min isothermal hold at 70°C after injection. At the end of the temperature programme the gas chromatograph oven was kept at 290°C for 5 mins. Samples were injected in the splitless mode at an injector temperature of 290°C. Carbon isotope ratios were expressed relative to VPDB.

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Figures

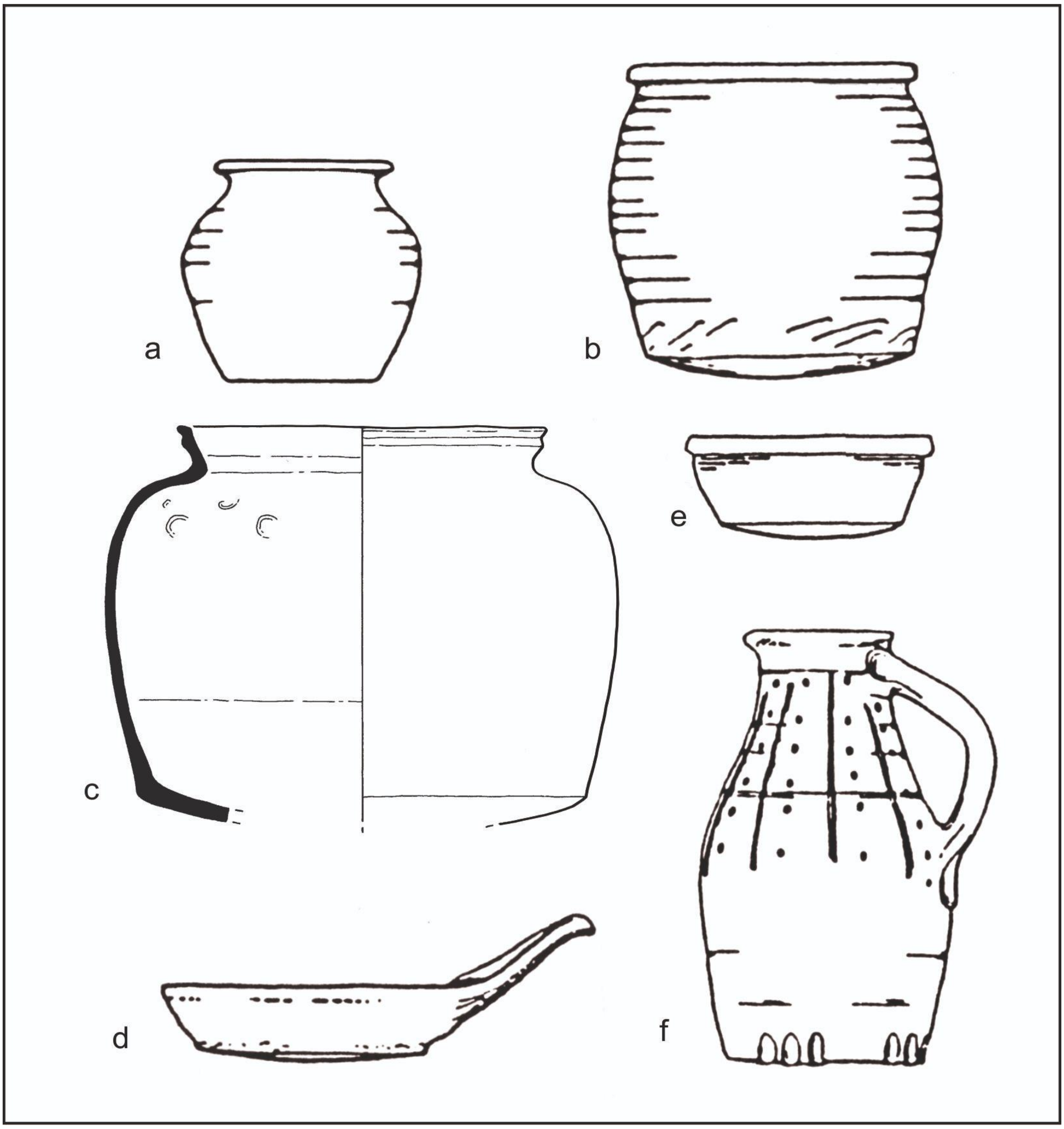


Fig. 1 Drawings of ‘typical’ medieval vessels including a. narrow-mouthed cooking pot, b. wide-mouthed cooking pot, c. storage vessel, d. roasting dish, e. serving bowl and f. jug (image: A. Chapman)

Fig. 2 Location map of West Cotton and reconstruction of medieval village (after Chapman 2010).

