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What's in the pots? Identifying Possible Extensification in Roman Britain Through Analysis of Organic Residues in Pottery

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ABSTRACT

This study examined absorbed organic residues in pottery to assess differences in subsistence practices in Roman Britain. Through this approach, we investigated foodways at a major urban site and a range of small towns, villas and farmsteads within its hinterland. The study revealed that consumption at Cirencester differed remarkably to consumption at other sites in the surrounding hinterland, with a greater contribution from pigs and/or chickens. Dairy products were a key contributor to the diet at rural sites, including a high-status villa. We contend that both findings are the result of extensification of food production. Thus, we show how reconstructing broad culinary patterns can reveal possible responses of inhabitants to the challenges of feeding the increasing population of Roman Britain.

Keywords: organic residue analysis; food; agriculture; animal husbandry; extensification; Cirencester; pottery

INTRODUCTION

Scholars of Roman Britain have long been interested in the relationship between rural and urban settlements. Cities have been characterised as 'alien',[1] bearing no relation to other settlement types, especially in the early Roman period. After the end of the first century A.D., they are also viewed as centres of market redistribution, at least for exotic foodstuffs.[2] More traditionally, towns have been classed as 'consumers' while rural settlements were 'producers'.[3]

The integration of late pre-Roman Iron Age societies into the Roman economy is also of great interest. Although late Iron Age societies were clearly able to produce a surplus,[4] this process was

1 Perring and Pitts 2013.
2 Livarda and Orengo 2015.
3 e.g. Hingley 1982; Millett 1990.
4 Van der Veen 2007.

undoubtedly formalised under Roman rule into a system of taxation,[5] even if the minutiae are lost to us. At the same time, the population of the island grew rapidly thanks to the arrival of the Roman army and an influx of merchants to newly founded cities.[6] By the end of the second century A.D., twice the number of settlements were recorded than for the late Iron Age.[7] All these people needed to be fed, and a surplus generated to supply the state. At the same time, the proportion of people working the land probably decreased as urban populations grew. The effects of this economic pressure are seen in many aspects of rural life: more land was taken under arable cultivation,[8] using newly imported heavy ploughshares.[9] Emphasis on sheep declined in favour of cattle, as urban meat markets boomed[10] and all three major domesticates, cattle, sheep and pigs, increased in size. Lodwick and Allen see these practices as 'extensification': the production of more food for the same labour input through increasing the area of land under cultivation, increasing animal and herd sizes and by decreasing labour-intensive activities such as manuring or dairy farming.[11] However, this general picture masks considerable variation in subsistence practices across Roman Britain. Were dairying practices abandoned by all farming people, in favour of cattle destined for the urban meat market? Were the inhabitants of cities simply consumers, drawing in all produce from their hinterlands and further afield?

The analysis of absorbed residues from large assemblages of pottery used in Roman Britain offers a direct way to compare everyday dietary practices over time and space, and in so doing offers an alternative approach to address these questions. This study investigated organic residues preserved in hundreds of sherds from cooking jars (rather than specialist or unusual forms) from a range of settlement types within a single region and spanning five centuries (100 B.C.–A.D. 400). This enabled examination of both variability between subsistence practices at different contemporaneous and connected site types operating within a landscape, as well as consideration of how subsistence strategies continued or emerged in response to the changing social and economic pressures of the Roman world over half a millennium.

USING ORGANIC RESIDUE ANALYSIS TO UNDERSTAND ROMAN FOODWAYS

Organic residue analysis is a powerful approach that provides direct evidence for vessel use through extraction and analysis of absorbed lipid residues surviving in the fabric of unglazed pots.[12] Recent experiments indicate that absorbed residues accumulate throughout the use-life of the pot.[13] Residues therefore represent a palimpsest of cooking incidents, not the first or last uses of the vessel. Thus far, organic residue analysis has been applied predominantly to prehistoric pottery, tracing the emergence and spread of specific key commodities, for example, dairy products,[14] aquatic resources[15] and bee products.[16] In so doing, it has been possible to

5 Corbier 1991; Stallibrass 2009.
6 Fulford and Allen 2017.
7 Fulford and Allen 2017, 8.
8 Lodwick 2017, 36–7.
9 Brindle 2017, 42.
10 Maltby 2007.
11 Allen and Lodwick 2017, 145.
12 Evershed 2008a.
13 Miller *et al.* 2020.
14 Dudd and Evershed 1998; Copley *et al.* 2005.
15 Craig *et al.* 2007.
16 Evershed *et al.* 1997; Kimpe *et al.* 2002.

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trace major shifts in ancient foodways, for example the earliest evidence for dairying activity in the Near East,[17] northwestern Europe[18] and Saharan Africa.[19]

This approach is based on the concept of detecting unique biomarkers, or suites of biomarkers, that can be related back to the signature of the original resource(s) that were processed in the pots.[20] The scope for the identification of different products depends on the presence of diagnostic finger-prints in the original source, and the survival of this finger-print or its degradation products in archaeological conditions and over archaeological timescales. While some surviving fingerprints can be relatively broad in terms of classification (e.g. the survival of characteristic saturated fatty acids from animal products), combining this approach with the analysis of the stable carbon isotope signature of individual compounds can lend further specificity, in this instance, allowing further classification of animal fats as from ruminant or non-ruminant species, and within the former, dairy fats from carcass fats.[21] Aquatic fats from marine or freshwater sources can also be recognised.[22] Other resources such as resins and gum-resins, insect waxes (beeswax) and leafy plants can also be determined.[23] Plant oils are characterised by high prevalence of unsaturated fatty acids which degrade rapidly and do not usually survive in high abundance; it is important to note that although olive oil contains a high abundance of oleic acid ($C_{18:1\ cis\text{-}9}$), this is both non-specific to this source and unlikely to survive archaeologically, more often reflecting a source of contamination when identified in high abundance.[24] Likewise highly water-soluble biomarkers such as tartaric and succinic acid (so-called 'wine markers') will be readily washed out of pottery during deposition.[25]

The British Iron Age has been subject to relatively extensive organic residue analysis, as part of a wider study into dairying in British prehistory. Copley *et al.* conducted residue analysis on 237 sherds from four sites dating to the Iron Age.[26] Between 39 and 71 per cent of extracted residues from these sites were identified as milk fats. There was no specific vessel associated with dairy-product processing. Instead, dairy fats tended to be associated with the most commonly used vessel form on each site. Therefore, at Maiden Castle, where jars predominated, dairy fats were most commonly found in jars, while at Danebury, 'saucepan pots' were the most common vessel form, and dairy fats were most commonly identified in these vessels. Copley *et al.* concluded that dairy products were an extremely important commodity to Iron Age populations.

A very small study, examining 29 sherds from 'a range of typical coarsewares' from late pre-Roman Iron Age Silchester, aimed to provide a 'snapshot of culinary practices'.[27] The vast majority of extracted residues derived from ruminant adipose fat (i.e. cattle and sheep), with the remainder deriving from a mixture of ruminant and non-ruminant adipose fats (i.e. pigs and chickens). There was no indication of dairy-product processing in any of these vessels.[28]

There has been more limited application of organic residue analysis for the study of Romano-British pots hitherto. Most notable is Cramp *et al.*'s work on *mortaria*.[29] *Mortaria* first appeared in the Late Iron Age and were traditionally viewed as a distinctively 'Roman'

17 Evershed *et al*. 2008a.
18 Cramp *et al*. 2014b.
19 Dunne *et al*. 2012.
20 For an overview of detectable commodities, see Roffet-Salque *et al.* 2017.
21 Dudd and Evershed 1998.
22 Craig *et al.* 2007; 2011; Cramp and Evershed 2014.
23 Evershed *et al.* 1991; Charters *et al.* 1995; Regert *et al.* 2003.
24 Cramp and Evershed 2015, 130.
25 Whelton *et al.* 2021.
26 Copley *et al.* 2005.
27 Colonese *et al*. 2018.
28 Colonese *et al*. 2018, 226.
29 Cramp *et al*. 2011; 2012.

form, and therefore an indicator of 'Romanisation'.[30] In typical 'Roman' cuisine, *mortaria* are used for grinding spices and making pastes, pestos and sauces,[31] but it has been suggested that in Roman Britain they were used for more traditional 'British' practices, such as dairy-product processing[32] or cereal processing.[33] However, the extraction of residues from large numbers of *mortarium* sherds and comparison with residues from other forms of Roman and Iron Age pots conclusively demonstrated that *mortaria* were not consistently associated with dairy products. In fact, the use of *mortaria* reflected a novel type of plant- and animal-resource processing method, but one that broadly fitted in with existing cultural traditions rather than implying a wholesale transition to 'Romanised' foodways.[34] At Faverdale, Co. Durham, and Stanwick, Northamptonshire, where Cramp *et al.* also analysed a range of domestic wares, *mortaria* could be clearly distinguished from other cooking wares. They had lower lipid concentrations and a high frequency of plant biomarkers, which were present in very high (greater than 80 per cent) proportions of *mortaria*. At the rural site of Stanwick, significantly higher proportions of residues were characterised as of dairy origin compared with the major settlement site of Faverdale. This differentiation persisted into the *mortaria* from each site, indicating that, while *mortaria* were not specifically a dairy-processing vessel, at Stanwick, dairy products retained their importance from the Iron Age into the Roman period and this pattern could be seen across vessel forms, including more 'Romanised' types.[35]

Dairy-product exploitation and processing is a very labour-intensive activity compared to rearing herds of cattle and sheep for slaughter. It is often asserted that dairy production is thought to have died out in Roman Britain, possibly as a result of invasion.[36] The existing organic residue data discussed above broadly support this hypothesis. However, would individual settlements and regions see a wholesale change from heavy emphasis on dairy products in the Iron Age to very little exploitation in the Roman period, as implied by the data from Silchester and Faverdale? Or did dairy products continue to be exploited on sites which transitioned from the Iron Age to the Roman period, as data suggest at Stanwick? Moreover, did different site types follow different consumption trajectories? As a proto-urban settlement, Silchester was qualitatively different from Copley's sites of Maiden Castle, Danebury Hilfort, Yarnton Cresswell Field and Stanwick. To address these questions, we examine patterns of meat and dairy-product exploitation through the Iron Age to Roman period transition across a broad range of site types in the Cirencester region. Small towns, rural settlements and villas were included, while overtly military and religious sites were excluded.

CIRENCESTER HINTERLAND

The Cirencester Hinterland is defined for this study as the region for which Cirencester can be considered the nearest major Roman city. It is a deliberately vague delineation, as the extent of the Dobunni tribal area is unknown,[37] as is the subsequent limit of the *civitas* for which *Corinium* (Cirencester) was the putative capital.[38] In the late, pre-Roman Iron Age, the centre of power was probably the oppidum at Bagendon,[39] which hosted elite, but also ritual,

30 e.g. Tyers 1996, 116; Alcock 2001.
31 Cramp *et al.* 2011.
32 Alcock 2001; Cool 2006.
33 Oswald 1944.
34 Cramp *et al.* 2011.
35 Cramp *et al.* 2012, 103–4.
36 e.g. Hesse 2011, on the basis of zooarchaeology.
37 McWhirr 1981.
38 Holbrook 2008.
39 Moore 2006, 76.

