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TITLE

‘Carcasses, ceramics and cooking at Makriyalos I: towards an integrated approach to human diet and commensality in Late Neolithic northern Greece’

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Abstract

Taking the Neolithic of northern Greece, and particularly the Late Neolithic flat-extended site of Makriyalos I, as a case study, we explore the challenges and potential of using multiple evidential categories and diagnostic tools to investigate human diet and commensality. This requires integration of datasets from several specialized sub-disciplines with contrasting methodological strengths and weaknesses and offering distinctive and selective proxies for past foodways. With due attention to such differences, ostensibly contradictory datasets may shed complementary light on Neolithic diet and commensality.

Here we evaluate the principal available dietary proxies for the Neolithic of northern Greece, situate Makriyalos I in its regional settlement context, and then discuss in turn likely subsistence patterns, commensal practices, and the role therein of the consumption of domestic animals. We argue that animals were of secondary nutritional importance in a largely grain-based diet, but central to occasional commensality transcending the small (household?) groups that shared daily meals. In exploring commensality, we attempt to integrate results of macroscopic, microscopic and isotopic studies of animal bones/teeth, human skeletal remains, and ceramic *cooking pots and tableware. While these different datasets are in some respects mutually consistent, apparent discrepancies between* $\delta^{13}C$ *values in cattle remains and those in human bone and ceramic lipid residues reveal otherwise undetected variability in commensal practices. The complexity of commensal practices, and thus social relations, at Makriyalos I is becoming increasingly evident from ongoing analyses of various datasets and especially from attempts to integrate their complementary insights.*

Keywords

commensality, diet, Late Neolithic, faunal, ceramic, human, $\delta^{13}C$, $\delta^{15}N$

Introduction

While it is now generally accepted that food and drink are, and probably always were, of social/cultural as well as nutritional/biological importance to humans, both aspects are multidimensional and difficult to investigate archaeologically. On the one hand, the biologically essential components of a balanced diet are typically derived from several different food sources of very variable archaeological visibility, while meaningful assessment of nutritional quality demands consideration of variation between individual consumers and also between years and seasons of plenty and scarcity (Dennell 1979). On the other hand, food as a social and symbolic resource may serve to unite or divide people at various scales (from close kin to members of the same tribe or fellow citizens), in various contexts (from daily meals to exceptional feasts), and in various ways (e.g. unusual quantities of food; distinctive ingredients or cooking styles; uniform or diacritical modes of consumption) (e.g. Dietler and Hayden 2001; Sherratt 1991).

Given the complexity of this subject, archaeologists draw on multiple categories of surviving evidence and multiple diagnostic tools and so are required to straddle several sub-disciplines with contrasting methodological strengths and weaknesses and offering distinctive proxies for past human foodways. Taking a multi-proxy case study from the Neolithic of northern Greece, we explore the potential to gain richer understanding of past foodways by integrating different sub-disciplines. A first step to this end, addressed in the following section, is to recognize the contrasting formation processes of the different categories of archaeological material available for this case study, the contrasting diagnostic potential of the different analytical tools that these demand, and thus the distinctive and selective nature of each proxy dataset.

Foodways in the Neolithic of northern Greece: available proxies

Discussion of foodways in Neolithic northern Greece has hitherto drawn primarily on three relatively abundant categories of archaeological material: the remains of plant and animal species that were transformed into food or drink; the skeletal remains of human consumers; and the strikingly rich repertoire of ceramic vessels in which food and drink were stored, prepared and especially consumed. We briefly review the strengths and limitations of each of these categories of material as a source of proxies for past foodways. For the sake of brevity and because what follows is an attempt at an integrative synthesis of published evidence from the Neolithic of northern Greece, we largely draw on studies conducted for this period and in this region, without systematic reference to the broader methodological literature on which these studies have to varying degrees built.

The ‘macroscopic’ remains of edible plants (usually charred) and bones/teeth and shells of animals offer the most direct proxies for the types of food and drink consumed in Neolithic northern Greece. Of course, plant remains include both those intended as food (e.g. cereal or pulse grains) and those discarded in preparing the latter for consumption (e.g. cereal chaff; accompanying weed seeds), while bone and shell assemblages include both by-products of (preparation for) consumption (parts discarded before or after cooking) and remains of other activities (e.g. skinning or burial of vertebrates thought unfit to eat; collection of shells for working). In large measure, however, macroscopic analysis of anatomical representation (seeds vs chaff – Valamoti 2005; meat-poor vs meat-rich skeletal parts – Tzevelekidi et al. 2014) and processing traces (butchery or burning marks and fragmentation patterns in bones and shells – Halstead 2007; Veropoulidou 2014) differentiates what was intended for consumption from what was not.

