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New light on early caprine herding strategies from isotope analysis: a case study from Neolithic Anatolia

J.A. Pearson [a,*], H. Buitenhuis [b], R.E.M. Hedges [c], L. Martin [d], N. Russell [e], K.C. Twiss [f]

[a] School of Archaeology, Classics and Egyptology, Hartley Building, Brownlow Street, University of Liverpool, Liverpool, L69 3GS, UK
[b] Center for Archaeological Research and Consultancy, Groningen, The Netherlands
[c] Research Laboratory for Archaeology and the History of Art, Dyson Perrins Building, South Parks Road, University of Oxford, Oxford, OX1 3QY, UK
[d] Institute of Archaeology, University College London, London, WC1H 0PY, UK
[e] Department of Anthropology, Cornell University, Ithaca, NY 14853, USA
[f] Department of Anthropology, Stony Brook University, Stony Brook, NY 11794-4364, USA

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Abstract

The measurement of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of caprine bone collagen from the Neolithic sites of Çatalhöyük and Aşıklı Höyük in south-central Anatolia have allowed examination of exploitation and herding practices of sheep and goats. The isotope values from protodomestic caprines at Aşıklı Höyük suggests that these animals were consuming very similar foods to each other and were all confined to the same or similar environments with no access to C_4 plants. At Çatalhöyük, the results show how the caprine management strategy develops from the strategy seen at Aşıklı Höyük into a more varied practice at an early stage as the site grows with an increasing dietary contribution obtained from C_4 plants. No change in diet is isotopically discernible at Aşıklı Höyük. Interestingly, no distinction could be made between the diets of sheep and goats at either site. Therefore, such studies are a useful method of examining the development of early herding or management strategies of caprines in the Near East.

Keywords: Caprines; Carbon isotopes; Nitrogen isotopes; Herding; Neolithic

1. Introduction

The Near East provides considerable evidence for some of the earliest close management of wild plant and animal resources by humans, particularly species which have come to dominate the diet of modern humans in Europe and the Near East (Renfrew, 2006). Key economic and social developments took place in the Neolithic, a period described by some as revolutionary, as humans adopted increasingly sedentary behaviours and took control of their environment by domesticating plants/animals (Childe, 1925). In Anatolia, divergent pastoral strategies seem to have developed in central and southeastern areas relating specifically to herding in the Neolithic (cf. Martin et al., 2002; Buitenhuis, 1997; Rosenberg et al., 1998; Hongo and Meadow, 2000; Hongo et al., 2002; Pearson, 2004) and are paralleled by differing social practices and contrasting material culture that may be related to these different economic strategies (Cauvin, 2000). We present results of stable carbon and nitrogen isotope analysis from the bone collagen of 109 caprines selected from the Central Anatolian sites of Çatalhöyük East (hereafter Çatalhöyük) and Aşıklı Höyük (Fig. 1). These results are used to explore the management and exploitation of caprines in order to document directly the degree of variability in early herding strategies and their interrelationship with Neolithic lifeways.

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* Corresponding author. Tel.: +44 151 794 5050.
E-mail address: pearson@liv.ac.uk (J.A. Pearson).

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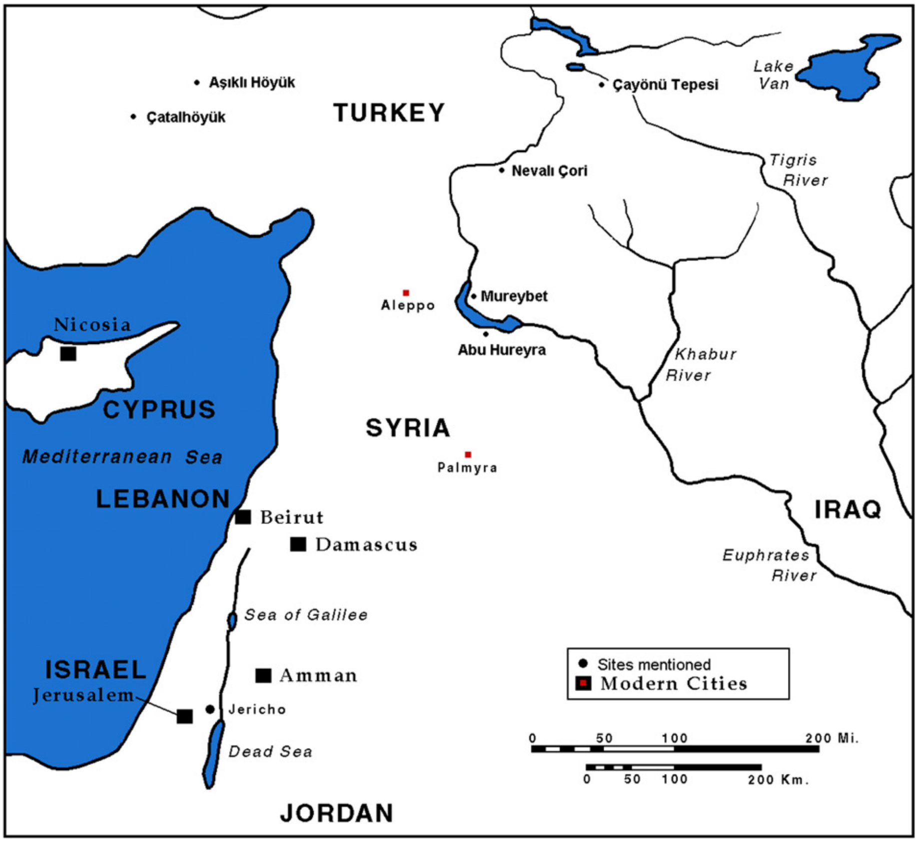