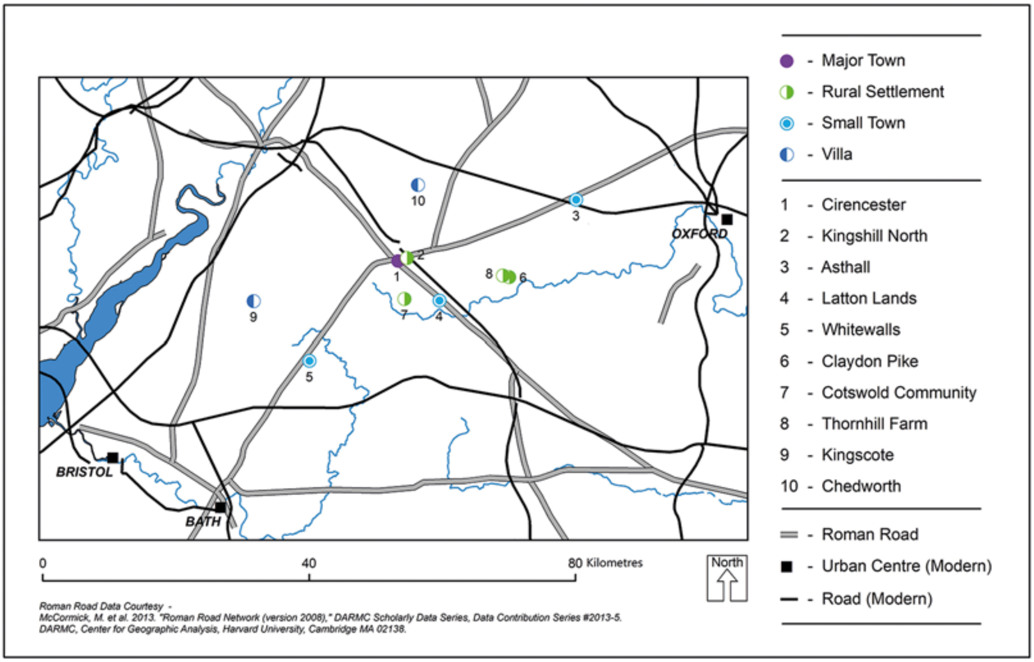

FIG. 1. Map showing the Cirencester Hinterland with major towns, Roman roads and the study sites indicated. (Roman road data courtesy of McCormick *et al.* 2013).

communal and industrial activities. Roman military occupation in the region lasted from around A.D. 50 to the late 70s and forts were established at both Cirencester and Gloucester.[40] Cirencester was founded around A.D. 60, and it is likely that it eventually replaced Bagendon as a centre of production and exchange,[41] though it has recently been shown that Cirencester and Bagendon were occupied concurrently in the first century A.D.[42] Cirencester probably became the capital of the *civitas Dobunorum* in the early second century A.D. and grew on a scale which outstripped other Romano-British urban centres.[43] At the end of the third century A.D., under the Diocletianic reforms, Cirencester probably became the capital of *Britannia Prima*[44] and in the third and fourth centuries A.D. the number of townhouses in Cirencester continued to grow, in contrast to other Romano-British cities.[45] Abundant urban occupation at Cirencester continued to the end of easily datable sequences in the early fifth century A.D. and possibly some decades beyond.[46]

The Cirencester Hinterland covers parts of both the Cotswolds and the Upper Thames Valley (FIG. 1). From the middle Iron Age onwards, both areas were reasonably densely

40 McWhirr 1981, 11.
41 Holbrook 2008, 301; Moore 2014, 29.
42 Moore 2020, 582–6.
43 Smith 2007a, 379.
44 White 2007; Smith 2007b, 392.
45 Faulkner 1998, 379–83.
46 Smith (2007b, 401) cautions against assuming that Cirencester ceased to function as a settlement or central place at the end of the fourth century, while White 2007 suggests that *Britannia Prima* survived in some form until the Anglo-Saxon conquest of the region in the sixth century, albeit in a changed form.

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settled,[47] with numbers of settlements increasing in the late Iron Age,[48] especially in the Upper Thames Valley. Despite the intensity of excavation in the Upper Thames Valley over the last twenty-five years[49] and relative paucity of excavation in the Cotswolds, it appears that there was a genuine difference in settlement patterns between the two regions in the late Iron Age and Roman periods.[50] In the most recent survey, an almost equal number of villas and farmsteads are recorded in the Cotswolds (40 and 49, respectively), while in the Thames and Avon Vales (grouped) there were 101 farmsteads and only 11 villas.[51]

The Conquest period is almost invisible in the archaeological record in this region, barring the establishment of major towns at Cirencester and Gloucester.[52] Even these had little immediate effect on the surrounding area: there was no flurry of newly established villas around first-century A.D. Cirencester as there was at St Albans.[53] A range of early roadside settlements was established in the Cotswolds in the mid-to-late first century A.D. and followed the layout of the major roads.[54] However, a major settlement dislocation occurred in the first quarter of the second century A.D. It was widespread in the Upper and Middle Thames Valley, affecting almost all sites across Gloucestershire and Oxfordshire.[55] New settlements such as Whitewalls[56] were established, while other settlements such as Thornhill Farm[57] were abandoned and overlaid with new enclosures and trackways that bore no relation to previous boundaries. Settlements which continued to be occupied often underwent profound change.[58] For instance, Claydon Pike morphed from a subsistence-level, mixed-agricultural site to one with a specialised focus on haymaking.[59] This dislocation seems to have happened very quickly, over the course of one generation at most. The Cotswolds seem to have been less severely affected, which some attribute to continuity of landholding by elites who allied with the Roman state, but which may reflect a lack of evidence from non-villa sites.[60] The reason for the dramatic reorganisation of the Cirencester hinterland is unknown: some suggest either that an external political or economic force must have been involved,[61] or that the motive may have been to break up any residual Iron Age structures.[62] It has been noted that early villas were little affected by the settlement change.[63]

Most of the roadside settlements in the Cotswolds and Upper Thames Valley date from the early second century.[64] Some were quite evenly spaced, such as Dorn, Chesterton and High Cross, all of which are *c.* 35 km apart on the Fosse Way, or Gloucester, Cirencester and Wanborough at *c.* 25–30 km along Ermine Street; scholars have been tempted to link the latter with the *cursus publicus* or at least some kind of official involvement.[65]

47 Moore 2006; Hey 2007.
48 Smith 2007a.
49 Allen and Lodwick 2017.
50 Smith 2007a.
51 Smith 2016, 146, table 5.2.
52 Henig and Booth 2000, 51; Holbrook 2006, 102; Smith 2007a.
53 Holbrook 2008, 318.
54 Timby 1998; Smith 2016, 165.
55 Henig and Booth 2000, 51; Holbrook 2006, 102; Smith 2007a, 377.
56 Also called Easton Grey: Wilmott and Shipp 2006.
57 Jennings *et al.* 2004.
58 Holbrook 2008, 319.
59 Miles *et al.* 2007.
60 Smith 2007a, 378; Holbrook 2008, 319.
61 Holbrook 2008, 318.
62 Hingley 1989, 105.
63 Henig and Booth 2000, 110.
64 Smith 2016, 166.
65 Timby 1998, 430–1; Smith 2007a, 390.

The third and fourth centuries saw most established sites continue to be occupied, with the number of villas increasing.[66] Roadside settlements in both regions were at their most prosperous in the fourth century.[67] New villas emerged, especially in the Cotswolds, such as Spoonley Wood, and other sites became villas, such as Frocester Court[68] and Claydon Pike.[69] There was some reorganisation of sites and landscapes in this period, but it was much less severe than in the second century and appears to have happened on a much more ad hoc basis, probably related to the creation of *Britannia Prima*.[70] At the very end of the Roman period, there is no sign of a dramatic decline in population or settlement occupation, as sometimes hypothesised,[71] and sites followed a range of trajectories. Some, like Watkins Farm, Whelford Bowmoor and Stubbs Farm, may have been abandoned due to environmental concerns, while others show little evidence for decline.[72] How long they persisted into the fifth century lies beyond the scope of the study in question.

METHODS

This study analysed pottery from ten sites in the Cirencester Hinterland. Sites were selected primarily on the basis of the ceramic assemblage. Assemblages needed to be substantial enough to provide at least twenty jar sherds from different vessels per period under investigation, to ensure statistical viability. The assemblage also needed to be accessible to the authors for destructive analysis. This meant that most small-scale, trial trench interventions were considered unsuitable. Where possible, sites with high-quality publications were selected, such as Claydon Pike, Cotswold Community and Thornhill Farm. However, the lack of accessible archives or recent publications of Roman villas and small towns in the region meant some smaller investigations were included to ensure full coverage, such as at Chedworth, Asthall and Whitewalls. The study aimed to characterise everyday civilian life, so military and overtly religious sites were excluded.

Ten sites in this region met all the necessary criteria to provide representation of four main site types (major towns, small towns, rural settlements and villas) spanning the period first century B.C.–A.D. fourth century. These four categories inevitably encompass a diverse range of settlements.[73] The sites sampled were Cirencester and its Iron Age precursor settlement at Kingshill North, 'small towns' at Asthall, Whitewalls and Latton Lands,[74] rural settlements at Claydon Pike, Thornhill Farm and Cotswold Community and two villa sites at Kingscote[75] and Chedworth. Vessel use across the whole of the Roman period can therefore be examined on an interconnected range of settlements and compared with late Iron Age practices.

66 Henig and Booth 2000, 106; Holbrook 2006, 108; Smith 2016, 160.
67 Timby, 1998, 139; Smith 2007b, 393.
68 Price 2000.
69 Miles *et al.* 2007.
70 Smith 2007b, 395; 2016, 148.
71 Faulkner 2000, 253–4.
72 Smith 2007b, 396.
73 e.g. Allen and Smith 2016 discuss the wide range of forms generally described as 'rural settlements'.
74 'Small town' is a catch-all category encompassing roadside settlements as well as more obviously 'urban' sites (Timby 1998, 3–5). All three 'small town' sites in this study lie on major Roman roads and were newly established at the beginning of the Roman period, distinguishing them from the 'rural settlement' category.
75 'Villa' is a somewhat contested term. Timby (1998, 290–3) describes Kingscote as a 'Roman estate centre' specialising in large-scale arable agriculture, including milling and malting of grain 'over and beyond the usual domestic requirements', and on this basis we include it as a 'villa', though it lacks the typical features of mosaics or hypocausts.

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As the study aimed to identify everyday dietary habits, it focused where possible on jars, which were the most commonly used cooking vessel in Roman Britain.[76] Other everyday forms were included in the sample groups where not enough individual jar sherds were present in the assemblage.[77] There is no reason to assume that the non-diagnostic coarseware cooking wares sampled are biased towards a different or unusual cooking practice that differs from jars. A mixture of black burnished wares and other ubiquitous coarsewares was selected, again to give an overview of everyday cooking and use habits. Rim sherds have been shown in experiments to contain the greatest concentration of lipid,[78] so these were preferentially selected. Care was taken to avoid adjoining sherds or those which may have originated from the same vessel. Sherds were selected from contexts dated in the published site narratives.[79]

A total of 571 sherds was selected from ten Iron Age and Romano-British sites in the Cirencester Hinterland for lipid extraction and analysis. The assemblage consisted of jars (n = 312) and, where too few jars could be positively identified in the assemblage, other forms (such as bowls) or coarseware fragments not identifiable to form (n = 259) were included. In most cases, such as at Kingshill North[80] and Thornhill Farm,[81] the majority of unidentified forms are likely to be jars, as these were the overwhelming majority of forms found on site. TABLE 1 summarises the number of sherds sampled on each site by period.

The analytical protocol is described in detail elsewhere.[82] In brief, the surface of a small area of each pottery sherd was removed using a modelling drill to remove any extraneous contamination. This portion was then removed using a solvent-washed chisel and hammer and crushed to a fine powder. Approximately 2 g was weighed into a culture tube and, after the addition of 20 µg *n*-tetratriacontane as a quantitative internal standard, lipids were simultaneously extracted and transesterified to fatty acid methyl esters using 5 mL of 2 per cent *v/v* H_2SO_4 (70 degrees Celsius, 1 h). Aliquots of the lipid extracts were derivatised using BSTFA containing 1 per cent TMCS (BSTFA, 70 degrees Celsius, 1 h) to derivatise any hydroxylated compounds to TMS ethers. Excess BSTFA was removed under N_2 and the extract dissolved in hexane. Extracts were screened and quantified using gas chromatography (GC) and characterised using GC/mass spectrometry (GC/MS) and GC-combustion-isotope ratio MS (GC/C/IRMS). Statistical analyses were performed using Graph Pad Prism 9.2.0.

RESULTS

Lipid recovery was generally very good, with assemblages from nearly all sites investigated having significant lipid contents in greater than 75 per cent of sherds. This ranged from 97 per cent of sherds from Kingscote through to 63 per cent of sherds from Asthall, although exceptionally poor preservation was observed at Kingshill North (7 per cent). The generally high overall rates of lipid recovery from investigated sherds are comparable with other cooking wares analysed from Iron Age and Roman Britain.[83]

The absolute lipid concentrations recorded in this study were very high. The mean lipid concentration for the entire assemblage of 571 sherds investigated from 10 sites was 2,154 $\mu g\ g^{-1}$. Within this, the individual site with the highest mean was Kingscote (3,342 $\mu g\ g^{-1}$), echoing the

76 Cool (2006, 39) reports that they are the most frequently sooted vessel form across the province.
77 A detailed description of sherds, their contextual information and associated organic residues can be found in the supplementary information.
78 Charters *et al.* 1993; Historic England 2017, 19.
79 See supplementary information for details on context of each sherd selected.
80 Biddulph 2011.
81 Timby 2004.
82 Correa-Ascencio and Evershed 2014.
83 Colonese *et al.* 2018; Cramp *et al.* 2011; 2012.

