Animal keeping in Chalcolithic north-central Anatolia: what can stable isotope analysis add?

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Received: 29 March 2016 / Accepted: 8 September 2016
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Abstract Stable isotope analysis is an essential investigative technique, complementary to more traditional zooarchaeological approaches to elucidating animal keeping practices. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values of 132 domesticates (cattle, caprines and pigs) were evaluated to investigate one aspect of animal keeping, animal forage, at the Late Chalcolithic (mid-fourth millennium BC) site of Çamlıbel Tarlası, which is located in north-central Anatolia. The analyses indicated that all of the domesticates had diets based predominantly on C3 plants. Pig and caprine $\delta^{13}C$ and $\delta^{15}N$ values were found to be statistically indistinguishable. However, cattle exhibited distinctive stable isotope values and, therefore, differences in diet from both pigs and caprines at Çamlıbel Tarlası. This difference may relate to the distinct patterns of foraging behaviour exhibited by the domesticates. Alternatively, this diversity may result from the use of different grazing areas or from the foddering practices of the Çamlıbel Tarlası inhabitants.

Keywords North-central Anatolia · Animal forage · Stable isotope analysis · $\delta^{13}C$ · $\delta^{15}N$

Introduction

Archaeological research in north-central Anatolia has focused predominantly on Late Bronze Age and Iron Age urban sites. By comparison, prehistoric settlement in the region has received relatively little attention (e.g. Parzinger 1993; Steadman 1995; Özdoğan 1996; Schoop 2005; Düring 2008). As a result, the animal keeping practices and human use of meat and secondary products of this region and time period are poorly understood.

Dietary stable isotope studies of animal bones offer a direct means of reconstructing at least one aspect of animal production: the type of forage domesticates had access to or were given. While such information will not be a panacea in understanding herding domesticates per se, it elucidates a new dimension directly relevant to animal keeping in the Anatolian region. Here carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope analyses of remains from domesticated animals and humans (Pickard et al. 2016) from the Late Chalcolithic settlement site of Çamlıbel Tarlası are used to investigate animal diets. The implications of the results for stock-keeping and the consumption of meat and secondary products by a rural farming community in north-central Anatolia are explored.

Çamlıbel Tarlası—archaeological background

Çamlıbel Tarlası is one of only a very small number of prehistoric sites to have been investigated in north-central Anatolia. Located 2.5 km east of the modern village of...
Boğazkale (the location of the Late Bronze Age Hittite capital Ḫatūša), the site was excavated, as a cooperative project between the German Archaeological Institute and Edinburgh University, over three seasons from 2007 to 2009 (Schoop 2010, 2011, 2015 for summary reports). A small, short-lived settlement and mortuary site, Çamlıbel Tarlası was occupied in the mid-fourth millennium BC (Schoop et al. 2009). The site is located on a small plateau (c. 1040 m asl) in a mountainous and previously wooded region (Dörfler et al. 2000; Marsh 2010), a short distance from the main Budaközü Plain (Fig. 1).

Seven phases of activity (summarised in Table 1) have been identified at Çamlıbel Tarlası, all of which date to the Late Chalcolithic between 3650 and 3375 cal BC. Extractive metallurgy and small-scale agriculture are the principal activities evident at the site. The site’s occupants may have been attracted to this location because, in addition to the close proximity of an outcrop of copper ore ∼2 km to the east of the site, the surrounding plateaus would have been ideally suited to small-scale agriculture (Marsh 2010).

Çamlıbel Tarlası—the animal remains

An assemblage of 2752 identifiable animal bones (67.7 kg) was recovered at Çamlıbel Tarlası (Bartosiewicz and Gillis 2011; Bartosiewicz et al. 2013). Wild species constituted less than 1 % of the assemblage by NISP (Fig. 2). The remains were predominantly waste from food consumption. Cattle dominated the domesticate remains with pig and caprines also common. Tooth wear and epiphyseal fusion data indicate that the vast majority of the cattle were mature animals. Longevity is attributable to several factors in cattle including the slow reproduction rate and intrinsically high value of individuals as well as secondary product exploitation. Single purpose pigs were slaughtered at or before adulthood for meat. The proportion of bones from young to mature caprines was low. In addition to cattle potentially having been used for traction and sheep for wool, all bovids (including goats) were likely exploited for dairy produce. Distinction between the bones of young lambs and kids, however, tends to be unreliable, further distorting
speculations concerning the ‘management’ of caprine herds (Bartosiewicz et al. 2013).

It has been inferred from remains of churns found at Çamlıbel Tarlası (Fig. 3) and nearby sites such as Yarıkaya (Boğazköy) that dairy produce was important at least in the local economy (Sauter et al. 2003, Figs. 1, 2 and 3). This is congruent with the identification of animal fats, in one case likely milk fat or a derivative, on two pottery sherds from Yarıkaya (Sauter et al. 2003).

### Problems with proxies

Animal remains recovered at settlements such as Çamlıbel Tarlası typically represent food refuse or manufacturing waste unless interpreted as ‘ritual’ deposits of intact or articulated skeletons. However, there is a tendency to contextualize them in broader terms, inseparably mixing evidence of consumption with far less tangible aspects of exploitation, especially for secondary products. Evidence for the latter is related to animal longevity as secondary products are renewable resources from live animals (e.g. Gerritsen et al. 2010). However, interpretations regarding the bones of calves or lambs/kids alternate between showing emphasis on milk or meat ‘production’ (cf. Gourichon and Helmer 2008 and Gerritsen et al. 2010). Moreover, age profiles treated as key evidence are often based on small or unknown numbers of ageable elements encountered among the food remains.