Fig. 1. Location map of Neolithic Anatolia with key sites and locations.

1.1. Animal exploitation in Neolithic Anatolia

Anatolia is within the natural distribution zone of the four most heavily exploited animals in the Neolithic: sheep, goats, cattle and pigs (Martin et al., 2002). Current research shows early evidence for sheep and goat domestication dating to about 10,000 years ago (Zeder and Hesse, 2000; Peters et al., 1999). The main source of animal protein in Neolithic central Anatolia was wild and domestic caprines and bovines, but caprines dominate assemblages and became the focus of emerging management or herding processes at most sites. This is in contrast to Neolithic sites in eastern Anatolia such as Çayönü Tepesi and Nevalı Çori where hunting continued and a greater exploitation of animals unsuited to steppe environment, such as suids, occurs (Peters et al., 1999). While there is some evidence for the origins of caprine domestication, the subsequent developments in early herding strategies have been comparatively neglected. We hope that this study will demonstrate the utility of isotope analysis in determining how early pastoral practices evolved during the Neolithic. We suggest that at sites where the human population was still small that a more limited scale of caprine herding or exploitation occurred where flocks were not moved large distances. But as sites expanded or later ones were established, herding must have been devolved or transferred to emerging specialized herders to separate growing flocks and pasture them further away from the settlement.

1.2. Stable isotope analysis and dietary inquiry in Neolithic Anatolia

The ability to look beyond the more generalised dietary information usually generated from the study of archaeozoology, archaeobotany and palaeoecology is a crucial development in the study of past diet. Through stable isotope analysis it is possible to ask questions that relate directly to individuals and to overcome issues relating to the visibility, survivability and importance of certain food sources in the archaeological record (see van der Veen, 2003 for discussion). This focus on the individual—which is characteristic of isotopic analysis—enables more complex variations in the socio-economic practices of past communities to be evaluated. Topics of inquiry may include the identification of status, agro-pastoral regimes and even the nature of consumption events such as feasting deposits and identification of divergent diets in the individual animals that make up such assemblages. To date, there have only been a few studies that have used isotopic analysis as a tool in diet reconstruction relating to the Near East and all use relatively small populations of individual genera to represent potential sources of animal protein (Bocherens et al., 2000, caprines $n = 10$; Bocherens et al., 2001, caprines $n = 2$, Richards et al., 2003, caprines $n = 2$; Losch et al., 2006, caprines $n = 10$). By focusing on larger populations of animals and by detecting variations in the diet of a single species exploited in a given region, this study provides a unique insight into herding strategies and animal protein provisioning in a key region of Neolithic developments in the Near East.

1.3. The archaeology of Central Anatolia

The exploitation of caprines, cattle, pigs and abundant wild resources in Neolithic Anatolia took place against a complex backdrop of indigenous and Levantine-derived influences. Anatolia is located on the western edge of the Fertile Crescent and its distance from the focus of archaeological excavations occurring in the nineteenth century and first half of the twentieth century led to the belief that prehistoric developments occurring in Anatolia were probably peripheral to mainstream developments in the Levant (Hauptmann, 1999). Indeed, until recently, scholars have tended to regard Anatolia as marginal to the Levantine zone. Independent developments, most notably in architecture and lithic technology, have been suggested for sites in south-central Anatolia such as Çatalhöyük. Özdoğan argues that the same is true for sites in the southeast such as Çayönü Tepesi (Özdoğan, 1997) while others suggest that village origins in southeastern Anatolia were heavily influenced by events in the Levantine area (Mellaart, 1975; Cauvin, 2000).