A strength of these macroscopic proxies is that routine analysis can identify dietary ingredients to taxon and, in the case of some animal remains, to sex and/or age (and thus, if timing of birth is known, perhaps season of death). Moreover, macroscopic traces of animal butchery and microscopic traces of plant pounding or grinding and heating (Valamoti et al. 2008) may reveal details of how food was prepared for consumption, while macroscopic (crop weeds; animal mortality, pathology, speed of dental macrowear – e.g. Tzevelekidi 2012, 96-113), microscopic (e.g. animal dental microwear – Mainland and Halstead 2005) and isotopic evidence (e.g. $\delta^{13}C$ and $\delta^{15}N$ values for both crops and domestic animals – Styring et al. 2015) may reveal aspects of the life history of edible plants and animals. A second strength of these proxies is that they may, under favourable depositional and post-depositional conditions, reveal associations of particular ingredients, preparation methods or even prior life histories at an intra-site level, for example with contexts representing collective versus domestic scales of commensality (e.g. Tzevelekidi et al. 2014). In principle, therefore, macroscopic plant and animal remains are amenable to multiple analytical techniques that, in combination, can shed contextualized light on food procurement, processing and consumption.

A weakness of these macroscopic proxies is that they may provide a very selective record of foodstuffs consumed. Thus, charred plant remains are heavily dominated by foods dried for storage (notably cereal and pulse grains), while those eaten fresh in season tend to be under-represented in the absence of waterlogged preservation (e.g. Valamoti 2009, 28). Equally, traces of butchery, burning or breakage on bones and shells may directly betray exploitation of meat and marrow, but the principal macroscopic proxy for dairy products is indirect – mortality patterns revealing whether male domestic ruminants were slaughtered young enough to enhance *potential* availability of milk to humans (Halstead 1998). Moreover, even the macroscopic remnants and by-products of grain and meat/marrow consumption are vulnerable to variable post-depositional survival and recovery during excavation and, although the effects of such processes are broadly predictable and so somewhat controllable, survival may – inconveniently – differ between consumption contexts. For example, scavenging dogs might largely destroy the few bones from a domestic meal, but have little impact on occasional large-scale feasting debris, which also might be buried deliberately (and so protected from scavenging, trampling and weathering) because of its volume or the importance of the occasion. On the direct evidence of macroscopic remains, therefore, given such variable and often severe losses, meaningful *absolute* quantification of foods is normally impossible and, while relative abundance may be estimated approximately for different cereal, large vertebrate or shellfish taxa, this cannot be attempted between such broad categories.

Human skeletal remains offer the most direct proxy for the overall balance and quality of dietary inputs. Stable isotope ratios in human bone offer some (relative rather than absolute) measure of animal protein ($\delta^{15}N$) and seafood ($\delta^{13}C$) intake over several years (Papathanasiou 2015; Papathanasiou et al. 2013; Triantaphyllou 2001), although the former does not distinguish between carcass and dairy products and is also influenced by consumption of pulses (negatively) and manured cereals (positively) and by the relative quality and frequency of plant and animal protein intake (van Klinken et al. 2000; Robbins et al. 2010), while the latter may also reflect consumption of C_4 plants (although these do not include *crops* until after the Neolithic in northern Greece – Valamoti 2016). Dental microwear of teeth sheds light on dietary texture over a shorter timespan before death (as also in the case of domestic animals), but even this proxy probably averages food intake in a range of different consumption contexts. While isotopic and microwear analyses thus offer only coarse information on dietary components (Pappa et al. 2013, 83-84), macroscopic data (stature, dental health, pathological conditions) provide the best available measure of dietary impact on human health (e.g. Triantaphyllou 2001). Perhaps the greatest strength of human skeletal remains is that macroscopic, microscopic and isotopic analyses alike can be directly related (in sharp contrast with macroscopic food remains) to the age, biological sex and perhaps cultural identity of individual consumers. On the other hand, human skeletal remains are only as representative as the burial record, which in the Neolithic of northern Greece is fairly sparse and may exhibit age- and/or gender-related selectivity (Triantaphyllou 2008).

Macroscopic analysis of *ceramics* may identify the size, shape and decoration of vessels used for at least some storage, cooking and serving/consumption of foodstuffs, and thus shed light on the scale, form and formality of consumption events (e.g. Urem-Kotsou 2002; Urem-Kotsou and Kotsakis 2007). Particularly in the case of cooking vessels, the analysis of vessel shape, size and fabric combined with that of use wares traces (Urem-Kotsou this volume; Urem-Kotsou et al. 2002; Saridaki et al. 2014; Lymperaki et al. 2016) offers valuable clues to forms of heating (e.g. direct or indirect contact with fire) and culinary methods (e.g. baking or boiling/stewing), but more precise information on contents is sometimes available from chemical analysis of food residues absorbed into the ceramic fabric. Among the latter, lipids attributable to ruminant and non-ruminant adipose fat and to ruminant milk products confirm heating of meat, fat and/or bones and provide an otherwise elusive direct proxy for milk consumption (e.g. Evershed et al. 2008; Lymperaki et al. 2016; Urem-Kotsou this volume). Unfortunately, meat cooked without pots, milk consumed fresh or processed in organic vessels and, for the most part, plant foods have been difficult to detect due to poor preservation (although starch grains and phytoliths in charred food crusts may partly offset this – García-Granero et al. 2017), so cooking-pot residues cannot reveal the relative dietary contributions of carcass vs dairy products or ruminant vs non-ruminant meat, let alone animal vs plant foods. As with macroscopic food remains, variation in the ceramic types associated with different depositional contexts may reveal some of the diversity in scales and forms of consumption, although lipid residues are likely to be palimpsests of multiple food-preparation episodes, some perhaps unrelated to the final context of discard.