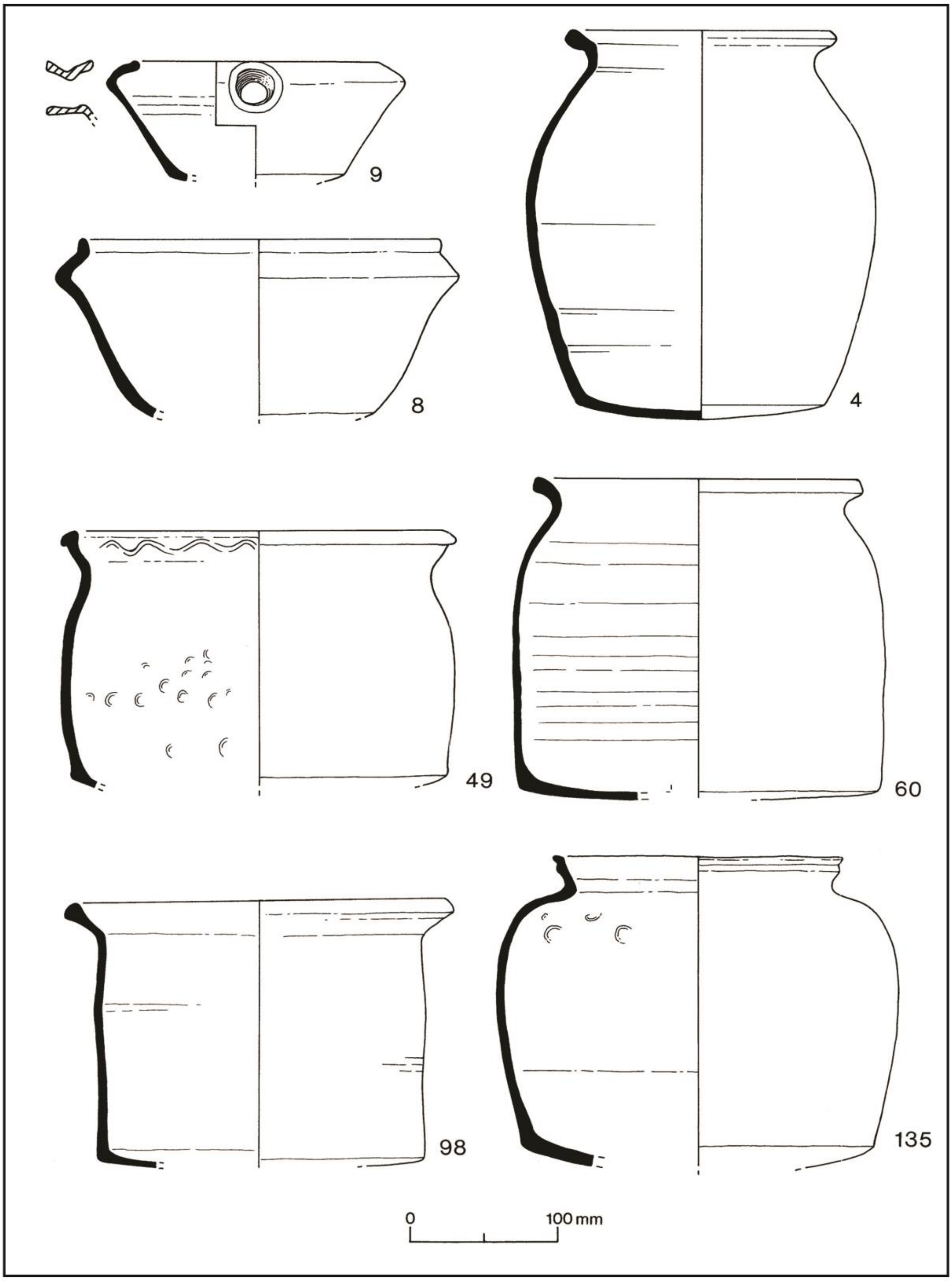


Fig. 3 Representative bowls and jars from West Cotton:

9 St Neots-type ware socketed or spouted bowl. Outer body is completely blackened except for the top of the rim and the upper half of the spout. Patches of blackening on the inner surface of the vessel.