The survey and excavation results of the last 40 years have revealed substantial sites away from the usual focus of the Levant. Large sites were found such as Çatalhöyük (Mellaart, 1967; Hodder, 1996) and others with impressive iconography (Nevalı Çori: Hauptmann, 1999). Indigenous developments have been identified in lithic composition (Aşıklı Höyük: Balkan-Atlı, 1998), architecture (Çatalhöyük and Aşıklı Höyük: Duru, 2002), faunal exploitation (Çayönü Tepesi: Hongo and Meadow, 2000) and burial practices (Çayönü Tepesi: Özbek, 1988). The location of substantial Neolithic settlements in Anatolia such as Çatalhöyük and Çayönü Tepesi, at some distance from the Fertile Crescent and a key centre of Neolithic economic developments in the Near East indicates that their importance is not as centres of domestication, but lies in others spheres such as those which involve participation in trade and exchange networks (Cauvin, 2000).

1.4. The study sites

The sites of Çatalhöyük and Aşıklı Höyük have been relatively extensively excavated and possess well studied assemblages with long occupational sequences. Aşıklı Höyük is the earlier of the two sites with its terminal levels of occupation close in date to or overlapping with those from the basal levels at Çatalhöyük, thus providing an almost continuous chronology of approximately 2500 years.

Çatalhöyük is located in south-central Anatolia about 50 km from the modern city of Konya. The site was discovered in the 1950s by James Mellaart and subsequently excavated between 1961 and 1965. The earliest deposits encountered so far have been radiocarbon dated to the second half of the eighth millennium with the end of occupation occurring sometime in the late seventh millennium Cal. B.C. Occupational levels are labelled as 0 (latest) to Pre Level XII E (earliest) (Cessford, 2001). The site is particularly well known for its agglomerated architecture with walls decorated with elaborate wall paintings, plastered relief and bucrania. Baked clay female figurines are also well known from this site (Mellaart, 1967). Renewed excavations began in 1995 under the direction of Ian Hodder (Hodder, 1996). These excavations have provided considerable new data and new interpretations of site subsistence strategies. They indicate that Çatalhöyük's inhabitants did not rely primarily on cattle (Russell et al., 2005), as was previously thought (Perkins, 1969), but consumed an abundance of domestic caprines, specifically sheep rather than goat (ca. 70% through to Level VI and 80% from Level V onwards) as well as aurochs, equids, suids and some birds (Russell and Martin, 2005). This reliance upon domestic caprines as the main animal protein source was also detected in an earlier pilot isotope study at the site (Richards et al., 2003; Richards and Pearson, 2005).

Aşıklı Höyük is an earlier, Aceramic Neolithic site located next to the Melendiz River approximately 25 km east of the modern city of Aksaray on the western fringe of Cappadocia (Fig. 1) (Esin and Harmankaya, 1999). The site dates from the mid ninth to the mid eighth millennium Cal B.C. Its occupational levels are numbered 1, 2 and 3 where 1 is the earliest level. Level 2 is the most extensively excavated and studied and is further divided into 7 subphases where 2A represents the latest through to 2G as the earliest subphase of occupation. The subsistence economy of Aşıklı Höyük (level 2) focused on plant cultivation (compared with full scale agriculture) (van Zeist and de Roller, 1995; Asouti and Fairbairn, 2002) and exploitation of a narrow range in animal species is noted from the faunal assemblage (Buitenhuis, 1997). The vast majority of the faunal assemblage is caprine (approximately 80%); with sheep more commonly encountered than goat. Buitenhuis argues that the caprine assemblage suggests a proto-domestic caprine population based on a combination of large, wild-size animals but with evidence for two phenomena indicative of a controlled population: slaughtering occurring at the age for maximum achievable weight (so as to avoid feeding animals that provide no extra meat as a result) and the presence of neonatal animals, which suggests that the breeding population was kept close to the settlement. Thus, these species were not simply hunted but in fact represent early evidence for experimentation with management, which is assumed to have been a rather non-intensive regime. Wild animal resources are also present in the faunal assemblage comprising a maximum of 20% in any one level and include aurochs, cervids, suids and equids (Buitenhuis, 1997). Buitenhuis concludes that the general absence of crania and lower extremities amongst the faunal remains points to an assemblage derived from kitchen refuse rather than as a primary butchering location (Buitenhuis, 1997).

1.5. Isotopes, diet and archaeology

Carbon and nitrogen isotopes are routinely measured for evaluation of palaeodiet because these isotopes, sourced from the carbon and nitrogen biological cycles directly, are assimilated from food to consumer tissue forming a dietary average of protein consumed over a period of months or years. Thus, all food consumed by living organisms contains carbon and nitrogen, which is synthesised to become body protein. Therefore, by analysing the carbon and nitrogen in the tissues of a consumer we can gain some idea of its source and thereby identify their diet (DeNiro and Epstein, 1978, 1981; Ambrose and Norr, 1993).