### Stable isotope analysis

Stable carbon and nitrogen isotope analysis of bone collagen has been widely demonstrated to be a useful tool in the investigation of animal diets (e.g. Pearson et al. 2007; Towers et al. 2011; Fuller et al. 2012; Gillis et al. 2013).

The technique involves the measurement of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios in samples of bone collagen (Sealy et al. 1995). $^{12}C/^{13}C$ isotopes are incorporated into plant tissues during photosynthesis. Carbon
isotope ratios ($\delta^{13}C$) vary between plants depending on the mechanism used to fix atmospheric carbon. Most plants fix carbon through one of two routes, either the C$_3$ or C$_4$ pathways (Edwards and Walker 1983). C$_3$ plants comprise cereals such as wheat and barley, and most fruits and vegetables, while C$_4$ plants include some tropical grasses and cereals such as millet and sorghum. Variation in plant $\delta^{13}C$ is passed on to the tissues of animal and human consumers. Plant $\delta^{13}C$ values may also exhibit inter-species variation within a C$_3$ plant environment (e.g. Feranec 2007). The $\delta^{13}C$ value of animal bone collagen can therefore be used to determine not only the relative importance of C$_3$ vs C$_4$ plants to diet but may also distinguish between different patterns of foraging behaviour in regions with an exclusively C$_3$ biome (DeNiro and Epstein 1978; Feranec 2007).

Nitrogen isotope ratios ($\delta^{15}N$) exhibit a ‘trophic level’ effect, becoming more ‘enriched’ with each step in the food chain, i.e. they indicate an organism’s position in the food chain. The increase in $\delta^{15}N$ values of animals over that of their diets has been observed to be in the order of 3–5 $\%$ (e.g. Bocherens and Drucker 2003)—although the diet-consumer offset may vary between species and has been demonstrated to be higher than 5 $\%$ in humans (Hedges and Reynard 2007; O’Connell et al. 2012). $^{14}N/^{15}N$ isotopes may be incorporated into plants from soils and/or drawn from atmospheric N$_2$. Plants that fix nitrogen from the atmosphere (e.g. legumes) generally have lower $\delta^{15}N$ values than those plants that fix nitrogen from soil nitrate or ammonium (DeNiro and Epstein 1981). Plant $\delta^{15}N$ values can also vary significantly depending on water stress (e.g. Ambrose 1990), salinity (e.g. Britton et al. 2008) and increased nitrogen cycling in forested environments (e.g. van der Merwe and Medina 1991). The variability in $\delta^{15}N$ values is passed on to the consumers of plants and may therefore indicate distinctive foraging behaviours among domesticates.

Although the fundamental principles of stable isotope analysis were established in the 1970s and have remained largely unchallenged, it is important to bear in mind that there are a number of additional issues (both dietary and non-dietary) that have implications for the reconstruction of animal forage from stable isotope values, for example the potential effects of physiological stresses, such as gestation and lactation on intra- and inter-individual isotope signatures, as well as the impact of practices such as manuring on isotopic signatures in plants and their animal consumers (e.g. Jenkins et al. 2001; Fuller et al. 2005; Bogaard et al. 2007; Nitsch et al. 2010; Olsen et al. 2014).

### Materials and method

A total of 163 domesticated animal (cattle, caprine and pig) bone specimens from Çamlıbel Tarlası were measured for $\delta^{13}C$ and $\delta^{15}N$ to investigate animal forage and human diets (see Pickard et al. 2016) in Late Chalcolithic north-central Anatolia—see Table 2 for animal data.

A sample of approximately 1 g of bone was taken from each specimen. Pre-treatment included cleaning to remove 1–2 mm of the outer surface of the bone. Collagen was extracted using a modified version of the Longin (1971) method (Brown et al. 1988). Each sample was demineralized in 1 N HCl at 20 °C for a minimum of 24 h, rinsed three times in Milli-Q™ purified water and gelatinized in 0.03 N HCl at 80 °C for approximately 16 h. The resulting solution was then lyophilised. Samples with well-preserved collagen, i.e. collagen wt% yield of >1.00% (Brock et al. 2010; van Klinken 1999), were measured for $\delta^{13}C$ and $\delta^{15}N$ by the SUERC Radiocarbon Laboratory in East Kilbride, UK, using a Thermo Scientific Delta V Advantage continuous-flow isotope ratio mass spectrometer (CF-IRMS) coupled via a Thermo Scientific ConFloIV to a Costech ECS 4010 elemental analyser (EA) fitted with a pneumatic autosampler. In-house gelatine standards, which are calibrated to the International Atomic Energy Agency (IAEA) reference materials USGS40 (l-glutamic acid, $\delta^{13}CV_{\text{PDB}} = -26.39\%$), USGS41 (l-glutamic acid, $\delta^{13}CV_{\text{PDB}} = +37.63\%$), IAEA-CH-6 (sucrose, $\delta^{13}CV_{\text{PDB}} = -10.45\%$), USGS25 (ammonium sulphate, $\delta^{15}N_{\text{AIR}} = -30.41\%$), IAEA-N-1 (ammonium sulphate, $\delta^{15}N_{\text{AIR}} = +0.43\%$) and IAEA-N-2 (ammonium sulphate, $\delta^{15}N_{\text{AIR}} = +20.41\%$), are run in duplicate for every ten unknown samples. Results are corrected for linearity and instrumental drift and are reported as per mil ($\%$) relative to the internationally accepted standards V-PDB and AIR, with 1σ precisions of ±0.2 and ±0.3 $\%$ for $\delta^{13}C$ and $\delta^{15}N$, respectively. Collagen integrity was assessed according to the following criteria: (i) C/N ratio in the range 2.9 to 3.6 (DeNiro 1985) and (ii) minimum %C and %N as outlined by Ambrose (1990).