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TABLE 1. SHERDS BY PERIOD, SITE AND VESSEL TYPE

Site	Site Code	Site Type	Number of Sherds Analysed by Vessel Type															Total
			First century B.C.			**First century A.D.**			**Second century A.D.**			**Third century A.D.**			**Fourth century A.D.**			
			Jars	**Other**	**?**	**Jars**	**Other**	**?**	**Jars**	**Other**	**?**	**Jars**	**Other**	**?**	**Jars**	**Other**	**?**	
Cirencester	CIR	Major town				5	0	9	10	0	5	14	0	0	15	0	0	58
Kingshill North	KH	Iron Age site				0	0	16										**16**
Asthall	AS	Small town				0	0	19	9	2 bowls, 2 storage jars	7	16	3 storage jars	0	20	0	0	**78**
Latton Lands	LL	Iron Age site and Small town				3	0	10	19	0	0							**32**
Whitewalls	EG	Small town							0		0	17			4	2 bowls	32	**58**
Claydon Pike	CP	Rural settlement/ Villa	0	0	20	16	0	2	20	0	0	13	0	0	20	0	0	**91**
Cotswold Community	CC	Rural settlement	6	0	14	1	0	18	20	0	0	18	0	0	12	1 strainer	0	**90**
Thornhill Farm	TP	Rural settlement	0	0	20	0	0	40										**60**
Kingscote	KC	Villa							20	0	0	20	0	0	18	0	0	**58**
Chedworth	CW	Villa													10	11 bowls	9	**30**
Total			**60**			**139**			**131**			**84**			**157**			**571**

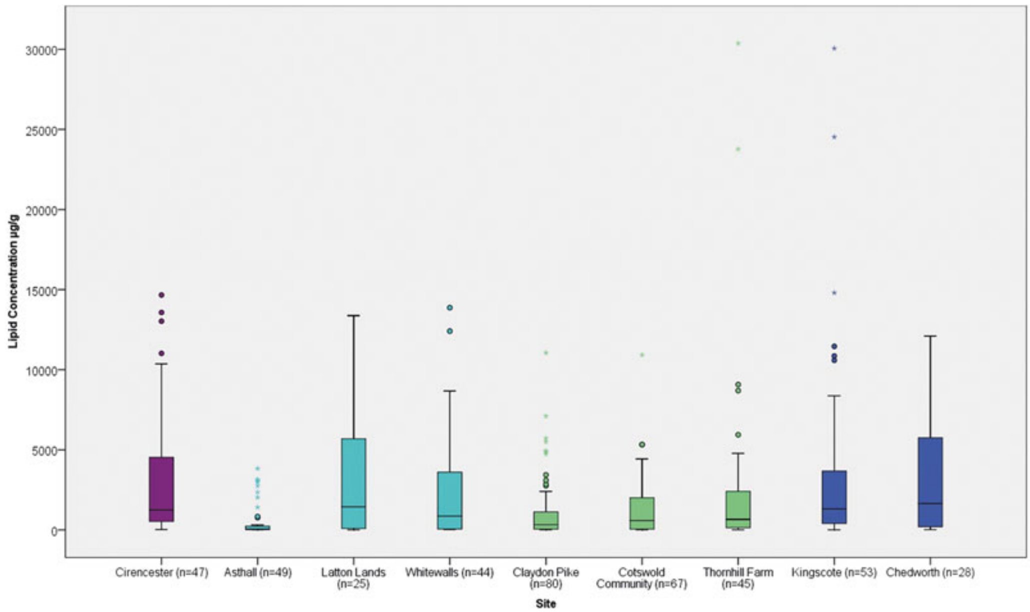

FIG. 2. Box-and-whisker plots showing lipid concentration data by site. Colour coding refers to site type: purple = major town; turquoise = small towns; green = rural settlement; blue = villa.

overall lipid recovery rates. Asthall had the lowest mean (524 µg g^{-1}), excluding Kingshill North, which only produced one sherd with a significant lipid content. Box-and-whisker plots describing the lipid concentration data by site are shown in FIG. 2.

The commodities detected in vessels from all sites were overwhelmingly degraded animal fats, determined by characteristically high proportions of $C_{16:0}$ and $C_{18:0}$ fatty acids (see FIG. 3).[84] This is not indicative that animal products were the sole contributor to diet on these sites: gramme for gramme, meat and milk are significantly fattier than plant products,[85] and biomarkers of staples such as grain have been shown to persist only in exceptional burial conditions.[86] However, given the absence of detected plant[87] or aquatic[88] biomarkers in the residues, it is likely that the recovered residues derived predominantly from terrestrial animal sources.

Lipid residues can be assigned an origin by comparing the measured $\delta^{13}C_{16:0}$ plotted against the $\delta^{13}C_{18:0}$ fatty acids compared with reference $\delta^{13}C$ values derived from modern fats with a known provenance.[89] Classification is based upon the metabolism of the animals and hence is not species-specific. Residues can be classified as predominantly ruminant adipose fats (meat/carcass fats from ruminant animals such as cattle and sheep); predominantly non-ruminant adipose fats (meat/carcass fats from non-ruminant animals such as pigs and chickens); predominantly dairy fats (milk fats from ruminant animals such as cattle and sheep), or a mixture of the above.[90] Additions from freshwater and marine fish can also be detected through

84 Pothoven *et al.* 1974; Deeth and Christie 1979.
85 Evershed 2008b, 34.
86 Hammann and Cramp 2018.
87 Such as wax esters and their degradation products: Evershed *et al.* 1991; Cramp *et al.* 2011; Dunne *et al.* 2016.
88 Such as long-chain ω-(*o*-alkylphenyl)alkanoic acids (APAAs) and isoprenoid fatty acids: Evershed *et al.* 2008b; Cramp *et al.* 2014a.
89 Reference fats used in this study are listed in the supplementary information.
90 Copley *et al.* 2003, 1526; Evershed *et al.* 2008b.

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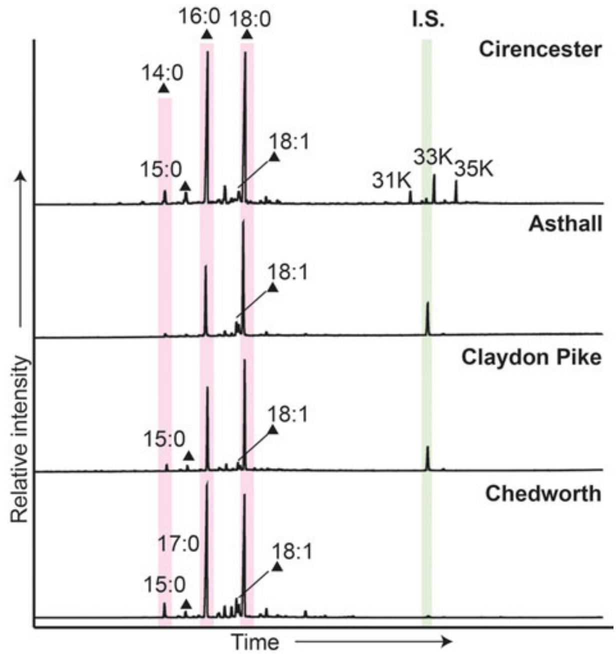

FIG. 3. Examples of high-temperature gas chromatograms from all four site types. Triangles with X:Y indicate fatty acids with X number of carbon atoms and Y number of double-bonds; XK indicates ketones with X carbon chain length. Sherd IDs are CIR 35, AS 37, CP 40, CW 01.

$\delta^{13}C$ values, though mixing with terrestrial fats can mask these signals.[91] Therefore, additional biomarkers are sought to confirm an aquatic origin. A total of 278 of residues underwent compound-specific stable carbon isotopic analysis to determine the ratios of ^{13}C:^{12}C in the $C_{16:0}$ and $C_{18:0}$ fatty acids ($\delta^{13}C$ values) in these residues. The majority of residues derived from ruminant adipose sources, but considerable amounts of non-ruminant adipose and milk fats were also identified. The results of these analyses are now discussed by site type. Unless otherwise stated, all percentages expressed below are out of the number of sherds subject to stable carbon isotopic analysis.

CIRENCESTER AND KINGSHILL NORTH

In the first century A.D., the settlement at Cirencester consisted of a fort and a substantial settlement. The forum was targeted for sampling in this period, so the data are likely to reflect civilian rather than military diet. All seven extracted residues from this phase were characterised as degraded animal fats; two residues were characterised as predominantly ruminant dairy fats. The one residue recovered from Kingshill North, the Iron Age precursor settlement, was also characterised as predominantly dairy fat. The remaining five residues from early Cirencester had $C_{16:0}$ and $C_{18:0}$ fatty acids with a range of $\delta^{13}C$ values that indicated mixing of ruminant and non-ruminant adipose fats. Two sherds from the vicus settlement had

[91] Cramp and Evershed 2015.

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$\delta^{13}C$ values consistent with a considerable non-ruminant adipose contribution to the residue.[92] Therefore, pigs and chickens (the main non-ruminant animals present on site) were clearly important additions to the diet in this phase, even in the civilian settlement.

The main street grid and forum basilica were laid out by the early second century and high-quality stone houses were built and occupied. Eleven residues from this period could be characterised: eight derived from a mixture of ruminant and non-ruminant adipose fats, four of which had $\delta^{13}C$ values indicative of a considerable contribution of non-ruminant fat to the residues. Fatty acids from one sherd had $\delta^{13}C$ values consistent with a purely non-ruminant product origin and, in the absence of aquatic biomarkers, it was judged that this residue probably derived from pig or chicken fat. Exploitation of pigs and chickens in this period seems to increase at the expense of dairy products, which were now absent, and possibly cattle and sheep meat products, though there is still plenty of evidence for exploitation of these species on site.

The third century at Cirencester saw little civic building besides the construction of a masonry town wall which was a common feature of third-century towns in Britain. All 12 residues which could be characterised derived from a mixture of ruminant and non-ruminant adipose fats. Two residues had $\delta^{13}C$ values from major fatty acids consistent with a purely non-ruminant source, probably derived from pigs and/or chickens. The remaining ten residues had $\delta^{13}C$ values consistent with mixture of ruminant and non-ruminant adipose products. This period sees a very slight decrease in importance of pigs and chickens on site, though they remained an essential contributor to the diet.

The population at Cirencester peaked in the mid-fourth century and a large civic building programme was undertaken in this period.[93] One residue, out of 13, had $\delta^{13}C$ values consistent with a non-ruminant adipose origin, and the remaining 12 had $\delta^{13}C$ values indicative of a mixture of ruminant and non-ruminant adipose fats. Pigs and chicken clearly remained very important contributors to diet in the fourth century.

The majority of characterised residues from Cirencester in all periods (shown in FIG. 4) have major fatty acid $\delta^{13}C$ values consistent with mixtures of ruminant and non-ruminant adipose products, while no aquatic biomarkers were detected in any residue. The data suggest considerable exploitation of cattle and sheep (ruminants) as well as pigs and chickens (non-ruminants) in all periods at Cirencester, but little to no exploitation of dairy products.

SMALL TOWNS

Three small towns were sampled. Asthall was occupied from the first to the fourth centuries A.D.[94] Whitewalls was occupied from the second/third century to the end of the fourth century A.D.[95] The Latton Lands site consisted of a late Iron Age settlement which was abandoned in the first century A.D. (see below) and a Roman period roadside settlement, occupied from the second century onwards.[96] Residues from the Cirencester hinterland small towns are shown in FIG. 5.

At Roman period Latton Lands, no residues were identified as being of predominantly dairy origin. Similarly at Asthall only two residues, from the first and third centuries, had a predominantly dairy-product origin (12 per cent, n = 2/17) while at Whitewalls, 27 per cent (n = 3/7) of residues from the second/third- and fourth-century sample groups derived from a predominantly dairy origin. The majority of fatty acids from residues from these sites had $\delta^{13}C$

[92] Non-ruminant contributions determined after Mukherjee *et al.* 2007.
[93] Faulkner 1998, 378–9, fig. 206.
[94] Booth 1997.
[95] Wilmott and Shipp 2006.
[96] Powell *et al.* 2009.