Nitrogen enters the food chain through plants, as either adsorbed nitrogenous compounds in soil or fixed from atmospheric nitrogen (Cheng et al., 1964). This nitrogen is then assimilated higher up the food chain with a fixed enrichment factor (approximately 3–5 per mil. or ‰) at each step in the food chain (DeNiro and Epstein, 1981; Ambrose and Norr, 1993). This effect is known as the trophic level effect and can be exploited to understand the relationship between consumers in the food chain. Nitrogen isotopic signatures in a food web can be additionally influenced by specific environmental factors such as aridity. Studies of animals have shown a correlation between rainfall and the stable nitrogen isotope values ($\delta^{15}N$) of bone collagen. This increase in $\delta^{15}N$ may be caused through a response to drought by water conservation in animals (for discussion of current work see Ambrose, 2000). One way this is done is to minimise the amount of water lost in urine. Research suggests that nitrogen-containing urea is recycled causing preferential use of ^{14}N and resulting in an elevation of the overall $\delta^{15}N$ in bone collagen (Sealy et al., 1987). Heaton (1987) and Gröcke et al. (1997) also found a correlation between rainfall and $\delta^{15}N$ values in herbivores. However, a study of North American white-tailed deer provided no evidence for such a correlation except when deer consumed extensive amounts of C_4 plants (Cormie and Schwarcz, 1996). Ambrose (1993) reports an increase between the diet to tissue spacing during a water deficit, supporting a physiological rather than dietary explanation. Additionally, rumination is a response triggered by high cellulose (and hence lower protein) content in food and the number of cycles made by the nitrogen might be greater in areas where plant protein is lower (arid areas). C_4 plants have a greater amount of cellulose relative to protein and are found in more arid areas. This aspect of animal physiology studies has been insufficiently resolved, but is currently under re-evaluation (cf. Sponheimer et al., 2003). Non-physiological effects are caused by anthropogenic activities such as manuring (Bogaard et al., 2007). All of these phenomena result in higher $\delta^{15}N$ values over time.

Carbon enters the food chain through plants during photosynthesis and is also assimilated at successive stages in the food chain such that the types of plant forming the foundation of a food web will be reflected at each trophic level in the stable carbon isotope ratio ($\delta^{13}C$) of consumer bone collagen (DeNiro and Epstein, 1978). At the base of the food chain there is an enrichment of approximately 5‰ from plant to consumer (Ambrose and Norr, 1993). For carbon isotope purposes there are three types of plant: C_3, C_4 and CAM. Each of these names relates to the pathway followed by elemental carbon during photosynthesis of particular plants (O'Leary, 1981). C_3 plants include trees (and therefore fruit and nuts), temperate grasses, legumes and most major food crops including wheat, barley, rye and rice. C_4 plants include species of grasses (e.g. *Aleuropus* sp.) and chenopods (e.g. *Salsola* sp.) from warmer temperatures and/or saline environments and include food crops such as sugarcane, sorghum and some millets. CAM plants are mostly cacti and other succulents and bromeliads such as pineapple (O'Leary, 1981). These different photosynthetic pathways manifest isotopically where differential discrimination of ^{13}C results in clear differences in $\delta^{13}C$ values of C_3 versus C_4 plants. The mean carbon isotope values of C_3 plants is reported to be around −28‰ with a range of −34 to −22‰ in contrast to the mean value for C_4 plants which is reported at −14‰ with a range between −20 and −10‰ (O'Leary, 1988). These are modern values of uncharred seeds and must also be corrected (by around 1‰) for the effect of anthropogenic CO_2 in the atmosphere contributed from the burning of fossil fuels (Marino and McElroy, 1991). Charred C_3 and C_4 plants were analysed from Çatalhöyük in earlier work (Pearson, 2000, 2004) and the results used to establish a mean value of −23‰ for C_3 plants and −12‰ for C_4 plants. Using these values an exclusively C_3 consumer would have $\delta^{13}C$ bone collagen values around −18‰ while an exclusively C_4 feeder would have $\delta^{13}C$ values around −7‰.

Previous studies using isotope analysis as a method of reconstructing animal lifeways have focused on sequential sampling of enamel and dentinal tissues with impressive time resolutions (Balasse et al., 2003). A recent study by Makarewicz and Tuross (2006) has highlighted isotope analysis as a tool for the identification of foddering practices. These studies make important methodological contributions to the application of isotope analysis in the evaluation of the diets of archaeological populations. However, few studies have attempted to measure large archaeological populations of samples to provide an evaluation of general livestock herding strategies at local and regional scales (Bocherens et al., 2000) and none attempt to reconsider the archaeological evidence in light of the isotope evidence.