Less than 1 % collagen yield was obtained from 22 samples (seven caprines, 11 cattle and four pig). A further nine samples (one caprine, seven pig and one sheep) had a collagen yield of wt% >1.0 % but when measured failed to meet the criteria cited for well-preserved collagen. These samples were excluded from the discussion below.

### Results

The average carbon isotope values of the domesticates (cattle, caprines and pigs) are typical of animals foraging predominantly on C$_3$ resources.

The domestic caprine $\delta^{13}C$ and $\delta^{15}N$ values were found to be relatively homogeneous, with average $\delta^{13}C = -19.2 \pm 0.5\%$ and $\delta^{15}N = 6.4 \pm 0.7\%$ ($n = 38$), and are typical of herbivores consuming exclusively C$_3$ resources (cf. Pearson et al. 2007). Little difference in the average isotope values of goat and sheep is evident (sheep average $\delta^{13}C = -19.1 \pm 0.5\%$ and
Table 2 Stable isotope data and collagen preservation indicators of Çamlıbel Tarlas domesticate remains (previously published in Pickard et al. 2016)

| Sample ID (GUsi) | Species   | Phase | $\delta^{13}$C | $\delta^{15}$N | C/N | %N  | %C  |
|------------------|-----------|-------|----------------|----------------|-----|-----|-----|
| 2202             | Cattle (*Bos*) | ÇBT III | −19.4 | 5.9  | 3.1 | 13.8 | 37.1 |
| 2205             | Cattle (*Bos*) | FPEU    | −19.6 | 6.0  | 3.2 | 14.6 | 39.9 |
| 2207             | Cattle (*Bos*) | ÇBT III | −19.4 | 8.0  | 3.2 | 13.3 | 35.9 |
| 2270             | Cattle (*Bos*) | ÇBT III | −18.1 | 6.2  | 3.2 | 13.6 | 37.7 |
| 2271             | Cattle (*Bos*) | ÇBT IV  | −18.9 | 7.7  | 3.2 | 14.8 | 40.7 |
| 2272             | Cattle (*Bos*) | ÇBT III | −17.6 | 9.8  | 3.2 | 14.2 | 39.1 |
| 2273             | Cattle (*Bos*) | ÇBT IV  | −19.0 | 8.1  | 3.2 | 14.3 | 39.8 |
| 2274             | Cattle (*Bos*) | ÇBT II  | −19.4 | 9.7  | 3.2 | 13.3 | 36.7 |
| 2275             | Cattle (*Bos*) | ÇBT I   | −16.8 | 7.0  | 3.2 | 12.1 | 33.6 |
| 2276             | Cattle (*Bos*) | ÇBT I   | −18.3 | 6.1  | 3.2 | 13.7 | 37.5 |
| 2326             | Cattle (*Bos*) | ÇBT II  | −19.4 | 6.7  | 3.2 | 13.3 | 36.9 |
| 2327             | Cattle (*Bos*) | ÇBT I   | −18.2 | 6.8  | 3.3 | 15.6 | 43.9 |
| 2328             | Cattle (*Bos*) | ÇBT III | −20.1 | 7.4  | 3.3 | 13.6 | 37.4 |
| 2329             | Cattle (*Bos*) | ÇBT I   | −19.9 | 6.1  | 3.2 | 15.8 | 43.9 |
| 2330             | Cattle (*Bos*) | ÇBT II  | −19.5 | 8.6  | 3.3 | 14.1 | 39.5 |
| 2331             | Cattle (*Bos*) | ÇBT I   | −18.7 | 6.5  | 3.3 | 15.6 | 43.4 |
| 2332             | Cattle (*Bos*) | ÇBT I   | −18.3 | 6.7  | 3.3 | 15.4 | 43.4 |
| 2333             | Cattle (*Bos*) | ÇBT IV  | −18.8 | 6.3  | 3.2 | 12.4 | 34.1 |
| 2334             | Cattle (*Bos*) | ÇBT II  | −17.4 | 8.9  | 3.3 | 14.9 | 41.6 |
| 2335             | Cattle (*Bos*) | ÇBT IV  | −18.2 | 9.1  | 3.2 | 14.7 | 40.8 |
| 3096             | Cattle (*Bos*) | SPEU    | −19.6 | 6.4  | 3.3 | 11.4 | 31.8 |
| 3114             | Cattle (*Bos*) | FPEU    | −18.5 | 5.5  | 3.2 | 11.3 | 31.4 |
| 3115             | Cattle (*Bos*) | ÇBT I   | −17.0 | 7.5  | 3.2 | 11.8 | 32.6 |