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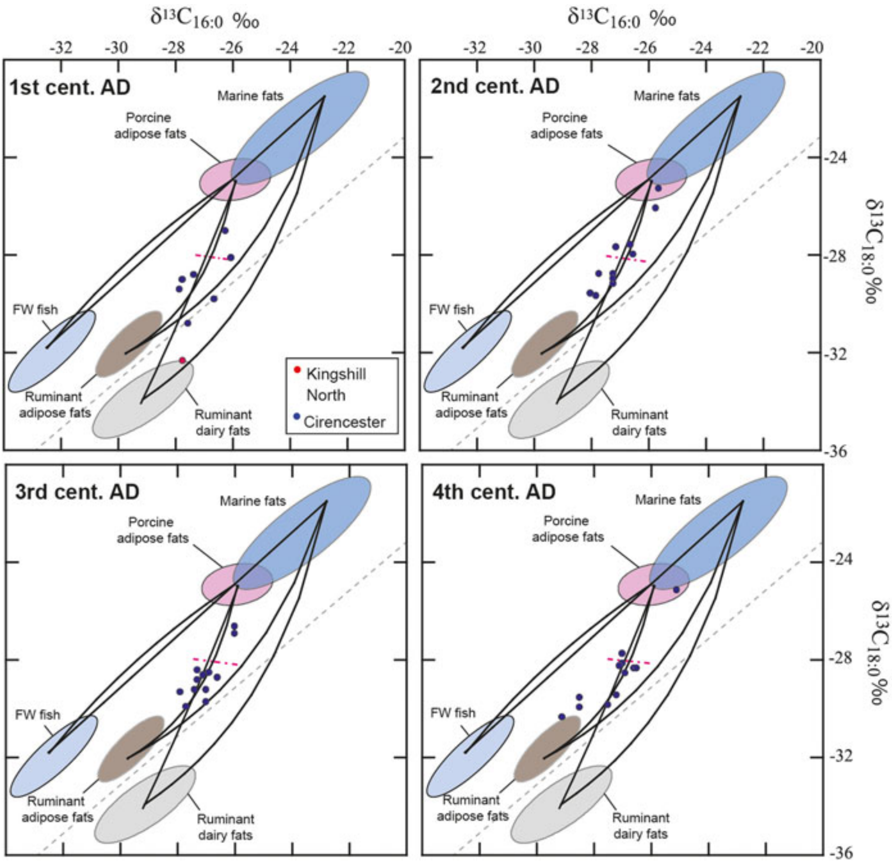

FIG. 4. Scatter plot showing $\delta^{13}C_{16:0}$ values plotted against $\delta^{13}C_{18:0}$ for sherds from Cirencester and Kingshill North, plotted by century. Ellipses are 1σ confidence ellipses derived from modern reference datasets (Cramp *et al.* 2019, 4, fig. 2) calculated from measured $\delta^{13}C$ values from modern UK terrestrial fats from animals raised on a C_3 diet (Copley *et al.* 2003), adjusted for addition of post-industrial effects of fossil-fuel burning through addition of 1.2‰ (Friedli *et al.* 1986). Solid mixing lines are calculated from the average $\delta^{13}C$ ranges of porcine adipose, ruminant adipose, ruminant dairy and freshwater and marine fish (values from Cramp *et al.* 2019). The black dashed line indicates the range below which residues are classified as predominantly dairy fats (Dudd and Evershed 1998). The pink dashed line indicates the range above which a residue is classified as >75 per cent non-ruminant origin (Mukherjee *et al.* 2007), although it should be noted that the non-ruminant threshold is derived solely from porcine reference fats.

values consistent with a purely, or mostly, ruminant adipose fat, indicating a heavy reliance on the meat from ruminant animals (cattle and sheep), with small indications of mixing with non-ruminant products (pigs and chickens) in all periods.

FIG. 5 plots $\delta^{13}C$ values from small towns from the second through to the later fourth centuries. They are broadly consistent, showing little diachronic change, until the later fourth century. The pottery from the putative later fourth-century A.D. *mansio* at Whitewalls produced residues with considerable contributions from non-ruminant products (n = 16), including two residues with $\delta^{13}C$ values from major fatty acids consistent with a considerable non-ruminant adipose contribution. No other residues from small towns had such abundant contributions from a non-ruminant adipose source.

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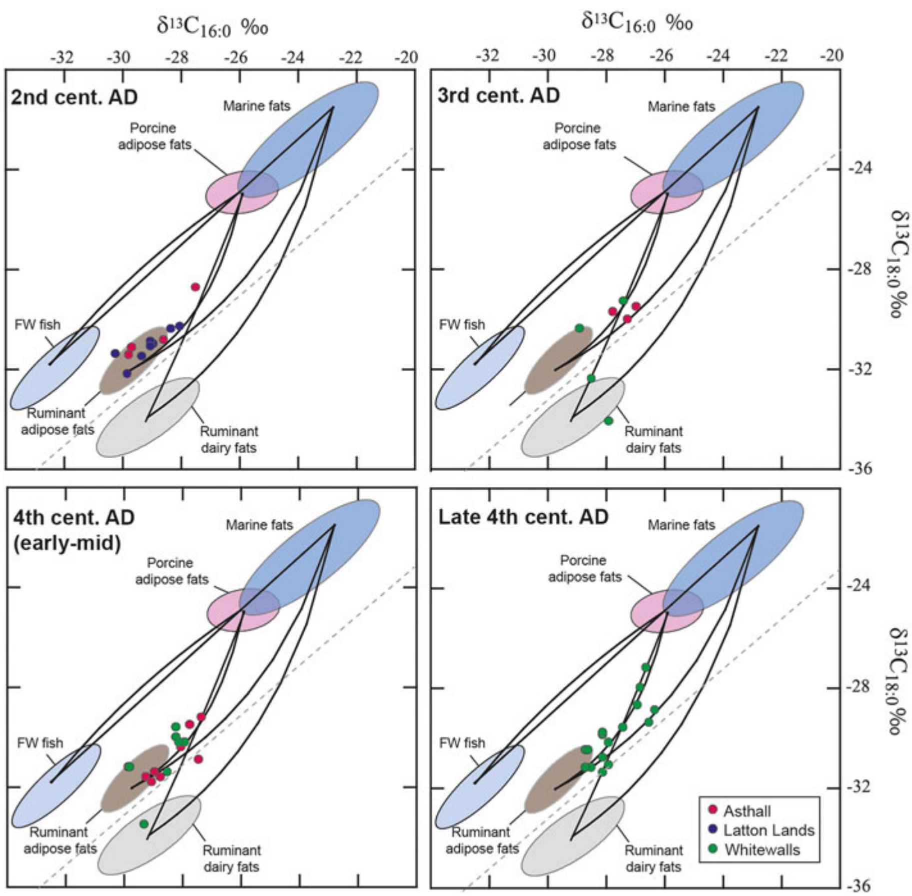

FIG. 5. Scatter plot showing $\delta^{13}C_{16:0}$ values plotted against $\delta^{13}C_{18:0}$ for sherds from the small towns of Asthall, Latton Lands and Whitewalls, plotted by phase. Reference ellipses as FIG. 4.

RURAL SETTLEMENTS

Four rural settlements were sampled, spanning the late Iron Age and the whole of the Roman period (see FIG. 6). These were the first-century A.D. Iron Age site at Latton Lands;[97] the late Iron Age settlement at Thornhill Farm, which was abandoned as part of the second-century landscape reforms;[98] and Claydon Pike and Cotswold Community, settlements originating in the Iron Age which continued to be farmed throughout the Roman period. Cotswold Community broadly avoided the sweeping second-century changes,[99] while Claydon Pike saw a complete reorganisation of the site, from a mixed agricultural regime to one focused on horticulture and hay production.[100]

97 Powell *et al.* 2009.
98 Jennings *et al.* 2004.
99 Powell *et al.* 2010.
100 Miles *et al.* 2007.

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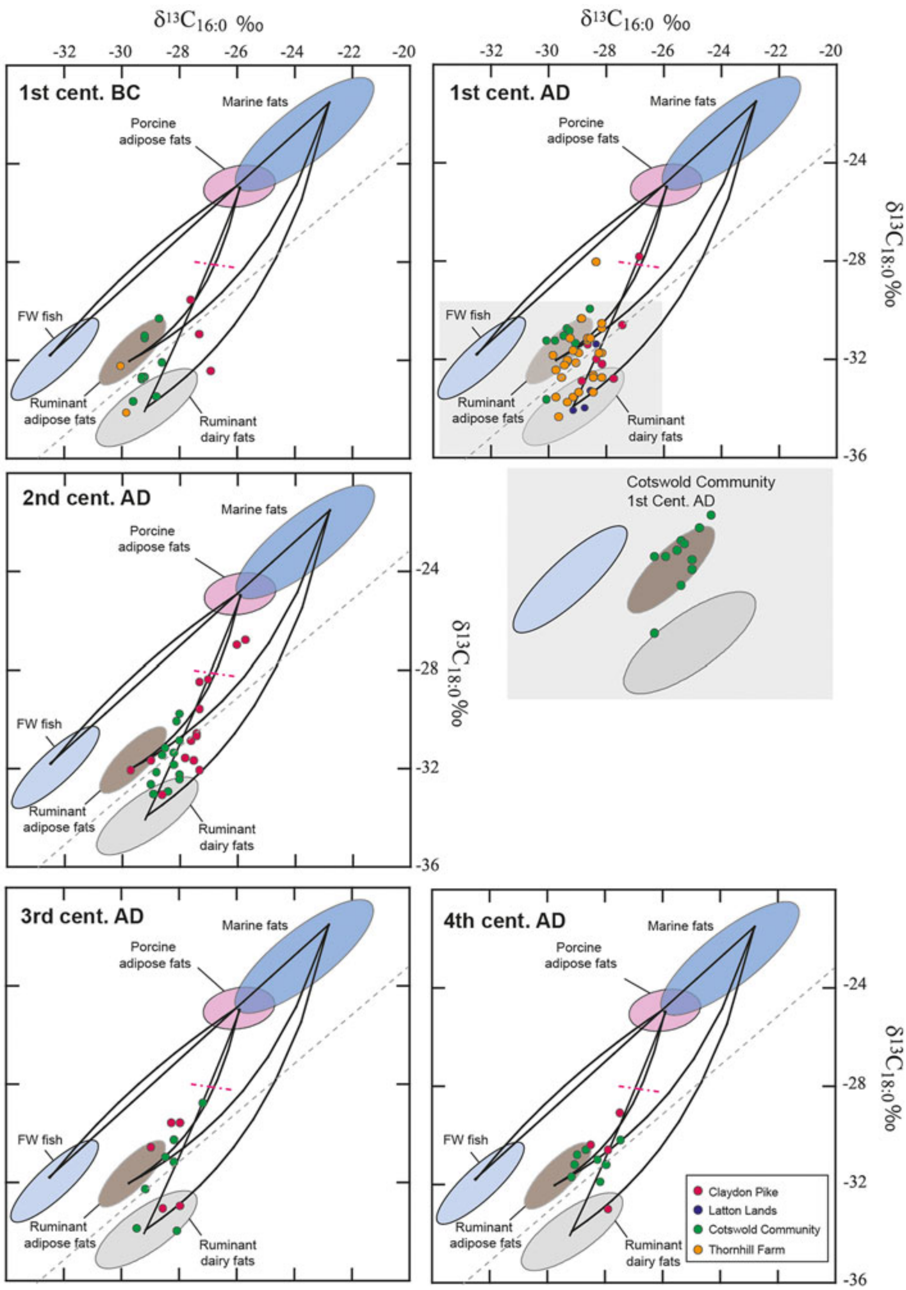

FIG. 6. Scatter plot showing $\delta^{13}C_{16:0}$ values plotted against $\delta^{13}C_{18:0}$ for sherds from the rural settlements of Claydon Pike, Latton lands, Cotswold Community and Thornhill Farm, plotted by century. Inset (shaded grey), the datapoints from second-century Cotswold Community are shown. Reference ellipses as FIG. 4.

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In the first century B.C., the emphasis at all sites was upon dairy products. At Thornhill Farm, 60 per cent (n = 6/10) of residues could be characterised as predominantly milk fat, while this figure was 67 per cent at Claydon Pike (n = 2/3) and at Cotswold Community (n = 6/9). There was little evidence for non-ruminant contributions to the residues on any site. This trend broadly continued for first-century A.D. residues. At Latton Lands, 100 per cent (n = 5) of residues had a predominantly dairy-product origin, in contrast to none at the second-century Roman small town on the same site, indicating a lack of continuity in site subsistence strategies at this location. At Thornhill Farm, dairy products, attested in 45 per cent (n = 9/20) of residues, remained central to the diet right up until the site's abandonment. At Claydon Pike, dairy products still contributed 67 per cent of the residues (n = 6/9), while one residue had a considerable input of fat of a non-ruminant origin. At Cotswold Community only 9 per cent (n = 1/11) of analysed residues were characterised as predominantly dairy fat.