Returning to our hypothesis, at later sites with larger populations of inhabitants, we would expect the isotope evidence to reveal broad ranging diets in herded animals because they were moved over larger distances from the site and were more likely to have encountered a greater range of habitats. Broad ranging diets would be identified by more varied carbon and nitrogen isotope values in distinctive plant biomasses which are subsequently reflected in caprine tissues. Throughout the occupation at Çatalhöyük there is macrobotanical evidence for C_4 plants in small quantities (Fairbairn et al., 2005) indicating a potentially large range in animal diet from the foundation of the settlement. Thus, any variation in the way in which such plants are consumed by domestic caprines would provide a key source of evidence for animal control, particularly if this source were to increase or disappear from their diets. Alternatively, where devolved herding practices are not in operation (suggested for earlier sites with smaller human populations) and flocks were managed uniformly (closer to the settlement, with constant access to the same

Table 1
Çatalhöyük stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope results for *Ovis* and *Capra* bone collagen (measured in duplicate)

Lab no.	δ^{13}C	δ^{15}N	% collagen	% N	% C	C:N	Genus	Level
CH339	−19.27	8.31	5.31	15.17	40.47	3.12	*Ovis*	VII
CH340	−18.35	10.36	11.54	15.46	42.04	3.17	*Ovis*	VII
CH348	−18.11	10.22	9.34	15.39	41.77	3.17	*Ovis*	VII
CH349	−18.96	9.87	0.75	13.65	41.06	3.51	*Ovis*	VII
CH350	−16.91	10.43	8.67	14.91	41.02	3.21	*Ovis*	VII
CH351	−18.68	10.40	9.48	14.73	40.18	3.18	*Ovis*	VII
CH352	−18.78	10.62	8.48	15.40	41.89	3.18	*Ovis*	VII
CH353	−19.09	6.97	4.57	14.84	40.86	3.22	*Ovis*	VII
CH388	−18.77	9.04	0.67	14.79	40.91	3.22	*Ovis*	VII
CH389	−17.34	9.04	5.94	15.55	42.16	3.17	*Capra*	VIII
CH397	−18.60	8.18	2.07	15.31	42.24	3.22	*Capra*	VIII
CH399	−18.51	8.30	12.77	15.45	41.57	3.14	*Capra*	VIII
CH205	−16.58	9.73	11.46	14.81	41.09	3.24	*Ovis*	VIII
CH245	−20.24	5.28	5.08	14.39	42.73	3.47	*Ovis*	VIII
CH368	−17.60	10.33	10.19	15.15	41.33	3.19	*Ovis*	VIII
CH369	−18.72	7.09	9.55	15.48	42.02	3.17	*Ovis*	VIII
CH375	−19.24	9.34	10.02	15.12	41.65	3.21	*Ovis*	VIII
CH390	−16.50	10.86	7.20	15.68	42.57	3.17	*Ovis*	VIII
CH394	−17.80	10.58	2.21	15.01	41.26	3.20	*Ovis*	VIII
CH395	−17.83	11.09	1.06	15.23	42.04	3.22	*Ovis*	VIII
CH402	−16.72	9.98	11.70	15.92	43.06	3.15	*Ovis*	VIII
CH403	−18.03	10.47	1.45	14.68	40.78	3.24	*Ovis*	VIII
CH385	−19.81	7.42	9.58	15.43	41.78	3.16	*Capra*	IX
CH371	−19.35	9.41	6.58	15.57	42.43	3.18	*Ovis*	IX
CH372	−17.68	9.18	9.15	15.59	42.76	3.20	*Ovis*	IX
CH380	−16.82	10.22	6.98	14.87	40.32	3.16	*Ovis*	IX
CH383	−19.38	8.86	10.01	15.40	41.78	3.17	*Ovis*	IX
CH239	−15.95	9.87	5.79	14.22	40.88	3.36	*Ovis*	X
CH250	−19.28	6.90	11.94	14.07	39.74	3.29	*Ovis*	XII
CH411	−19.68	8.58	8.64	16.31	44.34	3.17	*Ovis*	XII
CH238	−17.55	9.17	11.47	13.54	38.05	3.28	*Ovis*	Pre XII A
CH303	−17.81	9.35	10.83	15.77	43.80	3.24	*Ovis*	Pre XII A
CH304	−19.01	7.07	11.53	15.46	42.64	3.22	*Ovis*	Pre XII A
CH305	−18.24	9.36	6.25	15.60	43.94	3.29	*Ovis*	Pre XII A
CH306	−17.98	7.25	3.88	15.41	43.69	3.31	*Ovis*	Pre XII A
CH307	−18.54	8.39	11.02	15.74	43.83	3.25	*Ovis*	Pre XII A
CH308	−18.05	8.92	1.13	11.65	32.60	3.27	*Ovis*	Pre XII A
CH315	−18.19	10.47	11.33	15.96	44.70	3.27	*Capra*	Pre XII B
CH316	−15.09	10.32	10.52	16.34	45.19	3.23	*Capra*	Pre XII B
CH317	−18.89	6.30	14.06	15.82	43.86	3.24	*Capra*	Pre XII B
CH309	−18.86	9.92	12.73	15.93	44.73	3.28	*Ovis*	Pre XII B
CH310	−18.12	9.26	12.62	16.89	47.14	3.26	*Ovis*	Pre XII B
CH311	−17.82	8.76	0.78	13.52	38.68	3.34	*Ovis*	Pre XII B
CH312	−16.71	9.87	11.20	15.62	43.34	3.24	*Ovis*	Pre XII B
CH313	−17.28	10.44	12.33	15.64	44.00	3.28	*Ovis*	Pre XII B
CH314	−16.96	10.21	12.51	15.54	43.51	3.27	*Ovis*	Pre XII B
CH318	−18.37	10.85	7.80	15.68	44.32	3.31	*Ovis*	Pre XII B
CH319	−18.45	10.21	11.57	16.45	45.62	3.24	*Ovis*	Pre XII B
CH320	−17.45	10.14	12.28	15.89	44.29	3.25	*Ovis*	Pre XII B
CH321	−16.49	10.33	13.66	16.10	44.77	3.25	*Ovis*	Pre XII B
CH323	−17.35	9.35	13.79	15.78	44.23	3.27	*Capra*	Pre XII C
CH324	−17.24	10.24	14.96	16.64	46.34	3.26	*Capra*	Pre XII C
CH325	−17.03	9.77	13.21	15.31	42.92	3.27	*Capra*	Pre XII C
CH322	−16.86	10.59	6.79	14.48	40.79	3.29	*Ovis*	Pre XII C
CH328	−17.48	9.02	12.52	16.33	45.81	3.27	*Capra*	Pre XII D
CH422	−17.61	10.17	6.49	15.71	42.80	3.18	*Capra*	Pre XII D
CH327	−17.62	9.69	14.83	15.11	42.31	3.27	*Ovis*	Pre XII D
CH418	−17.17	10.50	8.93	15.02	41.11	3.20	*Ovis*	Pre XII D
CH419	−17.60	10.67	11.57	15.71	42.70	3.18	*Ovis*	Pre XII D
CH420	−17.91	10.10	2.58	14.81	42.08	3.32	*Ovis*	Pre XII D