| 3116             | Cattle (*Bos*) | ÇBT IV  | −17.5 | 7.4  | 3.3 | 10.7 | 30.1 |
| 3117             | Cattle (*Bos*) | ÇBT III/IV | −20.1 | 7.4  | 3.3 | 13.0 | 36.7 |
| 3118             | Cattle (*Bos*) | ÇBT III | −17.6 | 7.4  | 3.2 | 14.2 | 39.4 |
| 3119             | Cattle (*Bos*) | ÇBT I   | −17.6 | 6.5  | 3.3 | 13.8 | 38.9 |
| 3120             | Cattle (*Bos*) | ÇBT II  | −19.7 | 7.3  | 3.3 | 13.7 | 38.6 |
| 3135             | Cattle (*Bos*) | ÇBT I   | −18.8 | 6.8  | 3.3 | 12.7 | 36.3 |
| 3136             | Cattle (*Bos*) | ÇBT III | −19.3 | 6.2  | 3.3 | 13.1 | 37.0 |
| 3137             | Cattle (*Bos*) | ÇBT III | −18.4 | 6.5  | 3.3 | 10.3 | 29.2 |
| 3143             | Cattle (*Bos*) | ÇBT I   | −18.2 | 6.9  | 3.2 | 13.6 | 37.5 |
| 3144             | Cattle (*Bos*) | ÇBT IV  | −18.3 | 6.3  | 3.2 | 12.4 | 34.3 |
| 3145             | Cattle (*Bos*) | SPEU    | −19.2 | 7.5  | 3.2 | 14.3 | 39.7 |
| 3147             | Cattle (*Bos*) | FPEU    | −17.7 | 6.8  | 3.2 | 12.3 | 34.2 |
| 3149             | Cattle (*Bos*) | SPEU    | −18.1 | 8.2  | 3.3 | 10.6 | 29.8 |
| 3154             | Cattle (*Bos*) | SPEU    | −19.2 | 5.9  | 3.2 | 13.1 | 36.2 |
| 3155             | Cattle (*Bos*) | SPEU    | −19.5 | 6.0  | 3.3 | 11.6 | 32.4 |
| 3156             | Cattle (*Bos*) | FPEU    | −19.8 | 7.1  | 3.2 | 11.7 | 32.4 |
| 3157             | Cattle (*Bos*) | ÇBT I   | −20.0 | 6.1  | 3.2 | 12.4 | 34.3 |
| 2325             | Caprine     | ÇBT III | −19.2 | 6.5  | 3.2 | 14.8 | 41.3 |
| 3017             | Caprine     | ÇBT IV  | −18.6 | 7.9  | 3.2 | 12.7 | 35.2 |
| 3022             | Caprine     | ÇBT I   | −19.6 | 7.3  | 3.3 | 14.5 | 40.3 |
| 3023             | Caprine     | ÇBT II  | −19.4 | 6.6  | 3.3 | 12.4 | 34.6 |
| 3092             | Caprine     | ÇBT III | −19.5 | 7.2  | 3.2 | 13.2 | 36.7 |
| 3254             | Caprine     | ÇBT I   | −19.4 | 6.1  | 3.2 | 13.2 | 36.8 |
| 3255             | Caprine     | ÇBT II  | −19.9 | 5.5  | 3.3 | 5.0  | 14.2 |
| 3256             | Caprine     | ÇBT I   | −19.3 | 6.1  | 3.2 | 13.2 | 36.4 |
| 3257             | Caprine     | ÇBT II/III | −19.4 | 7.2  | 3.2 | 13.1 | 36.2 |
| Sample ID (GU6i) | Species | Phase   | δ¹³C | δ¹⁵N | C/N | %N | %C |
|-----------------|---------|---------|------|------|-----|----|----|
| 3258            | Caprine | ÇBT III/IV | −19.6 | 7.2  | 3.3 | 7.2 | 24.1 |
| 3259            | Caprine | ÇBT III  | −18.8 | 6.2  | 3.2 | 14.3 | 39.6 |
| 3090            | Goat (Capra hircus) | SPEU | −20.2 | 4.9  | 3.3 | 15.3 | 43.1 |
| 3161            | Goat (Capra hircus) | ÇBT IV | −18.0 | 6.0  | 3.2 | 13.4 | 37.2 |
| 3164            | Goat (Capra hircus) | ÇBT III | −19.3 | 5.1  | 3.2 | 10.6 | 29.1 |
| 3168            | Goat (Capra hircus) | SPEU | −19.6 | 6.5  | 3.2 | 8.9  | 24.8 |
| 2204            | Sheep (Ovis aries) | ÇBT I  | −18.8 | 5.7  | 3.2 | 12.0 | 32.5 |
| 2268            | Sheep (Ovis aries) | ÇBT III | −19.4 | 7.8  | 3.3 | 13.7 | 38.2 |
| 3018            | Sheep (Ovis aries) | ÇBT IV | −19.7 | 5.4  | 3.3 | 12.1 | 34.0 |
| 3019            | Sheep (Ovis aries) | ÇBT I  | −19.0 | 6.2  | 3.3 | 15.5 | 43.4 |
| 3020            | Sheep (Ovis aries) | FPEU | −19.2 | 7.1  | 3.2 | 13.9 | 38.4 |