This brief review of the three principal available proxies for Neolithic foodways in northern Greece emphasizes how each in isolation provides a distinctive but also incomplete window onto human diet, such that integration of their complementary perspectives offers both a fuller and a more dependable picture (also Papathanasiou et al. 2013). Even in combination, however, these proxies leave unanswered the very fundamental question of the balance between plant and animal contributions to human diet (see also below), resolution of which at present requires modeling of the likely relationship between human population and available resources. To this end we must also consider the evidence for community size from surface and sub-surface investigation of settlements and that for the nature of regional and local cultural landscapes from off- and on-site palaeoenvironmental studies.

The remainder of this contribution explores the potential of integrating the available proxies, highlighting – for their heuristic value – apparent contradictions between them. Albeit with selective comparative reference to other sites and periods, discussion focusses on early Late Neolithic (LN) Makriyalos I (MKI), c. 55/5400-5000 BC, in the Pieria region, which as yet offers more relevant datasets than other Neolithic sites in northern Greece (Pappa et al. 2013) and indeed richer multi-proxy evidence than all but a few Neolithic sites in Europe. Since work on all the Makriyalos datasets is ongoing, we attempt to illustrate the potential of integrated analysis rather than to provide a definitive study of MKI foodways.

Context: Makriyalos I and the Neolithic of northern Greece

Two principal types of Neolithic settlement have been widely distinguished in north and central mainland Greece: ‘flat extended’ settlements, with habitation spread over a relatively large area (28 ha in the case of MKI) and perhaps shifting horizontally over time; and more compact settlements (usually of 0.5-2 ha), with dwellings typically rebuilt more or less on their predecessor’s footprint and so gradually forming a raised ‘tell’. Examples of both types were enclosed within perimeter ditches, palisades or walls, but these represented a much larger-scale undertaking at flat-extended settlements (e.g. extending over 2 km at MKI). Recovered dwellings range from round or oval, semi-subterranean ‘huts’ with a light superstructure to rectangular, above-ground ‘houses’ with walls varying from wattle-and-daub to mudbrick construction. Flat-extended sites tended to comprise flimsy huts and compact settlements more substantial houses (Pappa 2008). Labour was thus preferentially invested in perimeter works on flat-extended sites, reinforcing collective rights to enclosed residential and probably cultivated space, but in 'domestic' architecture on compact settlements, where repeated re-building *in situ* arguably represented genealogical claims to house plots and perhaps cultivable land off-site (Kotsakis 1999; 2006; Halstead 2006). At MKI, collective solidarity was apparently reinforced not only by enclosure (the ditch initially being cut in sections, presumably by small work gangs – Pappa and Besios 1999, 181), but also by secondary commingled disposal of the dead (Triantaphyllou 1999) and by commensality. Loci of discard from apparently collective consumption include two borrow pits (Pits 212 and 214), containing very large quantities of ceramic and faunal debris, and the perimeter ditch, while groups of smaller 'habitation' pits have plausibly been identified as loci of domestic consumption (Pappa et al. 2013).