Percentage carbon (% C) and nitrogen (% N) and the atomic ratio C:N are also given to demonstrate good preservation.

plant biomass), we would expect to see no difference between sites in the same region where it is known that C_4 plants occur either from the macrobotanical evidence or by presence in other animals such as wild cattle. Thus the caprines at all sites should display a similar dietary breadth in both $\delta^{13}C$ and $\delta^{15}N$ over time. Wild cattle also provide a useful internal control for monitoring possible effects from climate change.

2. Experimental methodology

Samples for collagen extraction were taken from the compact midshaft of skeletal elements that could be confidently assigned to either sheep or goat following Boessneck et al. (1964) and Kratochvil (1969). In total 109 samples successfully yielded collagen and are presented here. These can be broken down into 60 samples from levels VI (latest) to Pre Level XII D (earliest) Çatalhöyük (South Area) and 49 from Aşıklı Höyük (Level 2 exposure). Stable carbon and nitrogen isotope analysis was carried out at the Research Laboratory for Archaeology and the History of Art, University of Oxford, UK. Collagen was extracted from approximately 300–500 mg of compact bone using a modified Longin (1971) method: bone samples were immersed whole in 0.5 M $HCl_{(aq)}$ until demineralised and then washed three times in Milli Q water. Samples were then gelatinised by adding pH 3 water and heating to 70 °C for 48 h. The gelatinous solution was then filtered through an 8 μm EZee filter and transferred to clean test tubes and freeze-dried. All reported samples fell within the acceptable range of atomic C:N values (2.9–3.6) and percent carbon (% C) and percent nitrogen (% N) content set down by Ambrose (1990) as indicators of well preserved collagen. Measurements were made on a Europa Geo continuous-flow isotope ratio monitoring mass spectrometer (CF-IRMS) using standards vPDB for carbon and AIR for nitrogen. Errors are $\pm 0.1‰$ $\delta^{13}C$ and $\pm 0.1‰$ $\delta^{15}N$ (Pearson, 2004).