| 3021            | Sheep (Ovis aries) | ÇBT III | −19.6 | 6.4  | 3.3 | 7.6  | 21.8 |
| 3024            | Sheep (Ovis aries) | ÇBT I  | −18.1 | 6.7  | 3.2 | 13.7 | 38.0 |
| 3025            | Sheep (Ovis aries) | ÇBT III | −19.2 | 7.0  | 3.3 | 13.5 | 37.6 |
| 3026            | Sheep (Ovis aries) | ÇBT I  | −19.0 | 6.1  | 3.2 | 14.7 | 40.6 |
| 3027            | Sheep (Ovis aries) | ÇBT II | −19.3 | 6.1  | 3.2 | 13.4 | 36.9 |
| 3089            | Sheep (Ovis aries) | ÇBT III | −19.2 | 6.4  | 3.2 | 15.6 | 43.2 |
| 3091            | Sheep (Ovis aries) | SPEU | −18.7 | 6.6  | 3.3 | 11.0 | 30.7 |
| 3093            | Sheep (Ovis aries) | ÇBT III | −19.6 | 7.1  | 3.2 | 14.6 | 40.4 |
| 3094            | Sheep (Ovis aries) | ÇBT IV | −19.0 | 6.2  | 3.2 | 13.1 | 36.3 |
| 3095            | Sheep (Ovis aries) | ÇBT IV | −19.1 | 6.0  | 3.2 | 13.6 | 37.7 |
| 3097            | Sheep (Ovis aries) | SPEU | −20.2 | 5.6  | 3.2 | 14.6 | 40.6 |
| 3098            | Sheep (Ovis aries) | FPEU | −19.3 | 6.5  | 3.3 | 7.7  | 21.9 |
| 3158            | Sheep (Ovis aries) | ÇBT II | −19.5 | 5.9  | 3.3 | 13.9 | 38.8 |
| 3163            | Sheep (Ovis aries) | FPEU | −18.2 | 5.9  | 3.2 | 13.5 | 36.9 |
| 3250            | Sheep (Ovis aries) | ÇBT I  | −18.8 | 7.1  | 3.3 | 14.6 | 40.9 |
| 3252            | Sheep (Ovis aries) | ÇBT III | −19.3 | 6.5  | 3.2 | 14.2 | 39.6 |
| 3251            | Sheep (Ovis aries) | ÇBT II | −18.5 | 5.7  | 3.2 | 13.0 | 35.8 |
| 3253            | Sheep (Ovis aries) | FPEU | −19.6 | 6.0  | 3.2 | 13.9 | 38.5 |
| 2203            | Pig (Sus) | ÇBT III | −19.0 | 7.3  | 3.2 | 13.1 | 35.8 |
| 2651            | Pig (Sus) | SPEU | −20.1 | 5.5  | 3.2 | 9.8  | 27.4 |
| 2652            | Pig (Sus) | ÇBT III | −19.5 | 7.1  | 3.2 | 13.7 | 37.8 |
| 2653            | Pig (Sus) | ÇBT I  | −19.9 | 5.6  | 3.4 | 4.5  | 12.9 |
| 2655            | Pig (Sus) | ÇBT II | −18.7 | 4.7  | 3.3 | 8.5  | 24.0 |
| 2657            | Pig (Sus) | ÇBT II | −19.2 | 7.3  | 3.2 | 11.8 | 32.9 |
| 2658            | Pig (Sus) | ÇBT IV | −18.9 | 5.9  | 3.3 | 10.2 | 29.0 |
| 2659            | Pig (Sus) | ÇBT II | −19.4 | 6.6  | 3.3 | 9.7  | 27.1 |
| 2661            | Pig (Sus) | FPEU | −19.8 | 8.0  | 3.2 | 9.7  | 26.9 |
| 2662            | Pig (Sus) | ÇBT IV | −19.8 | 6.7  | 3.3 | 10.9 | 30.9 |
| 2663            | Pig (Sus) | ÇBT III | −20.2 | 5.7  | 3.4 | 7.3  | 21.2 |
| 2664            | Pig (Sus) | SPEU | −20.0 | 6.5  | 3.3 | 8.9  | 25.3 |
| 2666            | Pig (Sus) | ÇBT IV | −18.7 | 6.0  | 3.3 | 8.7  | 24.8 |
| 2667            | Pig (Sus) | ÇBT II | −19.4 | 6.4  | 3.3 | 12.6 | 35.5 |
| 2668            | Pig (Sus) | FPEU | −19.7 | 7.6  | 3.5 | 4.0  | 12.0 |
| 2669            | Pig (Sus) | ÇBT IV | −20.3 | 6.7  | 3.3 | 10.4 | 29.2 |
| 2926            | Pig (Sus) | ÇBT I  | −19.1 | 6.0  | 3.2 | 13.2 | 36.2 |
| 2927            | Pig (Sus) | ÇBT IV | −19.6 | 7.2  | 3.2 | 15.4 | 42.1 |
| 2928            | Pig (Sus) | ÇBT I  | −19.4 | 6.3  | 3.2 | 13.5 | 37.1 |
| 3015            | Pig (Sus) | ÇBT I  | −19.0 | 6.7  | 3.2 | 14.1 | 39.1 |
\[ \delta^{15}N = 6.4 \pm 0.6\, \%e \quad (n = 23); \ \text{goat average} \ \delta^{13}C = -19.3 \pm 0.8\, \%e \]
\[ \text{and} \ \delta^{15}N = 5.8 \pm 0.8\, \%e \quad (n = 4) \].