8 St Neots-type ware inturned rim bowl, with totally blackened outer surface.

4 St Neots-type ware jar, with black surfaces. Base pad is slightly scorched internally and externally.

49 Saxo-Norman Cotswold-type oolitic jar, with the outer surface progressively more blackened from the shoulder to the base, with patches of sooting.

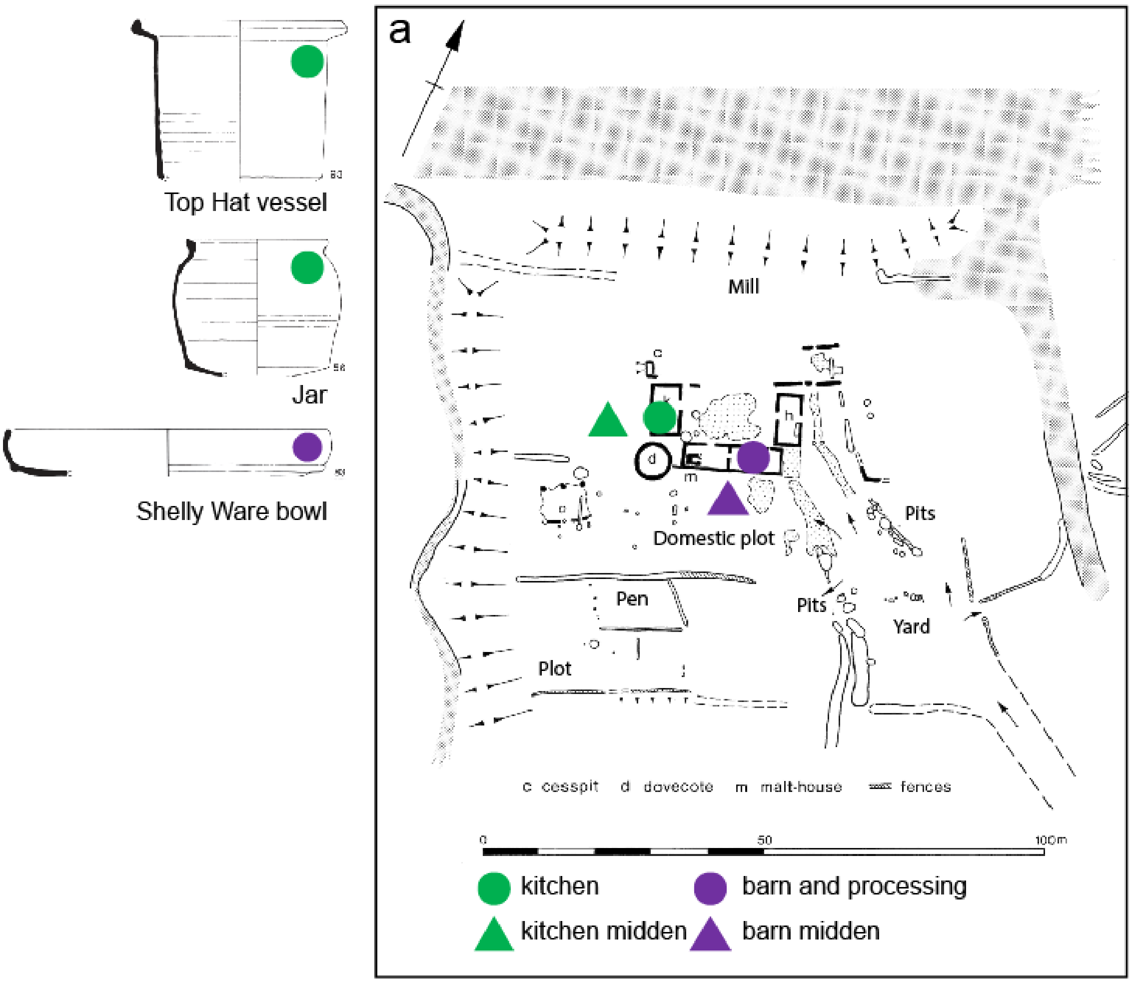
60 Shelly coarseware jar, the outer surface is extensively blackened, with a scorched red outer base pad.