Modelling Neolithic subsistence at Makriyalos I and beyond

MKI remains of edible plants imply processing or consumption on site of cereals (einkorn, emmer, new-type glume wheat and barley), pulses (lentil and perhaps also bitter vetch, grass pea and pea), flax (potentially for oil and/or fibre) and fruits (fig, grape and, more sporadically, blackberry and elderberry). These data are reasonably compatible with the record from Neolithic sites elsewhere in northern Greece (Valamoti 2007a), but the relative abundance of cultivated grains and fruits or of cereals and pulses cannot be assessed directly, not least because preservation of much of the assemblage may be due to use as animal fodder and burning of the resulting dung (Pappa et al. 2013). The large MKI animal bone assemblage is overwhelmingly comprised of domesticates (99%), as is usual for the Neolithic of Greece. Pig, cattle and sheep remains outnumber those of goat (Table 1a) and, consistent with proximity to the shores of the Thermaic Gulf, shells especially of cockle (*Cerastoderma glaucum*) are also very abundant (Veropoulidou 2014), albeit representing much smaller quantities of meat than bones of domestic animals. The ages at death of sheep, cattle and goats suggest management for carcass rather than dairy products (Tzevelekidi et al. 2014, 429-32, fig. 8) and the latter have not yet been reported from analysis of lipid residues in ceramics from this site (Evershed et al. 2008), although neither mortality nor lipid data preclude some use of milk from livestock. On available evidence, therefore, meat was procured overwhelmingly from domestic animals and there is no hint that the latter were intensively exploited for milk. Neither archaeobotanical nor faunal evidence sheds direct light on the relative dietary contributions of plant- and animal-based foods, while human skeletal remains, even if typical of consumers at MKI, do not clearly resolve the issue. Dental microwear indicates an abrasive diet, perhaps due to grit from grinding tools (below). Macroscopic analysis of MKI human teeth reveals high dental calculus and low caries, conventionally indicating relatively high animal protein and low carbohydrate intake (Triantaphyllou 2001), respectively. Frequency of carbohydrate intake and the nature of any accompanying foods, however, also influence oral health and some recent populations consuming unrefined foods at widely spaced meals exhibit low caries (Lingström et al. 2000). Isotopic analysis of human bone (Triantaphyllou 2001, 137-138; Styring et al. 2015) indicates that most individuals consumed animal protein (δ^{15}N values higher than those of local herbivores), but a few had a purely plant-based or pulse-rich diet (low δ^{15}N values), while δ^{13}C values offer no support for a significant marine component (although the dominant shellfish *Cerastoderma glaucum*, probably gathered from brackish waters [Veropoulidou 2014], might not be detectable regardless of intensity of consumption [cf. Robson et al. 2016; Michener and Kaufman 2007, 256-259]). Use of δ^{15}N data to model the relative dietary contribution of animal protein gives widely divergent results, depending on the assumptions made, but attempts at greater precision using $\delta^{15}N$ values of individual aminoacids have suggested contributions of 8%-36% and 41% for MKI humans, while cautioning that more data are needed for both archaeological and modern cereals (Styring et al. 2015). In sum, relatively direct archaeobotanical, faunal and human skeletal proxies for MKI human diet indicate that this was overwhelmingly non-marine, despite a coastal location, and included both plant- and animal-based foods, but in uncertain proportions. We explore this last issue *indirectly*, therefore, modeling diet from the twin constraints of local and regional subsistence needs and resource potential.

The size of north Greek Neolithic communities is uncertain, but the size and density of excavated houses on compact sites of up to 2 ha (e.g. at least ten structures of ca. 100-120 m^2 each at early LN Kleitos I – Ziota 2014; cf. Halstead 1981, 312-313) suggest a few dozen to a few hundred individuals. Similar estimates are even more problematic for flat-extended sites, but their greater overall size is offset by the wider spacing and/or apparently shorter lifespan of dwellings (e.g. Andreou and Kotsakis 1994, 19-20; Kotsos and Urem-Kotsou 2006; Pappa 2008). Plant remains in animal dung burnt as fuel at MKI do not register summer grazing, possibly reflecting seasonal absence of livestock (Valamoti 2007b), but the latter may simply have been penned elsewhere on site (e.g. on stubble fields) in summer and their dung not collected. Conversely, the ages recorded for young domestic animals suggest slaughter in all seasons (Halstead 2005), favouring the year-round presence of at least some inhabitants. The density of settlements in the landscape is obscured in the Pieria region, where sites have been variously – depending on topographic situation – truncated by erosion or buried by alluviation (Krahtopoulou 2003), but in eastern Thessaly (central Greece), where a particularly rich record of known sites reflects a long history of research and abundance of highly visible, compact tells, archaeologically contemporary Neolithic settlements are often located only 2-3 km apart (Halstead 1984).

Closely-spaced villages of several dozen persons or more, some at least apparently resident year-round, would have posed a demanding subsistence challenge. This far outstripped regional potential for gathering-hunting (anyway sparsely represented in available archaeobotanical and faunal data), but was comfortably compatible with subsistence dominated by grain crops. For example, even a community of 300 head (arguably at the upper end of the likely range), consuming 75 tons of grain per year (assuming a heavily grain-based diet) harvested from 100 hectares (with average yields of 750 kg/ha, probably pessimistic for intensive Neolithic cultivation – cf. Bogaard et al. 2013), could be sustained by land within a few hundred metres of home (cf. Isaakidou 2008, 103 table 6.2). Conversely, dietary dependence on domestic animals was viable *only* if the latter were intensively exploited for milk (which is not supported by mortality and ceramic lipid data) and/or kept in huge numbers (which demands a fairly open landscape and some mobility of livestock). North Greek pollen data suggest a Neolithic lowland landscape dominated by deciduous woodland, with little if any unambiguous evidence of clearance. Admittedly, most such studies are coarsely dated and based on large-catchment cores unlikely to detect small-scale deforestation (Kouli 2014), but wood charcoal from Neolithic sites in northern Greece, including Revenia-Korinou and Paliambela-Kolindrou near Makriyalos, gives no indication that human exploitation radically opened up local vegetation (Marinova and Ntinou 2017). The Neolithic landscape was thus apparently unfavourable to large-scale pasturing and control of livestock (especially sheep, ill-suited to woodland) and shows no sign of extensive degradation by large-scale herding (Halstead 2000).