The pigs sampled were identified as domestic based on their small phenotypic size in comparison to the wild progenitor and on the fact that other hunted animals were a very small component of the faunal assemblage (Bartosiewicz and Gillis 2011; Bartosiewicz et al. 2013, 111, Figs. 7 and 8). One of the pigs sampled, GUsi-2663, is a sub-adult specimen. However, the \( \delta^{13}C \) and \( \delta^{15}N \) values of this specimen overlap those obtained for the adults, i.e. no suckling enrichment effect is
evident by this age. This specimen is therefore considered along with the adults. Pig mean δ¹³C and δ¹⁵N values suggest a relatively uniform diet, with average δ¹³C and δ¹⁵N of −19.3 ± 0.4 and 6.8 ± 0.6 ‰ (n = 54), respectively.

By comparison, cattle δ¹³C and δ¹⁵N values are more variable, with a relatively large range in both isotope values evident (see Table 2 and Fig. 4). The average values with standard deviation are δ¹³C = −18.7 ± 0.9 ‰ and δ¹⁵N = 7.1 ± 1.1 ‰ (n = 40). The range of cattle δ¹⁵N values is wide, spanning 4.3 ‰ with a minimum value of 5.5 ‰ and a maximum value of 9.8 ‰. The range of cattle δ¹³C values is also broad, from −20.1 to −17.0 ‰. The variation in cattle stable isotope values does not correspond to diachronic change (there are no statistically significant differences in the δ¹³C and δ¹⁵N values between bones associated with various phases of activity at Çamlıbel Tarläs).

Statistical evaluation of domesticate herbivore stable isotope values

Bartlett’s test was used to assess the null hypothesis that the variance of the δ¹³C values of the domesticates (cattle, caprine and pig) is homogenous. The variance of the domesticate δ¹³C values was found to be significantly different (Bartlett χ² = 25.582 with probability 0.000003, χ² value for significance at 5 % and d.f. 2 is >5.991). Figure 5 shows the distribution of δ¹³C values by taxon. The non-parametric Kruskal–Wallis test was used to assess the null hypothesis that the δ¹³C values of the domesticates were uniform. The δ¹³C values were found to be statistically different (K = 12.466179, p = 0.001963). The same statistical tests were undertaken for the domesticates with the exclusion of goats (owing to small sample size) and the caprines that could not be identified to species level. Bartlett’s test indicated that the variance of the domesticate δ¹³C values (i.e. cattle, pig and sheep) remained significantly different (Bartlett χ² = 24.763 with probability 0.000004, χ² value for significance at 5 % and d.f. 2 is >5.991). The Kruskal–Wallis test also indicated that there is a statistically significant difference in the δ¹³C values of the different domesticates (K = 12.938133, p = 0.001551, for cattle, caprine and pig; K = 12.466179, p = 0.0001963, for cattle, sheep and pig).

The same sets of statistical analyses were repeated to compare the δ¹⁵N values of the domestic herbivores. The variances of the δ¹⁵N values were found to be unequal (Bartlett χ² = 9.957 with probability 0.002069, χ² value for significance at 5 % and d.f. 2 is >5.991, for cattle, caprines and pig; Bartlett χ² = 12.362 with probability 0.006885, for cattle, sheep and pig) —— see Fig. 6 for distribution of δ¹⁵N values. The δ¹⁵N values of the domesticates are significantly different (Kruskal–Wallis test—K = 10.135896, p = 0.006295, for cattle, caprines and pig; K = 9.423774, p = 0.008988, for cattle, sheep and pig).

A post hoc Mann-Whitney U test was used to examine pairwise differences in stable isotope values. Increased
stringency was employed to compensate for multiple testing \( p \) has significance at \( \leq 0.05/3 \), i.e. 0.0167). The \( p \) values of the Mann-Whitney \( U \) test and a summary of statistical significance are presented in Tables 3, 4 and 5. Figure 7 provides a graphical representation of the isotopic relationships of the cattle, caprines and pigs for both carbon and nitrogen values based on the Mann-Whitney results.

**Discussion**

**Domesticate forage and animal keeping at Çamlıbel Tarlası**

Statistical analysis of the carbon and nitrogen stable isotope values of the domesticates has demonstrated that the cattle have distinctive stable isotope values from both the pigs and the caprines at Çamlıbel Tarlası. There are several possible diet-related explanations that may account for these differences including (i) differences in foddering practices, (ii) differences in foraging behaviour and (iii) differences in areas grazed.

Domesticates often have multiple uses and may be fed distinctive diets depending on function (Bayer et al. 2003). For example, in traditional small-scale farming economies, cattle kept principally for milk may be non-grazed, fed exclusively on fodder crops to ensure high quality diet to maximise productivity (van Shaik et al. 1996). At Late Neolithic/Early Chalcolithic Ilıpar, barley kernels and chaff were recovered in the dung of stalled cattle, interpreted by Cappers (2008, p. 120) as a diet specific to ‘beasts that are used for ploughing’ (Cappers 2008, p. 120). Although the energy requirements of non-female draught cattle have been demonstrated to be similar to that of non-draught bulls (Goe and McDowell 1980), cows used for traction show reduced fertility and milk production partially mitigated if nutritionally high quality feed is provided (Jabbar 1993). The majority of the identified cattle remains were those of mature animals, a mortality profile consistent with use for traction or dairy (Bartosiewicz and Gillis 2011). There is no archaeological evidence to support confined stalling or selective foddering of cattle at Çamlıbel Tarlası. However, the most recent settlement at Çamlıbel Tarlası was surrounded by a boundary wall, a relatively weak construction which was clearly not defensive in character. Such a wall would have been extremely useful for the protection of livestock in an environment which was potentially home to a range of large predators such as leopards, lions, bears and wolves—the latter still present today.