In the second century, dairy products regained their importance at Cotswold Community, where 62 per cent (n = 8/13) of residues had a predominantly dairy-product origin. At Claydon Pike the residues indicate much greater evidence for mixing of non-ruminant products with ruminant adipose and dairy products, for 79 per cent (n = 11/14) of residues have $\delta^{13}C$ values indicative of some additions of non-ruminant adipose fat. This is likely to reflect the dramatic reorganisation of the site in the early second century.

In the third and fourth centuries, residues from both Claydon Pike and Cotswold Community suggest emphasis on meat and milk from ruminant animals and only small amounts of mixing with non-ruminant products. On both sites, 33 per cent (Claydon Pike n = 3/9; Cotswold Community n = 5/15) of residues had a predominantly dairy-product origin, while the remaining residues probably derived from ruminant carcass fats.

VILLAS

Two villa sites were sampled, Kingscote and Chedworth. Kingscote was occupied from the later first century onwards[101] and contexts were sampled dating from the second, third and fourth centuries. Although there was probably a villa on the Chedworth site from the second or third century,[102] only ceramics from the fourth century were accessible. The stable carbon isotope values of major fatty acids from organic residues from pottery from villa sites, including all periods from Kingscote and Chedworth, suggest that the majority of pot residues derived from consistent mixing of ruminant and small amounts of non-ruminant products (FIG. 7), and at Kingscote there was little diachronic change. Only two residues have $\delta^{13}C$ values indicative of a considerable contribution of non-ruminant fats, both from second-century Kingscote. There is some evidence for exploitation of dairy products, especially at Chedworth, where 27 per cent (n = 5/18) of residues had a predominantly dairy-product origin. At Kingscote, there was a small contribution from dairy products in all periods.

DISCUSSION

It is clear from the data presented above that residues from pots from Cirencester showed much greater contributions of non-ruminant adipose products than any other site in this study. As jars are strongly associated with cooking practices in Roman Britain,[103] it can be inferred that a

101 Timby 1998, 287.
102 Esmonde-Cleary 2013, 19.
103 Cool 2006; Marshall and Seeley 2018.

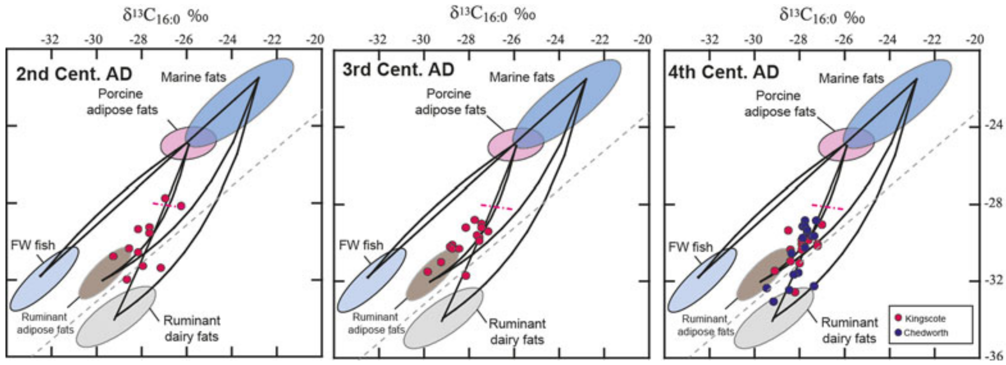

FIG. 7. Scatter plot showing $\delta^{13}C_{16:0}$ values plotted against $\delta^{13}C_{18:0}$ for sherds from the two villas of Kingscote and Chedworth, plotted by century. Reference ellipses as FIG. 4.

much greater quantity of non-ruminant meat was consumed at Cirencester than at any other site type. 'Non-ruminant animals' in the context of Roman Britain include all consumed animals that are not cattle, sheep, goats and deer. Therefore, non-ruminants of relevance to this study include pigs and wild boar,[104] chickens and other domestic or wildfowl,[105] and fish,[106], all of which were known to be eaten in Roman Britain, to a greater or lesser extent. However, zooarchaeological evidence from Cirencester paints a much narrower picture. Pigs contributed no more than 20 per cent of any animal bone assemblages at Cirencester. Chickens were much more frequently observed at Cirencester than other sites: four excavated areas within Cirencester provide the four highest counts of chicken on any site in the entire study area.[107] It is therefore not improbable that chicken fat contributed to the non-ruminant derived residues found here, although degraded porcine and chicken fats cannot be distinguished using organic residue analysis.[108] Few animal bones at Cirencester have been determined as originating from a wild animal, and of those (including specimens such as crow) very few exhibit butchery marks and few are thought to represent animals that were eaten.[109] There is little evidence for fish consumption at Cirencester, probably due to a lack of sieving programmes, but as no aquatic biomarkers were detected in the residues (despite performing highly sensitive screening for these biomarkers), we contend that fish was an infrequent contributor to the diet on this site, or were prepared in a way that did not use ceramic cooking pots.

A key finding of this study was the prevalence of milk fats in vessels from rural settlements, both farmsteads and the high-status villa at Chedworth. Milk fats were commonly detected in vessels from the late Iron Age from all sites analysed. This popularity continued through the first century A.D. at Claydon Pike and Thornhill Farm, but at Cotswold Community, reliance on milk products plummeted to less than 10 per cent. It is not clear why this change occurred; the continuity of settlement patterns argues against a population or wholesale cultural change caused by the Roman conquest. In the second century, dairy-product importance increased

[104] Cool 2006, though Maltby 2016 cautions that it may be mistaken for large domesticated pig in zooarchaeological records.
[105] Yalden and Albarella 2008.
[106] Locker 2007.
[107] Maltby 2017, fig. 7.
[108] Colonese *et al*. 2017 proposed a novel methodology for doing so, by creating site-specific standards based on animal bone assemblages. This was outside the scope of this study.
[109] Maltby 1998.

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again, to more than 60 per cent of residues. Notably, the second century saw an increase in the proportion of cattle on site at the expense of sheep, indicating new animal-management strategies.[110] Therefore the reappearance of dairy products in pottery residues should not be regarded as reflecting reversion to an Iron Age pattern, but rather as forming part of a broader development of new subsistence strategies.

Conversely, at the same time, second-century Claydon Pike saw much greater evidence for mixing of non-ruminant products with ruminant adipose and dairy products: the vast majority of residues have $\delta^{13}C$ values indicative of some additions of non-ruminant adipose fat. This rapid change in diet coincided with dramatic material culture change on site in the use patterns of glassware, pottery and dress accessories.[111] It is possible, then, that the changes in diet were part of the adoption of a 'wider cultural package'.[112] Interestingly, the faunal remains from this period show fewer pig remains compared to previous periods, but increased evidence for fishing, fowling and hunting, and domestic fowl was also seen on site.[113] It is probable, therefore, that the non-ruminant products recorded at Claydon Pike originated from a range of different animals, not merely pigs and chickens. Milk products remained important at both sites, being the predominant component of a third of the residues in the third and fourth centuries, despite zooarchaeological interpretations to the contrary.[114] Despite its high status, fourth-century Chedworth exhibited a very similar pattern, whereby milk fats were the predominant contributors to 27 per cent of the residues.

In contrast to the rural settlements, dairy products were relatively rarely identified in small towns, with only 13 per cent of analysed residues being characterised as having a predominantly dairy-product origin. Dairy products were identified only in the first century A.D. in one vessel from the vicus settlement at Cirencester and one vessel from the late Iron Age first-century A.D. site at Kingshill North.

The organic residue data clearly show that diet at the major urban centre of Cirencester was different to other site types throughout the Roman period (FIG. 8). However, it does not appear totally alien to the surrounding sites, and instead can be thought of as one end of a spectrum of different dietary practices (FIG. 9). At the other end of this spectrum lie rural sites, which show very little evidence for consumption of non-ruminant animal products on a regular basis, instead relying heavily on ruminant products, both meat and milk. Villas and small towns fall roughly between, with pot residues revealing less emphasis on dairy products than is observed at rural sites, but showing significantly less evidence for non-ruminant products too. Meanwhile, dairying continued to be practised at rural sites down to the end of the Roman period, including on the villa site at Chedworth.

Undoubtedly, some of this difference will have been driven by cultural factors, such as consumer desire in cities and possible rejection of new foods at rural sites. It is also extremely likely that the foods reflected in the residues will have been subject to different cooking practices, different methods of preparation, and accompanied by different ingredients on different sites; many of these developments will have been driven by cultural ideas about taste and economic factors such as access to a wider market economy. However, we contend that the main driver towards the differences seen between Cirencester and its hinterland was the increasing need to extensify food production: that is, to produce more food for the same labour input,[115] through the introduction of new animal subsistence strategies on urban and rural sites.

110 Strid 2010, 217.
111 Cool 2006, 134.
112 Cool 2006, 134.
113 Sykes 2007, 151.
114 e.g. Hesse 2011.
115 Allen and Lodwick 2017.

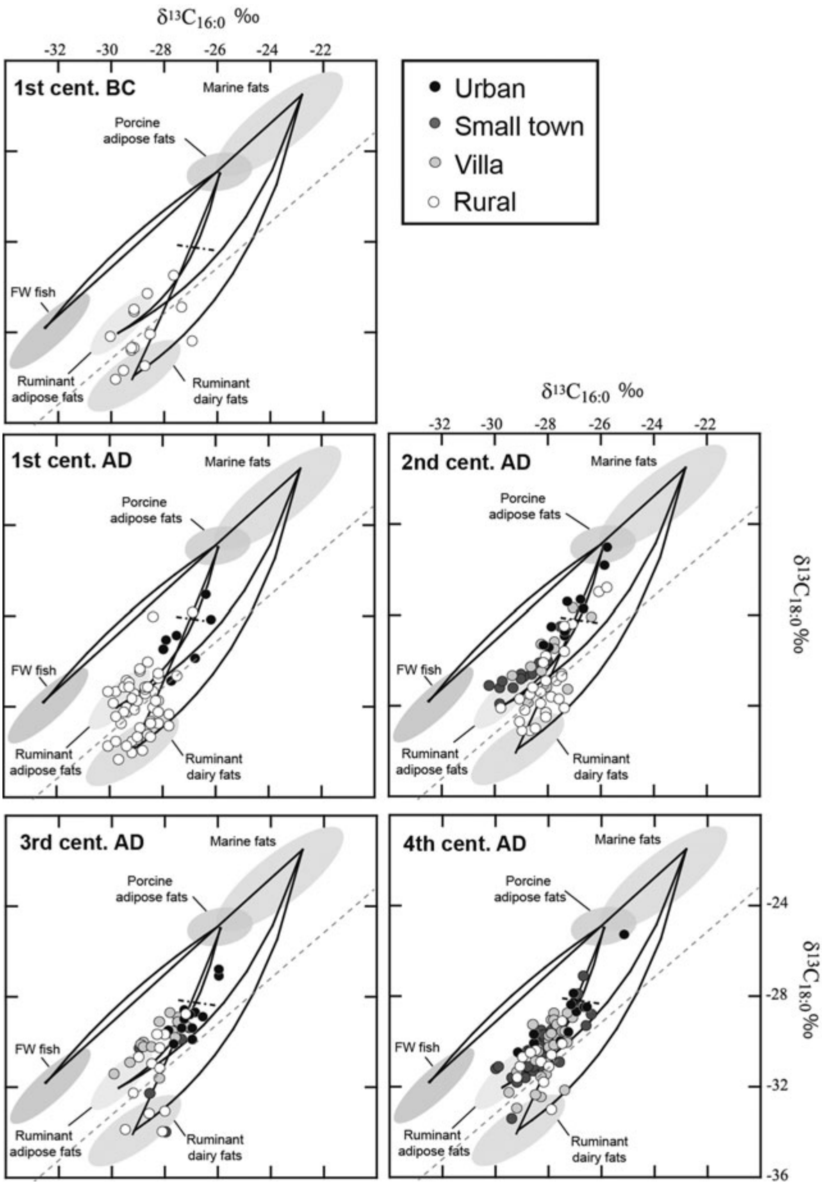

FIG. 8. Scatter plot showing $\delta^{13}C_{16:0}$ values plotted against $\delta^{13}C_{18:0}$ for sherds from all sites, plotted by century. Reference ellipses as FIG. 4.