98 Shelly coarseware “top hat” jar, with smoke blackened lower body and base.

135 Lyveden A ware jar, with the lower body and base quite evenly blackened.

Note: catalogue numbers as in original report (Blinkhorn 2010).

Fig. 4 a. Typical West Cotton Stanion jug, b. Shelly coarseware jars and c. spouted bowl


Top Hat vessel
Jar
Shelly Ware bowl
a
Mill
Domestic plot
Pits
Pen
Pits
Yard
Plot
c cesspit
d dovecote
m malt-house
fences
0
50
100m
● kitchen
● barn and processing
▲ kitchen midden
▲ barn midden

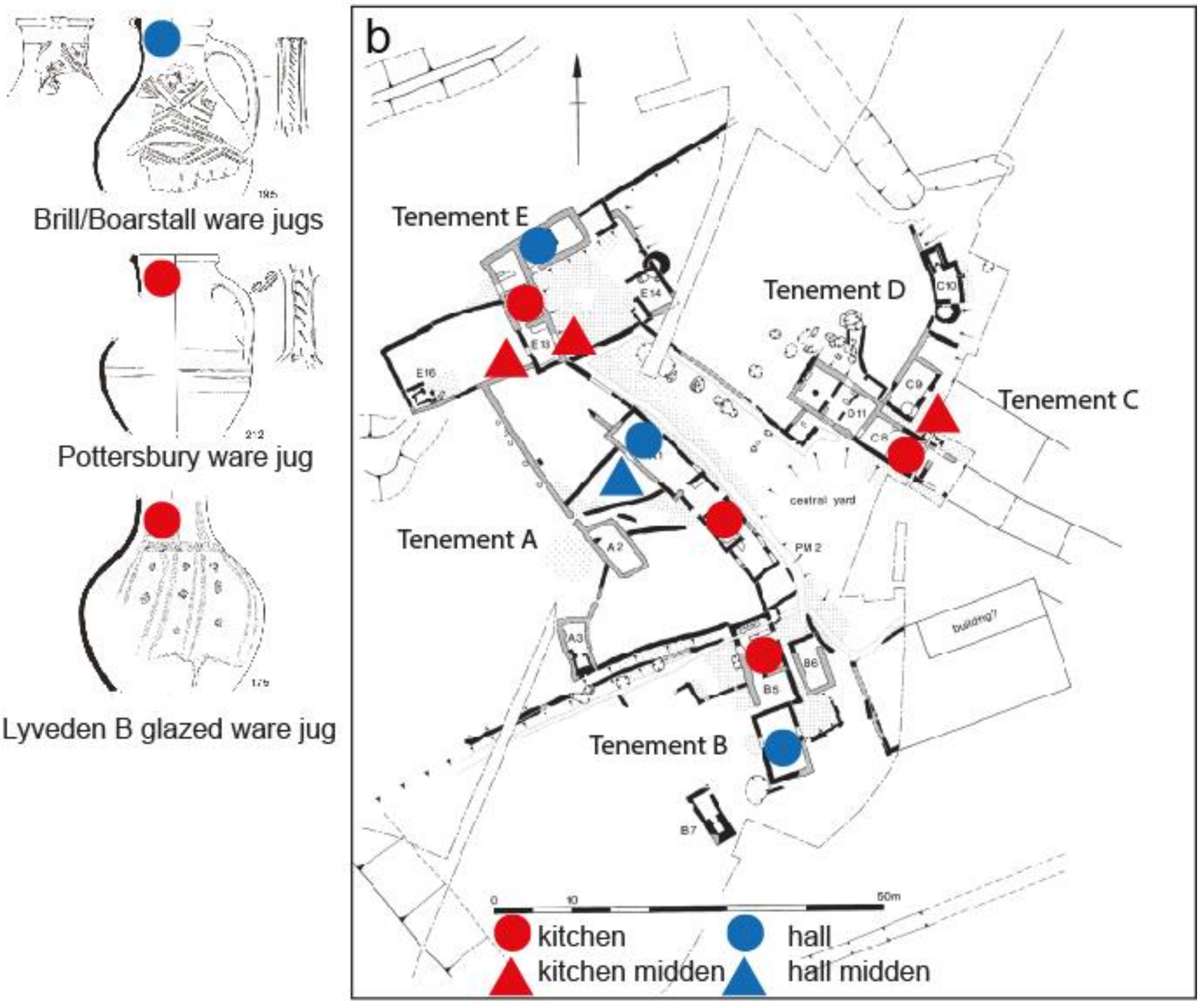


Fig. 5 a and b Site plans (after Chapman 2010) showing location of specific vessel types; Jar (green circle), Top Hat vessel (green circle), Shelly Ware bowls (purple circle), Brill/Boarstal ware jugs (blue circle), Pottersbury ware jugs (red circle) and Lyveden b ware jugs (red circle) in Post-Conquest Manor House (a, 1100-1250 AD) and Medieval tenement archaeological deposits (b, 1250-1450 AD).