Several details of MKI animal husbandry offer local support to this view. Table 1a presents faunal *deadstock* data, which overstate the contribution to *livestock* of sheep and especially pigs, that exhibit younger mortality (and thus shorter lifespans), and understate the contribution of goats and cattle, that lived longer (cf. Tzevelekidi et al. 2014, 432 fig. 8). All four common domesticates were thus well represented among MKI livestock. Given that macroscopic archaeobotanical evidence of C_4 crops is lacking for the Greek Neolithic and that the C_4 weeds common in summer in modern gardens and, in wetter years, stubble fields are, and probably were, too sparse and too short-lived for a major contribution to cattle diet, the high $\delta^{13}C$ values of most sampled MKI cattle (Styring et al. 2015, fig. S3) by default suggest grazing of coastal marshes, for example a few kilometres to the south (Krahtopoulou and Veropoulidou 2016). Conversely, the heavily abrasive diet of many young sheep and goats from MKI (Mainland and Halstead 2005) suggests grazing on very disturbed ground (perhaps freshly cultivated gardens/fields or over-grazed pens), while the isotopic signatures of sheep, falling between humans and goats (Styring et al. 2015, fig. S3), suggest association with the settlement and its surroundings rather than outlying woodland or wetland. Accordingly, sheep were probably kept nearby and in modest numbers and so too, unless sheep are heavily over-represented in the deadstock assemblage (see below), were cattle, pigs and goats. By default, therefore, cultivated cereal and pulse grains (perhaps in variable relative proportions, given the range of human $\delta^{15}N$ values reported - above) were arguably the MKI dietary staples.

From nutrition to meals and commensality

If cereal and/or pulse grains were the dietary staples at MKI and thus the basis of daily meals, how were they consumed? Transformation of whole grains to fine (as at EN Kapitan Dimitrievo in neighbouring southern Bulgaria – Valamoti et al. 2008) or coarse groats reduces cooking time and increases digestibility and, if executed with the stone pounding and especially grinding tools found at MKI, will have introduced fine stone particles that would plausibly account for the abrasive dental microwear observed in human teeth (Pappa et al. 2013, 81-82). MKI fire installations include hearths and ovens (Pappa et al. 2013, 80), so cereal and pulse grains, whole or ground, may variously have been boiled or baked, perhaps in spherical pots or shallow pans respectively, but there is no evidence that cooking methods differed between social contexts (Lymperaki et al. 2016; Urem-Kotsou this volume).

MKI ceramic cooking and serving vessels, of modest size like the hearths, ovens and grindstones, suggest preparation of food for, and its consumption by, groups each comprising a handful of persons and so are compatible with household daily meals. At least four lines of evidence, however, suggest that commensality also extended beyond the household. First, at Neolithic settlements across northern Greece, while many hearths and ovens associated closely with dwellings perhaps facilitated ‘private’ household commensality, others were located in open, more public space (e.g. Kalogiropoulou 2014; Lymperaki et al. 2016) and, at early LN Kleitos, several of these were unusually large or well made (Ziota 2014, 324-326). Secondly, most of the animals represented at MKI were too large for rapid consumption by a single household, but the intensity of deliberate bone breakage argues against wastage, the scarcity of filleting traces against drying for storage, and the modest size of cooking pots against large-scale preservation in fat. By default, most carcasses were arguably shared beyond the household while ‘fresh’ (Halstead

2007). Thirdly, two MKI borrow pits (212 and 214) contained prodigious quantities of food preparation and consumption debris (including grinding tools; storage, cooking and tableware vessels; animal bone and shell) and it seems, from the combined evidence of stratigraphy and ceramic joins, that Pit 212, at least, was filled rapidly. Both pits probably represent collective commensality and Pit 212, given the number (several hundreds) and size (mostly sheep, pigs and cattle) of animals involved, perhaps regional-scale rather than local provisioning and consumption (Pappa et al. 2004). Fourthly, inter-site stylistic similarities in fine tableware (Urem-Kotsou 2016; this volume) suggest that commensality supported social relationships at a regional as well as local and domestic scale.

The range of cooking and tableware forms expanded through the Neolithic, enabling increasingly diverse food preparation and presentation, but vessels of the same types and sizes were deposited in collective (Pits 212 and 214, the perimeter ditch) and domestic contexts at MKI, so collective commensality was not evidently differentiated from everyday domestic meals by elaboration of staple dishes. If, as argued above, animal carcasses were of secondary *nutritional* significance at MKI but mostly shared beyond the household, then meat may have contributed to differentiating occasional collective from routine domestic commensality. Indeed, given that most domestic animals in the MKI faunal assemblage could have been slaughtered at a younger age, more compatible with domestic consumption, provisioning of supra-household commensality was perhaps a major goal of livestock rearing. The following section explores MKI meat consumption in more detail.