3. Results

3.1. I Çatalhöyük

The individual isotope values for sheep and goats ($n = 60$) from Çatalhöyük South Area (Table 1) are plotted in Fig. 2. No isotopic differences were detected between sheep and goat as separate species (Fig. 3) and thus are considered together. The sampled population ranges in carbon from -20.24 to $-15.09‰$ ($5.15‰$ difference) and in nitrogen from 5.28 to 11.09 ($5.81‰$ difference). These data illustrate a considerable isotopic variability in plant foraging by caprines with a substantial proportion of C_4 plants in the diet of some animals compared to an exclusively C_3 diet of others. We used a cut off of $-18‰$ $\delta^{13}C$ to indicate the consumption of C_4 plants. These data were next examined by occupational level, where Pre Level XII D represents the earliest phase through to Level VII which is the latest phase in this area. Two important conclusions can be drawn in light of these separations. First, in Pre Level XII D and C ($n = 10$) the isotopic variability, which is assumed to equate to dietary variability, is narrow. But Pre Level XII phase B ($n = 13$) reveal a very different picture, one in which isotopic variability has increased considerably. This picture of isotopic variability is more or less maintained through to Level VII ($n = 30$). Second, because neither carbon nor nitrogen isotopic variation in the later levels is unidirectional (i.e. the values of some animals do not simply become more negative *or* more positive over time), it is possible to rule out climatic variation since such changes over time usually result in either lighter or heavier values over time but not both. The possible causes of such a large nitrogen isotope variation are discussed below.

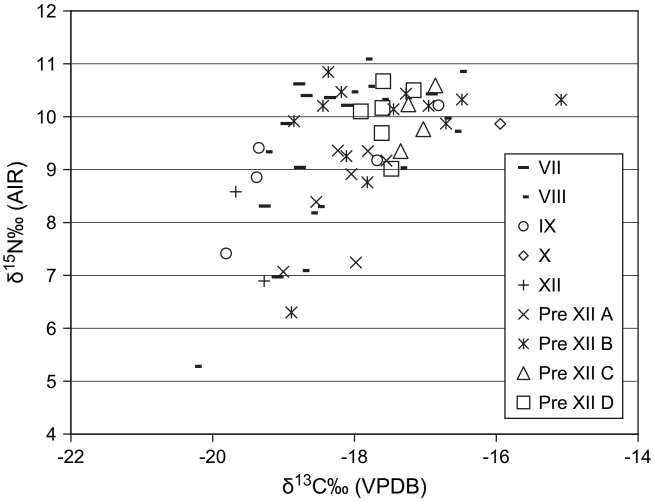

Fig. 2. Çatalhöyük South area: stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope values of caprine bone collagen plotted by occupational phase. Pre Level XII C and Pre Level XII D are enlarged for clarity.

3.2. II Aşıklı Höyük

The individual isotope values for sheep and goats ($n = 49$) from Aşıklı Höyük (Table 2) are plotted in Fig. 4. No isotopic difference was detected between the two species (Fig. 5) and

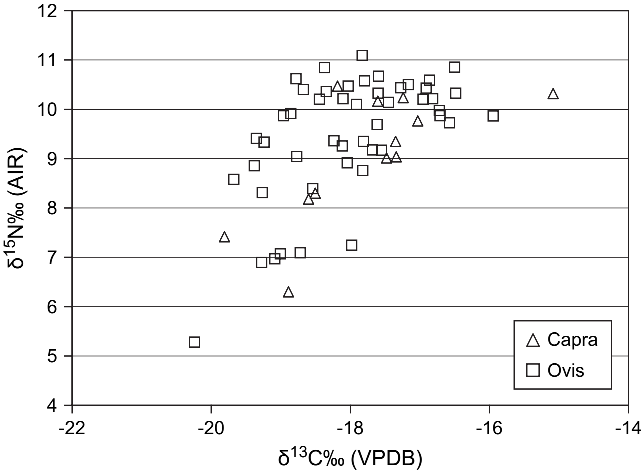

Fig. 3. *Capra* and *Ovis* stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope values of bone collagen from Çatalhöyük.