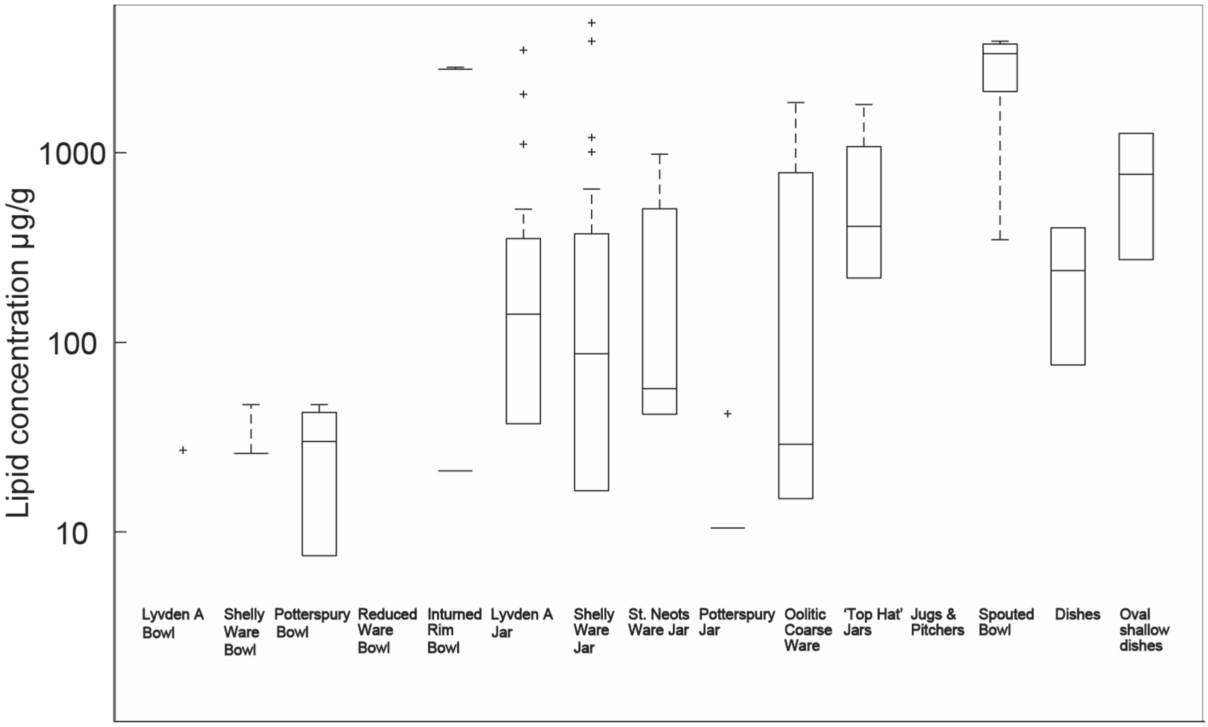


Fig. 6 Box and whisker plot showing lipid concentrations of West Cotton vessel types