NEW ANIMAL SUBSISTENCE STRATEGIES

TOWNS

Across Britain, cattle and sheep are usually thought to have been raised outside urban settlements, often in the site's hinterland, and brought to the city for slaughter and consumption or market

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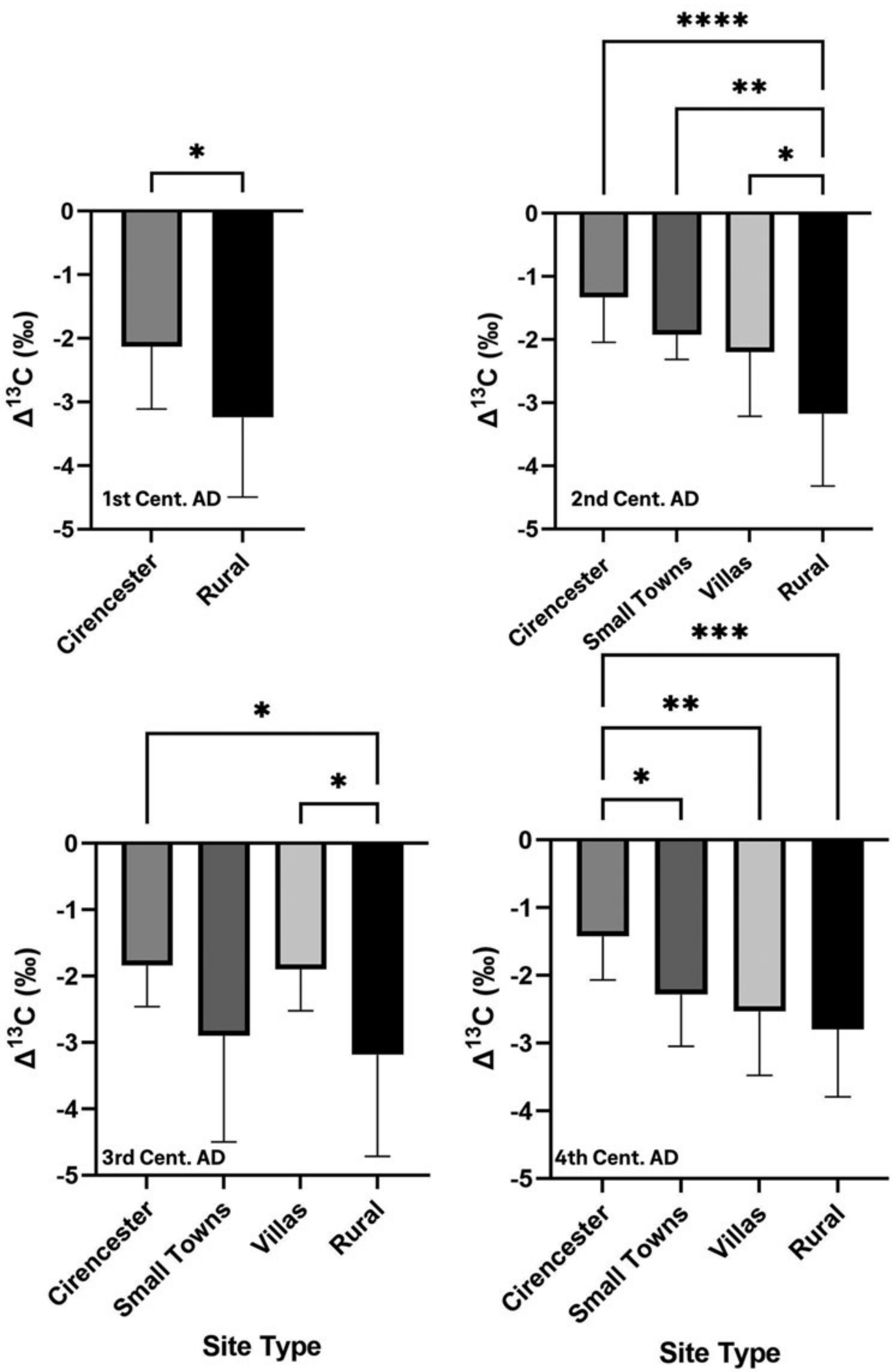

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redistribution. The butchery practices used in cities and by the Roman army are clearly distinguishable from those used elsewhere,[116] and it has been suggested that the brutality of these practices implies that animals were being processed by people other than those who raised them.[117] Strontium isotope ratios, which provide direct evidence for the non-local origin of individual animals, show that cattle recovered from Owslebury, Hampshire, could have come from the local area in the middle Iron Age, but that by the late Iron Age and early Roman periods the site was part of a wider exchange network or market.[118] In the Roman period some cattle came to the site from at least 70 km away. Similarly, at Caerleon, Wales, strontium isotope ratios indicate that while the majority of animals could have come from the local area, others must have originated further afield.[119]

Pigs rarely make a large contribution to faunal assemblages from rural sites in the Cirencester hinterland, especially in the Upper Thames Valley. There was a slight increase in percentage quantities of pigs on later Roman sites than earlier but the overall contribution remained small.[120] Chickens are thought rarely to have been raised on rural settlements; they contributed only 1.8 per cent of the combined sheep- and chicken-bone counts on these sites.[121] There was relatively little woodland cover in the Cirencester hinterland at this time, around 10–15 per cent,[122] which is thought to have been mostly hedges and similar plantations. This is not particularly suited to traditional pannage-type husbandry. It is harder to suggest an environmental cause for the lack of chickens on rural sites, as chickens tend to thrive in farmstead-like settings.[123] It is possible that this was a deliberate rejection on the part of rural Romano-Britons, who perhaps viewed the recently introduced birds as unusual or exotic animals, associated with ritual and funerary events, rather than a mundane food source.[124] Another possibility for low uptake could have been a lack of knowledge about how to husband poultry successfully:[125] the majority of people probably only encountered them on infrequent trips to major cities, or during ritual activities.

We consider the emphasis on pig and chicken products at Cirencester to be an example of urban extensification. At this location, both pig and chicken bones had relatively enriched $\delta^{13}C$ and $\delta^{15}N$ isotope values compared with cattle and sheep.[126] This is consistent with these animals being fed a

FIG. 9. (opposite). Statistical analysis comparing $\Delta^{13}C$ values of residues from all sites by century. Error bars represent 1σ confidence. $\Delta^{13}C$ is calculated by $\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$. $\Delta^{13}C$ therefore provides a measure of difference between the $\delta^{13}C$ values, allowing direct comparison between different sites (Copley *et al.* 2003). The first-century A.D. plot compares $\Delta^{13}C$ (‰) of major fatty acids from sherds from Cirencester and rural sites (two-tailed t-test, $* = P < 0.05$). The second-century A.D. plot compares $\Delta^{13}C$ (‰) of fatty acids from Cirencester, Small Towns, Villas and rural sites (One-way ANOVA with Tukey adjustment for multiple comparisons, $* = P < 0.05$, $** = P < 0.01$, $**** = P < 0.0001$). The third-century plot compares $\Delta^{13}C$ (‰) of fatty acids from Cirencester, Small Towns, Villas and rural sites (One-way ANOVA with Tukey adjustment for multiple comparisons, $* = P < 0.05$). The fourth-century plot compares $\Delta^{13}C$ (‰) of fatty acids from Cirencester, Small Towns, Villas and rural sites (One-way ANOVA with Tukey adjustment for multiple comparisons, $* = P < 0.05$, $** = P < 0.01$, $*** = P < 0.001$).

116 Maltby 2007.
117 Allen 2018.
118 Minniti *et al.* 2014.
119 Madgwick *et al.* 2019.
120 Booth *et al.* 2007, 295.
121 Maltby *et al.* 2018.
122 Rippon *et al.* 2015.
123 Sykes 2012.
124 Chickens were introduced to Britain in the late Iron Age: Cool 2006; Sykes 2012; Maltby *et al.* 2018.
125 Yalden and Albarella 2008 report little evidence for poultry keeping in the Iron Age.
126 Cummings 2009.

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mixture of animal and vegetable protein, possibly indicating a 'kitchen scraps'-type diet. Significant numbers of neonatal pig bones have been found on a range of urban sites such as Silchester,[127] and pig slurry has been identified at Leicester.[128] Pigs and chickens can therefore be considered 'recycling' animals: they convert human-inedible foodstuffs to human-edible foodstuffs (i.e. themselves), grow relatively quickly and can be raised in a relatively small space. It is likely that, where possible, people living in major towns produced their own meat supply by raising pigs and chickens on site. This was heavily supplemented by cattle and sheep brought in from the settlement hinterland. Towns were therefore by no means self-sustaining, but resourceful townspeople produced their own food where possible. We propose that this is the first evidence of urban extensification of food production in Roman Britain.

RURAL SETTLEMENTS

Milk products are generally thought rarely to have been exploited in Roman Britain,[129] in stark contrast to the Iron Age. This view is usually extrapolated from a lack of neonatal cattle bones, which would indicate infant slaughter often associated with dairying practices,[130] and by the increasing trend towards male cattle in Romano-British herds. It has often been argued that the emphasis on larger, male cattle in the Roman period was the result of their being used predominantly for traction.[131] Writing specifically on the Cirencester hinterland, Hesse declared that the zooarchaeology provides no evidence for significant dairying practices.[132] However, milk fats were found to be predominant in 46 per cent of residues from Roman period vessels from Claydon Pike and Cotswold Community, two of the same sites as Hesse's zooarchaeological evidence. Zooarchaeological evidence from both sites gives little indication that either cattle or sheep were exploited solely for milk, even in the Iron Age.[133] Indeed, there is no reason both species could not have been exploited in parallel, as ethnographic data show was common in twentieth-century rural Greece.[134] How, then, can the increasing emphasis on male cattle be explained?

The continued exploitation of dairy products on rural settlements should not be seen as the unproblematic continuation of Iron Age practices. The shift from milk to meat to milk seen in first-century B.C.–A.D. second-century Cotswold Community strongly indicates that the trend is more complex than a simple tradition handed down between generations. Moreover, exploitation of dairy products cannot be taken as the rejection of 'Roman' foodways in favour of 'British' foodways (whatever these might be), as dairy products were heavily utilised at the high-status villa at Chedworth and at Claydon Pike, where many high-status 'Roman' small finds and structures were recorded. Instead, we see the exploitation of dairy products as another example of extensification in the face of the new pressures caused by integration into the Roman economy.

It has been hypothesised that cattle in the Iron Age may have had a very similar status to those in modern agro-pastoral societies, where livestock are central to many forms of social exchange.[135] Early Medieval Ireland provides such a parallel. Most small settlements could not consume a whole bovine carcass before it began to spoil, so killing a cow became an event with

127 Ingrem 2012.
128 Maltby 2015, 184.
129 e.g. Hesse 2011; Allen 2018 problematises this view.
130 See McCormick 1992 for a problematisation of this pattern.
131 Hesse 2011.
132 Hesse 2011, 241.
133 Sykes 2007, 54–5; Strid 2010, 211.
134 Halstead 2017.
135 Allen 2018, 88.

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significance, often at community gatherings.[136] Dairy herding, on the other hand, could produce milk and milk derivatives such as cheese and butter at household-level efficiency. From the second century onwards, however, having enough people at a settlement to consume the animal was no longer a problem, due to the new existence of centralised markets with professional butchers to buy the cattle.[137] Moreover, dairying is very labour intensive compared to meat farming, and so a less practical way of producing the surplus required to feed the growing population of Britain. Therefore, we suggest that rural sites trended away from dairying practices as their main focus and, as a result, dairy products were rarely exported to towns. However, dairying continued to be practised on an ad hoc basis, probably around weaning time, as a way of supplying extra food to the inhabitants of the rural settlements themselves. In this way, rural inhabitants of the Cirencester hinterland extensified their animal husbandry practices.

CONCLUSION

The study aimed, through characterising the origins of organic residues surviving in the fabric of everyday cooking pots, to investigate the changing consumption and subsistence practices within the Cirencester hinterland, taking account of a range of site types, from major towns to small towns, rural farmsteads and villas and examining a broad chronological span from the late Iron Age to the end of the Roman period.

It demonstrates that although diet at Cirencester was different from other sites, it was on one end of a spectrum of possible diets, with rural settlements representing the other end. However, this was not a simple producer–consumer relationship: instead, Cirencester's occupants consumed both ruminant animals (cattle and sheep) raised in the surrounding settlements and non-ruminant animals (pigs and chickens) probably raised within the city itself. Dairy products were never widely consumed at Cirencester and only rarely contributed to diet in small towns.

However, at rural sites, including the villa at Chedworth, dairy products remained important through the end of the fourth century. Dairying was practised less frequently in the later centuries at rural sites, however, which we have interpreted as a move away from a mainly dairying economy in the late Iron Age to one in which dairying was undertaken as it suited the broader agricultural cycle.