The manner and contexts of MKI meat consumption

In the MKI perimeter ditch, in Pit 212 and in the smaller habitation contexts, pigs are best represented (32-38%), followed by cattle (27-29%) and sheep (24-29%), and then goats (11-12%), whereas in Pit 214 cattle (45%) are most frequent, followed by pigs (34%) and then sheep (12%) and goats (9%) (Table 1a). These figures are based on minimum numbers of anatomical units (MinAU – cf. Tzevelekidi 2012, 24-25), avoiding multiple counting of broken specimens and so minimizing the effects of differential fragmentation between species (below), and also controlling for differences in skeletal structure (e.g. more numerous foot bones in pigs). MKI was excavated under rescue conditions without routine sieving, however, and a fifth of the bones of the common domesticates bear traces of gnawing, so small and fragile bones should be underrepresented due to recovery losses and attrition respectively. Anatomical representation confirms that, as expected, these factors affected sheep, goats and pigs more severely than the larger cattle (Tzevelekidi et al. 2014, 426-429, figs. 2-4). The resulting losses can be corrected to some degree by estimating relative abundance of the common domesticates from the best-represented body part of each (a very basic 'minimum numbers of individuals' estimate): on this basis, the proportion of cattle drops to 30% in Pit 214 and 17-19% in the remaining contexts, while the proportions of the smaller domesticates rise commensurately (Table 1b). Nonetheless, both 'corrected' and uncorrected figures may *under*estimate the contribution of cattle to overall meat consumption at MKI, given their large carcass size (accentuated by high adult mortality).

Pit 214 has, in addition to the highest proportion of cattle bones, the oldest mortality pattern for all four principal domesticates, while Pit 212 has the highest proportion of male cattle, and habitation contexts have the youngest cattle mortality. The avoidance of older cattle in the latter may reflect expected smaller-scale commensality, while lack of the otherwise ubiquitous scattered human remains in Pit 212 (Triantaphyllou 1999) hints at a distinctive social/cultural rationale for collective commensality associated at least with this context. Whether for practical or cultural reasons, the species and ages of animals discarded (and presumably consumed nearby) differed between depositional contexts and, since the latter were preserved and excavated to varying degrees, simply summing or averaging their contents may provide a very unrepresentative picture of animal consumption at MKI.

Despite differences in the relative frequencies of the animal species consumed, carcass processing exhibits limited *contextual* variability. First, initial carcass dressing, involving discard elsewhere of many sheep, goat and pig feet and perhaps some cattle and pig heads (Tzevelekidi et al. 2014, 427-429, figs. 2-4), contrasts with more intensive and wholesale EN carcass processing at nearby Revenia-Korinou and Paliambela-Kolindrou (Halstead and Isaakidou 2011a). This increased formality of animal consumption would have reinforced the suggested distinction between largely plant-based daily meals and special occasions involving meat. Judging by numbers of observed cut marks (and despite differences in fragmentation favouring the opposite outcome), cattle were then butchered more intensively than the smaller pigs, sheep and goats (Halstead 2007, 37 table 3.2). Cut marks are rather scarce for all the principal domesticates, however, suggesting limited dismembering or filleting before cooking. It follows that carcasses were mostly cooked on the bone and in rather large sections and thus, given the modest size of MKI cooking pots, that most meat from cattle and much of that from smaller domesticates was cooked in pits, ovens or skins or adjacent to open fires. That much cooked meat was then shared beyond the small (?household) groups, implied by cooking and serving vessels of modest size, is likely given the quantities involved, but difficult to demonstrate directly. Such sharing arguably accounts, however, for the extreme rarity of observed left:right pairs of bones from individual cattle, pigs, sheep or goats, even though a few part-skeletons of dog and restorable ceramic vessels show that at least some deposits were formed rapidly and were not heavily disturbed post-depositionally.

Albeit less exhaustively than at EN Revenia-Korinou and Paliambela-Kolindrou, the carcasses of the principal MKI domesticates were also systematically exploited for marrow: most intensively in cattle, but more so in sheep and goats than in pigs – the species with the youngest mortality pattern (Halstead 2007, 37-38 tables 3.3-3.4). These differences between taxa in the intensity of fragmentation are the opposite of what would be expected from trampling or carnivore attrition and so plainly result from deliberate human processing of the largest and most marrow-rich bones. Consistent with this, many foot bones (metapodials) bear more or less clear traces of burning, probably resulting from heating to render the bone more brittle and the marrow easier to remove. Marrow may thus have been removed mechanically from heated bones as a snack (cf. Binford 1978, 145-155), but MKI cooking pots have yielded lipid traces of both ruminant and non-ruminant adipose fat (Urem-Kotsou 2006, fig. 6.29), implying also heating therein of broken bones and/or meat and/or stripped fat. The scarcity of dismembering and filleting traces argues against bones being broken in 'pot-sizing' of raw joints for cooking (because the resulting carcass sections, especially of cattle, would still have been too large for MKI cooking vessels). Rendering of fat for storage would perhaps, as in the recent past, have favoured use of pigs over ruminants (Halstead and Isaakidou 2011b), but pig bones are the least intensively broken and most frequently gnawed, implying that they were not systematically processed to remove all fat. The addition of broken bones (probably from cooked carcasses) to plant-based dishes as flavouring seems the most parsimonious interpretation of the data.

In whatever form animal fats were heated in MKI cooking pots, the $\delta^{13}C$ values of $C_{18:0}$ in absorbed ruminant and non-ruminant fats are very similar (in fact, slightly higher in non-ruminants) and do not register the strong C_4/coastal marsh dietary signal of most cattle, which is also not detected in the $\delta^{13}C$ values for human remains (Styring et al. 2015). These discrepancies between datasets might be accounted for in various ways.