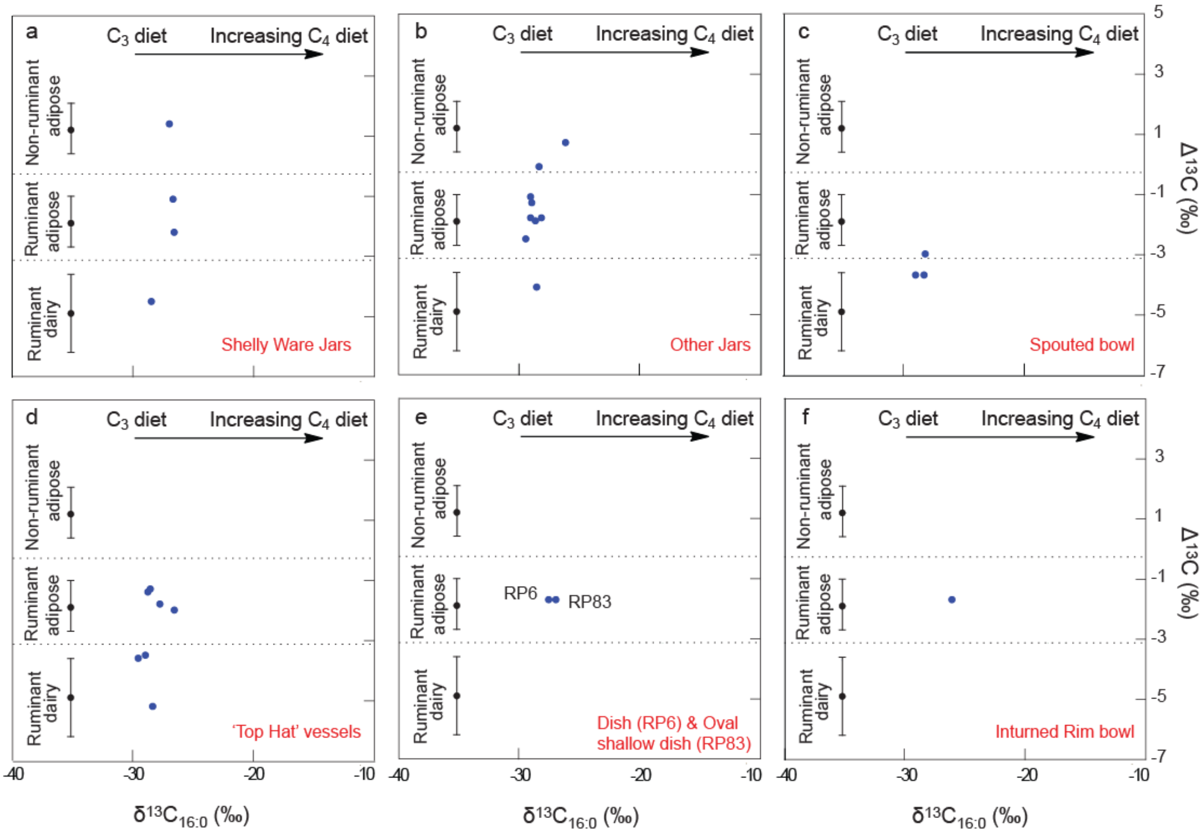


Fig. 7 Graphs (a-f) showing the Δ^{13}C ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) values from the West Cotton vessels by type, a. Shelly ware jars, b. other jars, c. spouted bowl, d. 'Top Hat' vessels, e. dish and Oval shallow dish f. Inturned-rim Bowl. The ranges shown here represent the mean ± 1 s.d. of the Δ^{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

Table 1. Sample number, vessel number and type, sherd type, date, structure, lipid concentration (µg g^{-1}), major lipid biomarkers, $\delta^{13}C_{16:0}$, $\delta^{13}C_{18:0}$, $\Delta^{13}C$ values, lipid composition and classification of residues from potsherds from West Cotton, Northamptonshire. Vessels that did not yield lipid concentrations of greater than 5 µg g^{-1} are not listed.

Vessel	**Vessel type**	**Sherd type**	**Date**	**Structure**	**Lipid concentration (µg g^{-1})**	**Major lipid biomarkers**	**$\delta^{13}C_{16:0}$**	**$\delta^{13}C_{18:0}$**	**$\Delta^{13}C$**	**Classification**
RP2	Shelly ware jars	Body	1100-1250	-	202	Saturated fatty acids (C_{14} to C_{18}),	-26.6	-27.7	-1.1	Ruminant adipose
RP4	Shelly ware jars	Rim	1100-1250	Third watermill	1008	Saturated fatty acids (C_{14} to C_{18}), ketones (C_{31}-C_{35})	-26.9	-25.5	1.4	Porcine fat
RP6	Late Medieval Reduced ware dish	Rim	1400-1450	Tenement A	402	Saturated fatty acids (C_{14} to C_{18}), ketones (C_{31}-C_{35})	-27.5	-29.2	-1.7	Ruminant adipose
RP7	St Neots ware jar	Body	950-1150	w.b ditch	57	Saturated fatty acids (C_{14} to C_{18}),	-28.9	-30.2	-1.3	Ruminant adipose
RP10	Shelly ware bowl	Body	1100-1250	-	28	Saturated fatty acids (C_{14} to C_{18}),	-26.4	-24.9	1.5	Porcine fat