The economic pressure to feed the non-food-producing population and produce a surplus for taxation led to extensification (producing more food by cultivating more land with less labour input) of both arable and pastoral farming. In Cirencester itself, people used pigs and chickens as a way of 'recycling' their food scraps and supplementing their diet. On rural sites, people trended away from the labour-intensive practice of dairying, focusing instead on mostly meat production, probably while using cattle for traction to plough heavier soils for arable farming. Dairy products remained important contributors to the rural diet, however, probably on a seasonal basis.[138]

This study has been the first regional exploration of Roman Britain using organic residue analysis. It has been able to highlight relationships between different site types not visible from other evidence. The success of this approach in elucidating evidence of the past otherwise invisible from other remains demonstrates the value of this technique to the wider study of Roman Britain, as well as economies of other periods and geographies.

136 McCormick 2002.
137 Maltby 2015.
138 Hesse 2011; Allen 2017; 2018.

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SUPPLEMENTARY MATERIAL

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BIBLIOGRAPHY

Alcock, J.P. 2001: *Food in Roman Britain*, Stroud.

Allen, M. 2017: 'Pastoral farming', in M. Allen, L. Lodwick, T. Brindle, M. Fulford and A. Smith (eds), *New Visions of the Countryside of Roman Britain Volume 2: The Rural Economy of Roman Britain*, London, 85–141.

Allen, M. 2018: 'The social context of animals and exploitation of wild resources', in A. Smith, M. Allen, T. Brindle, M. Fulford, L. Lodwick and A. Rohnbogner (eds), *New Visions of the Countryside of Roman Britain Volume 3: Life and Death in the Countryside of Roman Britain*, London, 78–119.

Allen, M., and Lodwick, L. 2017: 'Agricultural strategies in Roman Britain', in M. Allen, L. Lodwick, T. Brindle, M. Fulford and A. Smith (eds), *New Visions of the Countryside of Roman Britain Volume 2: The Rural Economy of Roman Britain*, London, 142–77.

Allen, M., and Smith, A. 2016: 'Rural settlement in Roman Britain: morphological classification and overview', in A. Smith, M. Allen, T. Brindle and M. Fulford (eds), *New Visions of the Countryside of Roman Britain: Volume 1: The Rural Settlement of Roman Britain*, London, 17–43.

Biddulph, E. 2011: 'Late Iron Age and Roman pottery', in E. Biddulph and K. Welsh (eds), *Cirencester before Corinium: Excavations at Kingshill North, Cirencester, Gloucestershire*, Oxford, 51–9.

Booth, P. 1997: *Asthall, Oxfordshire: Excavations in a Roman 'Small Town', 1992*, Oxford.

Booth, P., Dodd, A., Robinson, M., and Smith, A. 2007: *The Thames Through Time: The Archaeology of the Gravel Terraces of the Upper and Middle Thames: The Early Historical Period, AD* 1–1000, Oxford.

Brindle, T. 2017: 'Ards or ploughs', in M. Allen, L. Lodwick, T. Brindle, M. Fulford and A. Smith (eds), *New Visions of the Countryside of Roman Britain Volume 2: The Rural Economy of Roman Britain*, London, 42–4.

Charters, S., Evershed, R.P., Goad, L.J., Leyden, A., Blinkhorn, P.W., and Denham, V. 1993: 'Quantification and distribution of lipid in archaeological ceramics: implications for sampling potsherds for organic residue analysis and the classification of vessel use', *Archaeometry* 35.2, 211–23.

Charters, S., Evershed, R.P., Blinkhorn, P.W., and Denham, V. 1995: 'Evidence for the mixing of fats and waxes in archaeological ceramics', *Archaeometry* 37.1, 113–27.

Colonese, A.C., Lucquin, A., Guedes, E.P., Thomas, R., Best, J., Fothergill, B.T., Sykes, N., Foster, A., Miller, H., Poole, K., Maltby, M., Von Tersch, M., & Craig, O.E. 2017: 'The identification of poultry processing in archaeological ceramic vessels using in-situ isotope references for organic residue analysis', *Journal of Archaeological Science* 78, 179–92.

Colonese, A.C., Lucquin, A., Timby, J., and Craig, O.E. 2018: 'Organic residue analysis of ceramic vessels', in M. Fulford, A. Clarke, E. Durham and N. Pankhurst (eds), *Late Iron Age Calleva: The Pre-Conquest Occupation At Silchester Insula IX. Silchester Roman Town: The Insula IX Town Life Project: Volume 3*, London, 221–7.

Cool, H.E.M. 2006: *Eating and Drinking in Roman Britain*, Cambridge.

Copley, M.S., Berstan, R., Dudd, S.N., Docherty, G., Mukherjee, A.J., Straker, V., Payne, S., and Evershed, R.P. 2003: 'Direct chemical evidence for widespread dairying in prehistoric Britain', *Proceedings of the National Academy of Sciences* 100.4, 1524–9.

Copley, M.S., Berstan, R., Dudd, S.N., Straker, V., Payne, S., and Evershed, R.P. 2005: 'Dairying in antiquity. I. Evidence from absorbed lipid residues dating to the British Iron Age', *Journal of Archaeological Science* 32.4, 485–503.

Corbier, M. 1991: 'City, territory and taxation', in J. Rich and A. Wallace-Hadrill (eds), *City and Country in the Ancient World*, London, 211–39.

Correa-Ascencio, M., and Evershed, R.P. 2014: 'High throughput screening of organic residues in archaeological potsherds using direct acidified methanol extraction', *Analytical Methods* 6.5, 1330–40.

Craig, O.E., Forster, M., Andersen, S.H., Koch, E., Crombé, P., Milner, N.J., Stern, B., Bailey, G.N., and Heron, C.P. 2007: 'Molecular and isotopic demonstration of the processing of aquatic products in Northern European prehistoric pottery', *Archaeometry* 49.1, 135–52.

Craig, O.E., Steele, V.J., Fischer, A., Hartz, S., Andersen, S.H., Donohoe, P., Glykou, A., Saul, H., Jones, D.M., Koch, E., and Heron, C.P. 2011: 'Ancient lipids reveal continuity in culinary practices across the transition to agriculture in northern Europe', *Proceedings of the National Academy of Sciences* 108.44, 17910–15.

Cramp, L.J.E., Ethier, J., Urem-Kotsou, D., Bonsall, C., Borić, D., Boroneanţ, A., Evershed, R.P., Perić, S., Roffet-Salque, M., Whelton, H.L., and Ivanova, M. 2019: 'Regional diversity in subsistence among early farmers in Southeast Europe revealed by archaeological organic residues', *Proceedings of the Royal Society B: Biological Sciences* 286.1894, 20182347.

Cramp, L.J.E., and Evershed, R.P. 2014: 'Reconstructing aquatic resource exploitation in human prehistory using lipid biomarkers and stable isotopes', in H.D. Holland and K.K. Turekian (eds), *Treatise on Geochemistry 14*, Oxford, 319–39.

Cramp, L.J.E., and Evershed, R.P. 2015: 'Reading the residues: the use of chromatographic and mass spectrometric techniques for reconstructing the role of kitchen and other domestic vessels in Roman Antiquity', in M. Spataro and A Villing (eds), *Ceramics, Cuisine and Culture: The Archaeology and Science of Kitchen Pottery in the Ancient Mediterranean World*, Oxford, 125–40.

Cramp, L.J.E., Evershed, R.P., and Eckardt, H. 2011: 'What was a mortarium used for? Organic residues and cultural change in Iron Age and Roman Britain', *Antiquity* 85, 1339–52.

Cramp, L.J.E., Evershed, R.P., and Eckardt, H. 2012: 'Are you what you grind? A comparison of organic residues from ceramics at two Romano-British Sites', in I. Schrüfer-Kolb (ed.), *More Than Just Numbers?: The Role of Science in Roman Archaeology*, JRA supplementary series 91, Portsmouth, RI, 93–110.

Cramp, L.J.E., Jones, J., Sheridan, A., Smyth, J., Whelton, H., Mulville, J., Sharples, N., and Evershed, R.P. 2014a: 'Immediate replacement of fishing with dairying by the earliest farmers of the Northeast Atlantic archipelagos', *Proceedings of the Royal Society B: Biological Sciences* 281.1780, 20132372.

Cramp, L.J.E., Evershed, R.P., Lavento, M., Halinen, P., Mannermaa, K., Oinonen, M., Kettunen, J., Perola, M., Onkamo, P., and Heyd, V. 2014b: 'Neolithic dairy farming at the extreme of agriculture in northern Europe', *Proceedings of the Royal Society B: Biological Sciences* 281.1791, 20140819.

Cummings, C. 2009: 'Meat consumption in Roman Britain: the evidence from stable isotopes', in M. Driessen, S. Heeren, J. Hendriks, F. Kemmers and R. Visser (eds), *TRAC 2008: Proceedings of the Eighteenth Annual Theoretical Roman Archaeology Conference, Amsterdam 2008*, Oxford, 73–83.

Deeth, H.C., and Christie, W.W. 1979: 'Biosynthesis of triacylglycerols in ovine adipose tissue in vitro', *International Journal of Biochemistry* 10.7, 577–82.

Dudd, S.N., and Evershed, R.P. 1998: 'Direct demonstration of milk as an element of archaeological economies', *Science* 282.5393, 1478–81.

Dunne, J., Evershed, R.P., Salque, M., Cramp, L.J.E., Bruni, S., Ryan, K., Biagetti, S., and di Lernia, S. 2012: 'First dairying in green Saharan Africa in the fifth millennium BC', *Nature* 486.7403, 390–4.

Dunne, J., Mercuri, A.M., Evershed, R.P., Bruni, S., and di Lernia, S. 2016: 'Earliest direct evidence of plant processing in prehistoric Saharan pottery', *Nature Plants* 3, 16194.

Esmonde Cleary, S. 2013: *Chedworth: Life in a Roman Villa*. Stroud.

Evershed, R.P. 2008a: 'Organic residue analysis in archaeology: the archaeological biomarker revolution', *Archaeometry* 50.6, 895–924.

Evershed, R.P. 2008b: 'Experimental approaches to the interpretation of absorbed organic residues in archaeological ceramics', *World Archaeology* 40.1, 26–47.

Evershed, R.P., Payne, S., Sherratt, A.G., Copley, M.S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A.E., Nieuwenhuyse, O., Akkermans, P.M.M.G., Bailey, D., Andeescu, R.-R., Campbell, S., Farid, S., Hodder, I., Yalman, N., Özbaşaran, M., Bıçakcı, E., Garfinkel, Y., Levy, T., and Burton, M.M. 2008a: 'Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding', *Nature* 455.7212, 528–31.

Evershed, R.P., Copley, M.S., Dickson, L., and Hansel, F.A. 2008b: 'Experimental evidence for the processing of marine animal products and other commodities containing polyunsaturated fatty acids in pottery vessels', *Archaeometry* 50. 1, 101–13.

Evershed, R.P., Heron, C., and Goad, L.J. 1991: 'Epicuticular wax components preserved in potsherds as chemical indicators of leafy vegetables in ancient diets', *Antiquity* 65, 540–4.

Evershed, R.P., Vaughan, S.J., Dudd, S.N., and Soles, J.S., 1997: 'Fuel for thought? Beeswax in lamps and conical cups from late Minoan Crete', *Antiquity* 71, 979–85.

Faulkner, N. 1998: 'Urban stratigraphy and Roman history', in N. Holbrook (ed.), *Cirencester: The Roman Town Defences, Public Buildings and Shops*, Cirencester Excavations 5, Cirencester, 371–88.

Faulkner, N. 2000: *The Decline and Fall of Roman Britain*, Stroud.

Friedli, H., Lötscher, H., Oeschger, H., Siegenthaler, U., and Stauffer, B. 1986: 'Ice core record of the $^{13}C/^{12}C$ ratio of atmospheric CO_2 in the past two centuries', *Nature* 324.6094, 237–8.

Fulford, M., and Allen, M. 2017: 'Introduction: population and the dynamics of change in Roman South-Eastern England', in D.G. Bird (ed.), *Agriculture and Industry in South-Eastern Roman Britain*, Oxford, 1–14.

Halstead, P. 2017: 'Calf mortality and milking: was Tony Legge right after all?' in P. Rowley-Conwy, D. Sergeantson and P. Halstead (eds), *Economic Zooarchaeology: Studies in Hunting, Herding and Early Agriculture*, Oxford, 119–25.

Hammann, S., and Cramp, L.J.E. 2018: 'Towards the detection of dietary cereal processing through absorbed lipid biomarkers in archaeological pottery', *Journal of Archaeological Science* 93, 74–81.

Henig, M., and Booth, P. 2000: *Roman Oxfordshire*, Stroud.

Hesse, R. 2011: 'Reconsidering animal husbandry and diet in the Northwest Provinces', *Journal of Roman Archaeology* 24, 215–48.