(1) The discrepancy between faunal (specifically cattle) and ceramic $\delta^{13}C$ would be accounted for if meat and/or bones of pig, sheep and goat were routinely added to cooking pots, but those of cattle only rarely so. Such differential treatment would not have been for practical reasons of pot-sizing if, as argued above, butchered sections of raw meat of all four common domesticates were often too large, and their broken bare bones normally small enough, to fit in MKI cooking pots.

(2) Because fat may have considerably lower $\delta^{13}C$ values than muscle and especially bone collagen of the same animal (e.g. -28‰ versus -23‰ and -20‰, respectively – van Klinken et al. 2000, 47; also Lee-Thorp et al. 1989, 592 figs. 4-5; González-Martin et al. 1999; Piasentier et al. 2003), the discrepancy between faunal (cattle) and ceramic data sets might be accounted for if fat, rather than lean meat, was heated in cooking pots in the case of cattle. Since MKI ceramic $\delta^{13}C$ values are very similar for ruminants and non-ruminants, this scenario demands that lean meat too (or even instead) was heated in cooking pots in the case of pigs. Cooking of fat rather than lean meat in pots was indeed suggested above, on the basis of faunal butchery and fragmentation patterns, for all four common domesticates, but especially so in the case of cattle. On the other hand, the cattle $\delta^{13}C$ values would still be incompatible with those from the human skeletons, unless the meat of cattle was discarded uneaten

– which involves considerable ‘special pleading’ and in some cases is perhaps contradicted by filleting marks.

(3) The discrepancy between faunal (cattle) and human $\delta^{13}C$ would be accounted for if the sampled humans did not eat the sampled animals. This would be the case if the two datasets were of different date, but both are drawn from a range of MKI contexts, making this unlikely. Alternatively, on-site burial may have been restricted to a subset of the population (not implausible – Triantaphyllou 2008) and this subset might (but with considerable special pleading) have had no access to cattle carcass products.

(4) More parsimoniously, the faunal (cattle) and human $\delta^{13}C$ data might be reconciled if cattle were consumed very rarely in dramatic episodes of unassimilated carnivorous excess (cf. van Klinken et al. 2000, 51; Bilsborough and Mann 2006; Milton 2000) and so made a much smaller contribution to human bone chemistry than to the faunal record.

(5) The discrepancies between faunal (cattle) and human $\delta^{13}C$ would also be accounted for if, as a result of assemblage formation processes, the recovered and recorded faunal data hugely exaggerate the contribution of cattle to MKI meat consumption. The method of quantification used avoids multiple counting of more intensively broken cattle bones, however, while ‘corrected’ taxonomic abundance figures (Table 1b) to at least some degree counter known post-discard survival and recovery biases against pig, sheep and goat. Moreover, even if ‘corrected’ figures significantly underestimate survival and recovery losses, cattle should still, given their large carcass size, have made a substantial if not dominant contribution to meat consumption associated with excavated contexts. Only the deeper sub-surface contexts at MKI survived for investigation, however, so formation processes may have greatly exaggerated the contribution of cattle if their bones were preferentially

discarded in *excavated* deposits. If most meat consumption episodes were small-scale (e.g. hospitality to, or sharing of carcasses with immediate neighbours or close kin), if they mainly involved just the smaller domesticates, and if they ended in discard on living surfaces or in shallow sub-surface pits, they will be severely underrepresented in the recovered faunal assemblage. This scenario might also account for the discrepancy between faunal and ceramic $\delta^{13}C$, but only (and perhaps implausibly) if sampled MKI cooking pots from sub-surface contexts had a sufficiently long use-life in (previous?) 'above-ground' commensal preparations involving pigs, sheep and goats that none of them registered the (latest?) cooking of carcass parts from high-$\delta^{13}C$ cattle.

(6) The discrepancy between faunal (cattle) $\delta^{13}C$ values and those of both humans and ceramics might in principle be attributable to the variable rates of turnover in different animal tissues (Tieszen et al. 1983; Dalerum and Angerbjörn 2005), with the sampled cattle bone collagen reflecting bovine diet over a much longer period than the muscle and fat (cf. Lobley et al. 2003, 328) that humans are likely to have eaten and perhaps cooked in pots. On this scenario, cattle would have grazed probably distant (see above) C_4-rich pastures long enough, or at a young enough age of rapid growth and skeletal turnover, to acquire elevated bone-collagen $\delta^{13}C$. They would subsequently have spent long enough on C_3-dominated pasture (perhaps nearer to Makriyalos) for edible muscle and fat to develop lower $\delta^{13}C$ values. Incremental analysis of $\delta^{13}C$ and $\delta^{18}O$ isotopes in teeth (Vaiglova et al. forthcoming) sheds some light on the temporal rhythm of grazing movements by MKI cattle, but the latter's widely varying $\delta^{13}C$ bone collagen values suggest considerable variability between individuals in some combination of the balance between C_3 and C_4 plants in the grazed 'C_4 pasture', the length of time spent grazing it, their age while grazing it, or the time subsequently

elapsed until slaughter. In isolation, therefore, this scenario arguably reconciles the faunal with the human as well as ceramic datasets only with excessive special pleading.