RP13	Lyveden A ware jars	Body	1150-1225	Malt House	122	Saturated fatty acids (C_{14} to C_{18}),	-29.0	-30.1	-1.1	Ruminant adipose
RP16	Lyveden A ware jars	Body	1150-1225	Main domestic range	3474	Saturated fatty acids (C_{14} to C_{18}),	-28.6	-30.5	-1.9	Ruminant adipose
RP22	Lyveden A ware jars	Base	1150-1225	Yard B	26	Saturated fatty acids (C_{14} to C_{18}), *n*-alkanes (C_{29}, C_{31}),	-29.4	-31.9	-2.5	Ruminant adipose
RP28	Shelly ware 'Top Hat' vessels	Base/body	1100-1250	Boundary walls A to B	269	Saturated fatty acids (C_{14} to C_{18}), *n*-alcohols (C_{24}-C_{30}), *n*-alkanes (C_{29}, C_{31}), wax esters (C_{44}-C_{48})	-26.5	-28.5	-2.0	Ruminant adipose
RP30	Oolitic Coarseware jar	Base/body	950-1150	-	1840	Saturated fatty acids (C_{14} to C_{18}), *n*-alkanes (C_{29}- to C_{31}), ketones (C_{29})	-28.5	-32.6	-4.1	Dairy fat

RP41	Potterspury bowl	Rim/base	1300-1400	Barn	47	Saturated fatty acids (C$_{14}$ to C$_{18}$), *n*-alkanes (C$_{29}$- to C$_{31}$)	-	-	-	Animal/plant
RP44	Potterspury bowl	Base	1250-1300	Yard	30	Saturated fatty acids (C$_{14}$ to C$_{18}$), *n*-alkanes (C$_{29}$- to C$_{33}$)	-	-	-	Animal/plant
RP50	Thetford ware	Body	950-1150	-	4163	Saturated fatty acids (C$_{14}$ to C$_{18}$),	-27.9	-29.2	-1.3	Ruminant adipose
RP53	Shelly ware 'Top Hat' vessels	Body	1100-1250	Building enclosure	351	Saturated fatty acids (C$_{14}$ to C$_{18}$),	-28.7	-30.1	-1.4	Ruminant adipose
RP60	Shelly ware 'Top Hat' vessels	Base	1100-1250	West boundary ditch	1194	Saturated fatty acids (C$_{14}$ to C$_{18}$),	-29.5	-33.1	-3.6	Dairy fat
RP61	Shelly ware jars	Body	1100-1250	Late Saxon domestic range	22	Saturated fatty acids (C$_{14}$ to C$_{18}$),	-28.4	-32.9	-4.5	Dairy fat
RP71	Shelly ware 'Top Hat' vessels	Base	1100-1250	Northern boundary ditch	1076	Saturated fatty acids (C$_{14}$ to C$_{18}$), *n*-alcohols (C$_{26}$-C$_{30}$), n-alkanes	-28.5	-29.8	-1.3	Ruminant adipose

						(C_{29} - C_{33}), wax esters (C_{44}-C_{48})				
RP72	St Neots Spouted ware bowl	Rim	950-1150	n.b. ditch	3868	Saturated fatty acids (C_{14} to C_{18}),	-28.3	-32.0	-3.7	Dairy fat
RP73	St Neots ware inturned rim bowl	Rim	950-1150	Earliest watermill	2731	Saturated fatty acids (C_{14} to C_{18}),	-26.1	-27.8	-1.7	Ruminant adipose
RP73	St Neots ware inturned rim bowl	Base	950-1150	Earliest watermill	2821	Saturated fatty acids (C_{14} to C_{18}), *n*-alcohols (C_{24}-C_{32}), n-alkanes (C_{25} - C_{31}), wax esters (C_{40}-C_{52})	-	-	-	Beeswax (honey)
RP78	Shelly ware jars	Rim	1100-1250	Third watermill	4840	Saturated fatty acids (C_{14} to C_{18}), *n*-alcohols (C_{24}-C_{30}), n-alkanes (C_{25} - C_{31}), wax esters (C_{42}-C_{48})	-26.5	-28.7	-2.2	Ruminant adipose