Hey, G. 2007: 'Unravelling the Iron Age landscape of the upper Thames Valley', in C. Haselgrove and T. Moore (eds), *The Late Iron Age in Britain and Beyond*, Oxford, 156–72.

Hingley, R. 1989: *Rural Settlement in Roman Britain*, London.

Hingley, R. 1982: 'Roman Britain: the structure of Roman imperialism and the consequences of imperialism on the development of a peripheral province', in D. Miles (ed.), *The Romano-British Countryside: Studies in Rural Settlement and Economy*, Oxford, 17–52.

Historic England 2017: *Organic Residue Analysis and Archaeology: Guidance for Good Practice*, London.

Holbrook, N. 2006: 'The Roman period', in N. Holbrook and A.R.J. Juřica (eds), *Twenty-Five Years of Archaeology in Gloucestershire: A Review of New Discoveries and New Thinking in Gloucestershire, South Gloucestershire and Bristol 1979–2004*, Cirencester, 97–132.

Holbrook, N. 2008: 'Cirencester and the Cotswolds: the early Roman evolution of a town and rural landscape', *Journal of Roman Archaeology* 21, 304–23.

Ingrem, C. 2012: 'Animals in the economy and culture of Roman Britain: a case study from southern England', in M. Fulford, *Silchester and the Study of Romano-British Urbanism*, JRA supplementary series 90, Portsmouth, RI, 184–212.

Jennings, D., Muir, J., Palmer, S., and Smith, A. 2004: *Thornhill Farm, Fairford, Gloucestershire: An Iron Age and Roman Pastoral Site in the Upper Thames Valley*, Oxford.

Kimpe, K., Jacobs, P.A., and Waelkens, M. 2002: 'Mass spectrometric methods prove the use of beeswax and ruminant fat in late Roman cooking pots', *Journal of Chromatography A* 968.1, 151–60.

Livarda, A., and Orengo, H.A. 2015: 'Reconstructing the Roman London flavourscape: new insights into the exotic food plant trade using network and spatial analyses', *Journal of Archaeological Science* 55, 244–52.

Locker, A. 2007: 'In piscibus diversis; the bone evidence for fish consumption in Roman Britain', *Britannia* 38, 141–80.

Lodwick, L. 2017: 'Arable farming, plant foods and resources', in M. Allen, L. Lodwick, T. Brindle, M. Fulford and A. Smith (eds), *New Visions of the Countryside of Roman Britain Volume 2: The Rural Economy of Roman Britain*, London, 11–84.

Madgwick, R., Lewis, J., Grimes, V., and Guest, P. 2019: 'On the hoof: exploring the supply of animals to the Roman legionary fortress at Caerleon using strontium (87Sr/86Sr) isotope analysis', *Archaeological and Anthropological Sciences* 11, 223–35.

Maltby, M. 1998: 'Animal bones from Romano-British deposits in Cirencester', in N. Holbrook (ed.), *Cirencester: The Roman Town Defences, Public Buildings and Shops*, Cirencester Excavations 5, Cirencester, 252–370.

Maltby, M. 2007: 'Chop and change: specialist cattle carcass processing in Roman Britain', in R. Croxford, N. Ray and R. Roth (eds), *TRAC 2006: Proceedings of the 16th Annual Theoretical Roman Archaeology Conference*, Oxford, 59–76.

Maltby, M. 2015: 'Commercial archaeology, zooarchaeology and the study of Romano-British towns', in M. Fulford and N. Holbrook (eds), *The Towns of Roman Britain: The Contribution of Commercial Archaeology Since 1990*, Britannia monograph 27, London, 175–93.

Maltby, M. 2016: 'The exploitation of animals in Roman Britain', in M. Millett, L. Revell and A.J. Moore (eds), *The Oxford Handbook of Roman Britain*, Oxford, 791–806.

Maltby, M. 2017: 'The exploitation of animals and their contribution to urban food supply in Roman Southern England', in D.G. Bird (ed.), *Agriculture and Industry in South-Eastern Roman Britain*, Oxford, 180–209.

Maltby, M., Allen, M., Best, J., Fothergill, B.T., and Demarchi, B. 2018: 'Counting Roman chickens: multidisciplinary approaches to human–chicken interactions in Roman Britain', *Journal of Archaeological Science: Reports* 19, 1003–15.

Marshall, M., and Seeley, F. 2018: 'From the spreadsheet to the table? Using "spot-dating" level pottery records from Roman London to explore functional trends among open vessel forms', *Internet Archaeology* 50. DOI: 10.11141/ia.50.9

McCormick, F. 1992: 'Early faunal evidence for dairying', *Oxford Journal of Archaeology* 11.2, 201–10.

McCormick, F. 2002: 'The distribution of meat in a hierarchical society: the Irish evidence', in P. Miracle and N. Milner, *Consuming Passions and Patterns of Consumption*, Cambridge, 25–31.

McCormick, M., Huang, G., Zambotti, G., and Lavash J., 2013: 'Roman Road Network (version 2008)', *DARMC Scholarly Data Series 2013–5*, Harvard University, https://darmc.harvard.edu/data-availability (accessed March 2023).

McWhirr, A. 1981: *Roman Gloucestershire*, Gloucester.

Miles, D., Palmer, S., Smith, A., and Jones, G.P., 2007: *Iron Age and Roman Settlement in the Upper Thames Valley: Excavations at Claydon Pike and Other Sites within the Cotswold Water Park*, Oxford.

Miller, M.J., Whelton, H.L., Swift, J.A., Maline, S., Hammann, S., Cramp, L.J.E. and McCleary, A., 2020: 'Interpreting ancient food practices: stable isotope and molecular analyses of visible and absorbed residues from a year-long cooking experiment', *Scientific Reports* 10.1, 13704.

Millett, M. 1990: *The Romanization of Britain: An Essay in Archaeological Interpretation*, Cambridge.

Minniti, C., Valenzuela-Lamas, S., Evans, J., and Albarella, U. 2014: 'Widening the market. strontium isotope analysis on cattle teeth from Owslebury (Hampshire, UK) highlights changes in livestock supply between the Iron Age and the Roman period', *Journal of Archaeological Science* 42, 305–14.

Moore, T. 2006: 'The Iron Age'. in N. Holbrook and A.R.J. Juřica (eds), *Twenty-Five Years of Archaeology in Gloucestershire: A Review of New Discoveries and New Thinking in Gloucestershire, South Gloucestershire and Bristol 1979–2004*, Cirencester, 61–96.
Moore, T. 2014: 'The birth of a capital? Bagendon "oppidum" and the impact of Rome on the southern Cotswolds', in D. Breeze, *The Impact of Rome on the British Countryside. A Conference Organised by the Royal Archaeological Institute, Chester, 11–13 October 2013*, London, 26–30.
Moore, T. 2020: 'The Bagendon complex: a biography' in T. Moore (ed.), *A Biography of Power: Research and Excavations at the Iron Age Oppidum of Bagendon, Gloucestershire (1979–2017)*, Oxford, 541–90.
Mukherjee, A.J., Berstan, R., Copley, M.S., Gibson, A.M., and Evershed, R.P. 2007: 'Compound-specific stable carbon isotopic detection of pig product processing in British Late Neolithic pottery', *Antiquity* 81, 743–4.
Oswald, F. 1944: 'The mortaria of Margidunum and their development from A.D. 50 to 400'. *Antiquaries Journal* 24.1–2, 45–63.
Perring, D., and Pitts, M. 2013: *Alien Cities: Consumption and the Origins of Urbanism in Roman Britain*, London.
Pothoven, M.A., Beitz, D.C., and Zimmerli, A. 1974: 'Fatty acid compositions of bovine adipose tissue and of in vitro lipogenesis', *Journal of Nutrition* 104.4, 430–3.
Powell, K., Laws, G., and Brown, L. 2009: 'A later Neolithic/early Bronze Age enclosure and Iron Age and Romano-British settlement at Latton Lands, Wiltshire', *Wiltshire Archaeological and Natural History Magazine* 102, 22–113.
Powell, K., Smith, A., Laws, G., Allen, L., and Wachnik, M. 2010: *Evolution of a Farming Community in the Upper Thames Valley: Excavation of a Prehistoric, Roman and Post-Roman Landscape at Cotswold Community, Gloucestershire and Wiltshire*, Oxford.
Price, E. 2000: *Frocester: A Romano-British Settlement, Its Antecedents and Successors: Volume 1, The Sites*, Stonehouse.
Regert, M., Vacher, S., Moulherat, C., and Decavallas, O. 2003: 'Adhesive production and pottery function during the Iron Age at the site of Grand Aunay (Sarthe, France)', *Archaeometry* 45.1, 101–20.
Rippon, S., Smart, C., and Pears, B. 2015: *The Fields of Britannia: Continuity and Change in the Late Roman and Early Medieval Landscape*, Oxford.
Roffet-Salque, M., Dunne, J., Altoft, D.T., Casanova, E., Cramp, L.J.E., Smyth, J., Whelton, H.L., and Evershed, R.P. 2017: 'From the inside out: upscaling organic residue analyses of archaeological ceramics', *Journal of Archaeological Science: Reports* 16, 627–40.
Smith, A. 2007a: 'The late Iron Age and Roman landscape', in D. Miles, S. Palmer, A. Smith and G.P. Jones (eds), *Iron Age and Roman Settlement in the Upper Thames Valley: Excavations at Claydon Pike and Other Sites within the Cotswold Water Park*, Oxford, 373–90.
Smith, A. 2007b: 'The late Roman landscape', in D. Miles, S. Palmer, A. Smith and G.P. Jones (eds), *Iron Age and Roman Settlement in the Upper Thames Valley: Excavations at Claydon Pike and Other Sites within the Cotswold Water Park*, Oxford, 391–403.
Smith, A. 2016: 'The central belt', in A. Smith, M. Allen, T. Brindle, and M. Fulford (eds), *New Visions of the Countryside of Roman Britain: Volume 1: The Rural Settlement of Roman Britain*, London, 141–207.
Stallibrass, S. 2009: 'The way to a Roman soldier's heart: a post-medieval model for cattle droving in the Hadrian's Wall region', in M. Driessen, S. Heeren, J. Hendriks, F. Kemmers, and R. Visser (eds), *TRAC 2008: Proceedings of the Eighteenth Annual Theoretical Roman Archaeology Conference, Amsterdam 2008*, Oxford, 101–12.
Strid, L. 2010: 'Animal bone', in K. Powell, A. Smith and G. Laws (eds), *Evolution of a Farming Community in the Upper Thames Valley: Excavation of a Prehistoric, Roman and Post-Roman Landscape at Cotswold Community, Gloucestershire and Wiltshire. Volume 2: The Finds and Environmental Reports*, Oxford, 207–37.
Sykes, N. 2007: 'Animal bone', in D. Miles, S. Palmer, A. Smith and G.P. Jones (eds), *Iron Age and Roman Settlement in the Upper Thames Valley: Excavations at Claydon Pike and Other Sites within the Cotswold Water Park*, Oxford, 53–5, 84–5, 151–3, 203–4.
Sykes, N. 2012: 'A social perspective on the introduction of exotic animals: the case of the chicken', *World Archaeology* 44.1, 158–69.
Timby, J. (ed.) 1998: *Excavations at Kingscote and Wycomb, Gloucestershire*, Cirencester.

Timby, J. 2004: 'The pottery', in D. Jennings, J. Muir, S. Palmer and A. Smith (eds), *Thornhill Farm, Fairford, Gloucestershire: An Iron Age and Roman Pastoral Site in the Upper Thames Valley*, Oxford, 90–108.

Tyers, P. 1996: *Roman Pottery in Britain*, London.

Van der Veen, M. 2007: 'Food as an instrument of social change: feasting in Iron Age and early Roman southern Britain', in K.C. Twiss (ed.), *The Archaeology of Food and Identity*, Carbondale, IL: 112–29.

Whelton, H.L., Hamman, S., Cramp, L.J.E., Dunne, J., Roffet-Salque, M., and Evershed, R.P. 2021: 'A call for caution in the analysis of lipids and other small biomolecules from archaeological contexts', *Journal of Archaeological Science* 132, 105397.

White, R. 2007: *Britannia Prima: The Romans in the West of Britain*, Stroud.

Wilmott, T., and Shipp, D. 2006: 'The Romano-British roadside settlement of Whitewalls, Easton Grey, Wiltshire: recent fieldwork', *Wiltshire Archaeological and Natural History Magazine* 99, 165–89.

Yalden, D., and Albarella, U. 2008: *The History of British Birds*, Oxford.