Domesticates have distinct ingestive and digestive capabilities (Prache et al. 1998) resulting in different behaviours in free-foraging animals. Pigs, as facultative omnivores, might be anticipated to have a distinctive diet from the domesticated ruminants. The diets of domestic pigs vary depending on husbandry practices. Pig farmers traditionally practice one of three feeding strategies, (i) free roaming and foraging; (ii) grazing in fields often with other livestock; and (iii) penning,
i.e. confined to spaces such as pig sties. Free roaming pigs tend to forage over large areas and while they consume a wide range of animal foods including insects, eggs, small mammals and carrion, they are predominantly herbivorous (Studnitz et al. 2007). Penned pigs will generally be fed on plants and on domestic/household waste. If the waste products include animal proteins (e.g. milk and meat or even faeces) resulting pig δ15N values will be higher than those of free roaming or field grazed animals. However, as indicated above, the δ13C and δ15N values of the pigs at Çamlıbel Tarlası are statistically equivalent to those of the sheep as well as the extended group that includes all caprines (i.e. obligate herbivores), suggesting that the pigs were unlikely to have been fed on domestic refuse often rich in animal proteins.

Cattle and sheep, despite both being grazing ruminants, may also have distinctive foraging behaviours. Sheep tend to target higher quality forage owing to reduced gut size and shorter digestion times as well as being able to be more selective in forage owing to the shape and reduced size of the ovine dental arcade (Prache et al. 1998). Cattle tolerate lower quality and rougher forage more readily than sheep (Prache et al. 1998).

Local vegetation heterogeneity accompanied by different foraging behaviours could potentially account for the differences evident in the isotope values of cattle and sheep at Çamlıbel Tarlası. Given the range of the cattle δ13C values at Çamlıbel Tarlası, from −20.1 up to −17.0 ‰, it could be argued (cf. Pearson et al. 2007; Budd et al. 2013) that the source of this heterogeneity is the inclusion (or greater inclusion) of C4 plants in cattle diet. However, all of the crop and wild grass species identified at Çamlıbel Tarlası use the C3 photosynthetic pathway (Papadopoulou and Bogaard 2012, Table 4). Two plants recovered were not identifiable to species level, one from the borage (Boraginaceae) or sedge (Cyperaceae) families and the other from the saltbush genus (Atriplex sp.). These families include both C3 and C4 species (Edwards and Walker 1983). However, the presence of these broad taxa does not convincingly indicate the presence of C4 plant species in the Çamlıbel Tarlası locale. Furthermore, it is unlikely that C4 cereal crops such as millet (Panicum miliaceum) were available to the inhabitants of Çamlıbel Tarlası. Millet was not cultivated in central Anatolia in large quantities before at least the Bronze Age and possibly later (e.g. Nesbitt and Summers 1988; Riehl and Nesbitt 2003).

An alternative scenario to heterogeneity in local plant forage is the movement of domestic livestock between different pastures, potentially some distance from settlements and possibly with access to isotopically distinct plants (cf. Peters et al. 2013). Although C3 plants have dominated Anatolian vegetation throughout the Holocene (Rao et al. 2012), C4 plants were certainly present at least regionally. Consumption of C4 plants is clearly indicated by the range of δ13C values of wild cattle (Bos spp.) and the plant remains at the Aceramic Neolithic site of Aşıklı Höyük in the Cappadocian region of Turkey (Pearson et al. 2007). C4 plants have also been recovered from a number of sites in Anatolia and in some cases were evidently

### Table 3

|        | Cattle | Caprines | Pig |
|--------|--------|----------|-----|
| δ13C   |        |          |     |
| Caprines | 0.032544 |          |     |
| Pig     | 0.000630 | 0.138028 |     |
| Sheep   | 0.139705 | 0.466061 | 0.039171 |

### Table 5

|        | Cattle | Caprines | Pig |
|--------|--------|----------|-----|
| δ13C   |        |          |     |
| Cattle |        |          |     |
| Caprines | 0.003240 |          |     |
| Pig     | 0.232884 | 0.025863 |     |
| Sheep   | 0.004600 | 0.743375 | 0.22187 |

### Table 4

|        | Cattle | Caprines | Pig |
|--------|--------|----------|-----|
| δ15N   |        |          |     |
| Cattle |        |          |     |
| Caprines | 0.0003240 |          |     |
| Pig     | 0.232884 | 0.025863 |     |
| Sheep   | 0.004600 | 0.743375 | 0.22187 |

Fig. 7 Graphical representation of statistical significance based on Mann-Whitney U test with increase stringency. Lines between the groups represent statistically indistinguishable isotope values. Statistical equivalence of δ15N values is indicated by the green line, while that of δ13C is indicated by the red line.
consumed by livestock. For example, at Çatalhöyük, located in south-central Anatolia, C₄ grasses *Aeluropus*, *Crypsis* and *Sporobolus*, as well as *Eleocharis* (generally a C₄ plant although Bruhl and Wilson (2007) describe C₃/C₄ intermediate and variant species), were recovered from animal dung (Richards et al. 2003; Bogaard et al. 2013a). The C₃ ruderal, sun spurge (*Euphorbia helioscopia*), is present at Late Neolithic/Early Chalcolithic Ilıncar, in North West Anatolia, but is not abundant (Cappers 2008).