Of these six hypothetical scenarios, the first (cattle meat/bone not cooked in pots) only 'explains' the discrepancy between faunal (cattle) and ceramic $\delta^{13}C$ values. The second (pots used for cooking only fat of cattle, but also/instead lean meat of pigs) likewise accounts for only the faunal-ceramic and not the faunal-human bone discrepancy unless, abandoning parsimony, we also assume that human consumers avoided lean meat of cattle. Conversely, only the faunal-human discrepancy is accounted for by the third scenario (sampled humans not consuming cattle), by the fourth (rare beef-eating excess) and likewise – without some rather special pleading regarding the life-histories of MKI cooking pots – by the fifth (preferential survival of cattle-bearing deposits). The sixth scenario ostensibly accounts equally well for the faunal-ceramic and faunal-human discrepancies in $\delta^{13}C$, but makes some as yet unsubstantiated and (given uncertain absolute turnover rates of different tissues) loosely defined assumptions about the timetable of grazing movements by cattle and so, in isolation, does not offer a convincing overall solution.

In sum, without special pleading, each of these six scenarios in isolation at best accounts for the discrepancy between faunal and ceramic *or* between faunal and human data, but not both. For the most part, however, the six scenarios are not mutually exclusive and some are mutually very compatible, suggesting that a combined solution should be sought. Thus, due to the topographic situation of MKI, surface/shallow deposits are indeed largely lost (scenario 5) and the deeper contexts, because of the size of the task, are more likely to have been dug with collective labour (most obvious in the chain of irregular pits making up the enclosure ditch) and thus associated with larger-scale commensality. In the recent past (before electricity and refrigerators reached the Greek countryside), even in village communities of a few thousand head (ten times larger than the upper end of the range usually envisaged for the Neolithic), cattle were rarely slaughtered locally, but were instead normally sold to urban butchers (Halstead 2007). The consumption of cattle at MKI, therefore, even if more or less restricted to infrequent large-scale commensal occasions, is likely to have involved poorly assimilated carnivorous excess (scenario 4). The discrepancy between faunal and human $\delta^{13}C$ values is thus accounted for quite parsimoniously. A contrast, at slaughter, between sampled cattle bone of higher $\delta^{13}C$ and cattle meat and fat of lower $\delta^{13}C$ (scenario 6) is also plausible and, to a probably variable degree, would help reconcile faunal with ceramic as well as human values. Even if cattle were eaten rarely and their meat tended to a significantly lower $\delta^{13}C$ than their bones, however, it is surprising that the ceramic residues offer no hint of a more C_4-rich diet in ruminants than in pigs. Although most pots with lipid traces yielded a mix of ruminant and non-ruminant adipose fat (Urem-Kotsou 2006), it seems unlikely that all these vessels were discarded at a stage in their life-history when any trace of use for cooking beef was obscured by lipids from cooking of smaller domesticates (scenario 5). Arguably, therefore, we must also invoke some difference between species in methods of preparation for consumption, with cooking pots being avoided (scenario 1) or used for fat rather than lean meat (scenario 2) in the case of cattle; both scenarios are compatible with the faunal butchery and fragmentation evidence and both could be attributed to the practicalities of cooking large carcasses or to distinctive cultural value ascribed to rare events of cattle consumption. In any event, variation is implied in meat consumption practices (in form, frequency, context or participants) that is not apparent from any single category of evidence and that, given the size of cattle carcasses, is probably related to differences between small- and large-scale commensality. Together with contextual variation in faunal (species, age and sex differences), human (lack of mortuary evidence in Pit 212) and perhaps ceramic (variety of drinking vessels in Pit 212) remains in isolation, the discrepancies between $\delta^{13}C$ datasets highlight the diversity of MKI commensal practices and thus social relations.

Conclusions

Archaeologists use diverse material remains and analytical methods to investigate past foodways, but different categories of material are subject to divergent preservation, recovery and analytical biases, while different sub-disciplines offer distinctive proxies for particular aspects of past foodways. With close attention to these issues, apparent discrepancies between proxies may actually offer complementary insights into past foodways. Here we have explored the complementary perspectives of currently available datasets for LN foodways at northern Greek Makriyalos I, where contradictions between datasets expose otherwise undetected variability in who ate what, how, and when. In particular, the consumption of meat from cattle seems to have taken place in infrequent, large-scale commensal events that are overrepresented in the surviving macroscopic faunal sample and underrepresented in the δ13C values of human skeletal remains. Such variability in the temporal rhythm of consumption patterns complicates the investigation of human diet and nutrition, but offers the ultimate prize of a much richer understanding of its social and cultural dimensions.

Bibliography

Separate file

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Figure caption

Figure 1. $\delta^{15}N$ and $\delta^{13}C$ values for humans, cattle, sheep and goats at Makriyalos I (after Triantaphyllou 2001 and Styring et al. 2015)