RP78	Shelly ware jars	Body	1100-1250	Third watermill	3869	Saturated fatty acids (C_{14} to C_{18}), *n*-alcohols (C_{24}-C_{32}), n-alkanes (C_{25} - C_{31}), wax esters (C_{40}-C_{50})	-	-	-	Ruminant adipose(?)/beeswax
RP78	Shelly ware jars	Base	1100-1250	Third watermill	284	Saturated fatty acids (C_{14} to C_{18}), *n*-alcohols (C_{24}-C_{34}), n-alkanes (C_{25} - C_{31}), wax esters (C_{40}-C_{52})	-	-	-	Beeswax (honey)
RP81	St Neots ware jar	Body	950-1150	-	2033	Saturated fatty acids (C_{14} to C_{18}),	-29.0	-30.8	-1.8	Ruminant adipose
RP82	Furnells 'Top Hat' pot	Rim	No date	-	1793	Saturated fatty acids (C_{14} to C_{18}),	-27.7	-29.5	-1.8	Ruminant adipose
RP83	Lyveden B fish dish/dripping dish/	Rim	No date		1263	Saturated fatty acids (C_{14} to C_{18}),	-26.9	-28.6	-1.7	Ruminant adipose

RP85	Furnells Lyveden A jar	Rim	No date	-	1101	Saturated fatty acids (C_{14} to C_{18}),	-28.3	-28.4	-0.1	Mixed porcine/ruminant adipose fat
RP86	Furnells 'Top Hat' pot	Body	No date	-	428	Saturated fatty acids (C_{14} to C_{18}),	-28.9	-32.4	-3.5	Dairy fat
RP87	Furnells Lyveden A jar	Rim	No date	-	315	Saturated fatty acids (C_{14} to C_{18}),	-28.1	-29.9	-1.8	Ruminant adipose
RP88	Furnells Lyveden A jar	Body	No date	-	28	Saturated fatty acids (C_{14} to C_{18}),	-26.1	-25.4	0.7	Porcine fat
RP89	Furnells Manor cooking pot	Body	No date	-	1918	Saturated fatty acids (C_{14} to C_{18}), ketones (C_{31}-C_{35})	-28.1	-30.5	-2.4	Ruminant adipose
RP91	Furnells site reused as griddle?	Rim	No date	-	1169	Saturated fatty acids (C_{14} to C_{18}),	-27.4	-32.3	-4.9	Dairy fat
RP93	Late Medieval Reduced spouted bowl	Spout	1400-1450	-	3326	Saturated fatty acids (C_{14} to C_{18}),	-28.2	-31.2	-3.0	Mixed dairy/ruminant adipose fat
RP94	Late Medieval Reduced	Rim/body	1400-1450	w.b. ditch	2686	Saturated fatty acids (C_{14} to C_{18}),	-29.0	-32.7	-3.7	Dairy fat

	spouted bowl								
WC30	Top Hat vessel	-	1100-1250	-	1079	Saturated fatty acids (C_{10} to C_{18}),	-28.3	-33.5	-5.2	Dairy fat

Table 2. Number of sherds and vessels and lipid concentrations for different ware types of reconstructed vessels (reconstructed from Charters *et al.* 1993b; Charters 1996)

Vessel form	**Ware type**	**No. of sherds**	**No. of vessels**	**Mean lipid content (ug/g^{-1} sherd)**	**Range of lipid content (ug/g^{-1} sherd)**
Bowls	Lyveden A	11	9	2	tr-27
	Shelly Ware	15	14	9	tr-47
	Potterspury	3	2	26	30-47
	Reduced Ware	4	3	trace	trace
Inturned Rim Bowl	St Neots Ware	5	4	1115	21-2821
Spouted Bowl		5	3	2785	348-3868
Jars	Lyveden A	17	7	500	26-3474
	Shelly Ware	21	9	609	22-4840
	St Neots Ware	7	3	279	41-982
	Potterspury Ware	5	3	8	tr-42
	Oolitic Coarseware	5	3	465	20-1840
Shelly 'Top Hat' vessels		12	8	618	149-1793
Jugs and pitchers		9	5	trace	trace
Dishes		2	2	239	76-402
Oval shallow dish		2	1	768	273-1263