A further possibility cannot be ruled out, that is the external, and possibly long-distance, provisioning of smaller settlements such as Çamlıbel Tarlası with at least some of their livestock or meat. Arbuckle (2012) noted increasing complexity in the management of sheep herds throughout the Chalcolithic in central Anatolia, which were at least in part distributed to settlements by specialist mobile pastoralists. Concrete evidence for far-reaching trade contacts at Çamlıbel Tarlası include finds of cockle shells (*Cardiidae*), which must have originated from either the Black Sea or the Mediterranean, obsidian from Cappadocia, flint blades from unknown exotic sources and a casting mold for ring-shaped figurines indicating an ideological link to the Southern Balkans (Schoop 2011; Schoop and Lehner 2013). Livestock may thus have been imported in the form of exhumed human remains (although three outliers with comparatively high δ¹⁵N values may be an exception). By contrast, at Çatalhöyük the relatively low average δ¹⁵N value of the domesticates is 6.7 ‰. Assuming a diet-herbivore offset of 4 ‰, the average δ¹⁵N value of the domesticate forage at Çamlıbel Tarlası was 2.7 ‰; this relatively low forage δ¹⁵N value suggests that these animals were not fed on manured crops/stubble (cf. Bogaard et al. 2013b). However, identifying manuring practices and/or animal penning from the stable isotope values of domesticates is non-trivial. In part, this is a consequence of the temporal and spatial variability in soil δ¹⁵N values (e.g. Ambrose 1991). Also problematic is the inclusion of ¹⁵N-depleted pulse crops in domesticate diet, which may mask the effects of consuming manured cereals or stubble. Moreover, ¹⁵N enrichment of pulse crops is evident only with intensive and protracted manuring (Fraser et al. 2011; Bogaard et al. 2013b). Pulses including bitter vetch and lentil were identified at Çamlıbel Tarlası and may have comprised a significant part of human (see Pickard et al. 2016) and/or domesticate diet.

The comparative analysis of the domesticate stable isotope datasets presented above is offered cautiously because of (i) spatial and temporal variations in environmental δ¹³C and δ¹⁵N values (e.g. Schwartz et al. 1999; van Klinken et al. 1994; van Klinken et al. 2000) and the broad geographical

**Domesticate forage and animal keeping across prehistoric Anatolia**

The results from Çamlıbel Tarlası add to a small but growing body of isotope data from domesticates at Neolithic and Chalcolithic sites across prehistoric Anatolia. At Çamlıbel Tarlası, the relatively low δ¹⁵N values of the pigs in comparison to ruminants suggest that they were likely free roaming and foraging. Pearson et al. (2015) also noted that the relatively low average δ¹⁵N value of pig in comparison to the human inhabitants and domesticates of Neolithic Çatalhöyük suggested that these animals were not fed on domestic waste (although three outliers with comparatively high δ¹⁵N values may be an exception). By contrast, at the PPNB site of Nevalı Çori in southeast Turkey, domestic pig and humans have similar δ¹⁵N mean values (5.5 ± 1.9 and 6.1 ± 1.0 ‰, respectively) and ranges (3.9 to 8.2 ‰ and 4.4 to 8.8 ‰, respectively) implying similar diets, i.e. at Nevalı Çori, the pigs were likely fed on household waste and thus possibly penned (Lösch et al. 2006). However, only four pig specimens were analysed at this site. The wide ranges of δ¹³C and δ¹⁵N values of sheep and cattle from Çatalhöyük were attributed by Pearson et al. (2007, 2015) to the grazing of herds in different areas—in pastures with only C₃ species, as well as those with both C₃ and C₄ plants. Extra-local grazing of at least some cattle is paralleled at Çamlıbel Tarlası. By contrast, the sheep from Çamlıbel Tarlası have relatively homogeneous δ¹³C and δ¹⁵N values. The differences in sheep forage and by implication stock-keeping practices between Çatalhöyük and Çamlıbel Tarlası may reflect the distinctive nature of the two sites. The scale of Çatalhöyük, a large agglomerated village or proto-urban site spanning c. 130,000 m² (Hodder and Cessford 2004), likely necessitated extra-household herding strategies and grazing in various pastures potentially at some distance from the site (Pearson et al. 2015). In contrast, Çamlıbel Tarlası was a small-scale rural settlement covering an area of no more than 250 m²—small herds of sheep were likely managed locally.
range and chronological span of sites with stable isotope datasets in prehistoric Anatolia, (ii) the difficulty of distinguishing early domesticates from wild progenitors from morphological characteristics at Early Neolithic sites (see Zeder et al. (2006) for summary), (iii) the small datasets available from some sites and (iv) the complexities of identifying the consumption of pulses.

Conclusion

Carbon and nitrogen stable isotope analyses indicate that the domesticates from Çamlıbel Tarlası had diets based mainly on C₃ resources. Of all the domesticates at Çamlıbel Tarlası, cattle exhibit the widest range of δ¹³C and δ¹⁵N values. Moreover, cattle have statistically distinct isotope values from both the sheep/caprines, and the pigs recovered from the site. This indicates that the cattle had distinctive foraging behaviour not only from that of the pigs (which is perhaps not surprising) but also from that of the sheep. The δ¹³C values of the cattle hint at the inclusion of C₄ plants in diet. However, no C₄ plants were identified in the plant macro assemblage recovered at the site and this suggests (if indeed C₄ plants were included in the diet of cattle) that they were grazing in non-local pastures. The inter-species variability in isotope values points to distinctive and potentially complex foraging and/or feeding behaviours at Late Chalcolithic Çamlıbel Tarlası.

Acknowledgments
This research was supported by the British Academy/Leverhulme Small Research Grants (SG121910) and the School of History, Classics and Archaeology, University of Edinburgh. The excavations at Çamlıbel Tarlası were conducted as a collaborative project by the University of Edinburgh and the German Archaeological Institute. Thanks are extended to Professor Gordon Cook (SUERC). We are also grateful to Juliet Voon, Samantha Williamson, Lisa Bird and Caroline Hall-Eastman who helped select and prepare the samples for analysis.

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