Table 2
Aşıklı Höyük stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope results for *Ovis*, *Capra* and *Bos* bone collagen (measured in duplicate)

Lab no.	δ^{13}C	δ^{15}N	% collagen	% N	% C	C:N	Genus
AH103	−19.98	7.72	0.99	14.76	41.19	3.26	*Bos*
AH104	−19.78	9.07	8.59	15.45	41.97	3.17	*Bos*
AH102	−19.75	9.60	1.22	7.04	20.96	3.47	*Bos*
AH111	−19.65	10.03	5.77	16.07	43.72	3.17	*Bos*
AH106	−19.58	10.69	1.55	14.53	41.45	3.33	*Bos*
AH109	−19.52	7.64	4.04	15.49	43.14	3.25	*Bos*
AH115	−19.49	7.35	3.39	15.67	38.76	2.89	*Bos*
AH116	−19.41	6.92	2.44	15.06	42.33	3.28	*Bos*
AH123	−19.10	8.18	6.61	15.53	42.53	3.20	*Bos*
AH126	−18.65	9.29	6.21	14.48	39.48	3.18	*Bos*
AH107	−18.55	11.50	9.17	15.14	41.54	3.20	*Bos*
AH114	−18.45	9.76	5.33	15.56	42.67	3.20	*Bos*
AH117	−18.41	8.16	7.95	15.20	40.29	3.10	*Bos*
AH108	−18.05	10.56	3.26	15.37	42.41	3.22	*Bos*
AH113	−17.55	10.13	4.42	15.45	41.97	3.17	*Bos*
AH110	−16.62	10.15	7.65	15.43	42.96	3.25	*Bos*
AH112	−16.44	8.22	2.20	15.79	39.94	2.95	*Bos*
AH119	−16.27	9.89	1.22	14.31	40.28	3.29	*Bos*
AH120	−15.32	8.60	4.54	15.33	39.90	3.04	*Bos*
AH98	−19.33	4.48	4.87	15.45	43.37	3.28	*Capra*
AH97	−19.19	7.86	4.61	15.92	45.17	3.31	*Capra*
AH81	−19.19	8.08	6.09	15.95	45.36	3.32	*Capra*
AH78	−19.16	8.16	3.46	15.43	43.82	3.32	*Capra*
AH100	−19.15	8.73	7.17	15.49	42.80	3.23	*Capra*
AH90	−19.12	7.48	2.10	15.22	43.62	3.35	*Capra*
AH95	−19.09	7.66	6.61	15.87	45.27	3.33	*Capra*
AH89	−19.07	8.09	7.81	16.11	45.73	3.31	*Capra*
AH85	−19.02	8.08	10.00	15.52	44.01	3.31	*Capra*
AH88	−18.99	8.54	1.40	14.69	41.57	3.30	*Capra*
AH94	−18.97	8.25	1.17	11.86	34.05	3.35	*Capra*
AH92	−18.96	8.28	3.09	15.69	44.29	3.30	*Capra*
AH84	−18.92	8.15	1.25	13.30	37.21	3.27	*Capra*
AH82	−18.91	8.90	4.74	15.39	43.59	3.30	*Capra*
AH96	−18.86	8.45	3.73	16.02	44.98	3.28	*Capra*
AH79	−18.81	8.00	5.42	16.32	46.13	3.30	*Capra*
AH87	−18.73	8.11	1.61	15.52	43.99	3.31	*Capra*
AH101	−18.72	9.00	4.43	15.25	41.57	3.18	*Capra*
AH77	−18.71	8.11	2.38	15.79	44.03	3.26	*Capra*
AH83	−18.70	8.33	9.71	15.85	44.69	3.30	*Capra*
AH86	−18.69	8.20	10.33	15.71	44.17	3.28	*Capra*
AH99	−18.56	8.66	3.01	15.53	44.26	3.32	*Capra*
AH93	−18.45	8.36	5.81	16.15	45.33	3.28	*Capra*
AH91	−17.67	8.37	4.75	16.28	45.89	3.29	*Capra*
AH72	−19.56	9.40	4.49	14.88	42.24	3.32	*Ovis*
AH52	−19.39	8.51	4.01	15.38	43.99	3.34	*Ovis*
AH54	−19.35	8.43	5.08	15.54	43.78	3.29	*Ovis*
AH65	−19.21	8.40	6.52	15.37	43.28	3.29	*Ovis*
AH67	−19.20	8.28	2.93	15.32	42.89	3.27	*Ovis*
AH74	−19.19	6.99	9.86	16.20	45.51	3.28	*Ovis*
AH57	−19.18	7.55	2.70	15.11	42.74	3.30	*Ovis*
AH73	−19.06	8.82	10.13	16.21	45.41	3.27	*Ovis*
AH75	−19.05	9.71	0.46	14.54	41.92	3.37	*Ovis*
AH71	−19.03	7.91	6.01	15.20	42.52	3.27	*Ovis*
AH59	−19.00	8.03	6.44	15.38	43.47	3.30	*Ovis*
AH53	−18.97	8.09	10.87	14.22	40.06	3.29	*Ovis*
AH70	−18.96	7.74	4.11	15.25	42.77	3.27	*Ovis*
AH63	−18.95	8.36	6.09	15.53	43.34	3.25	*Ovis*
AH66	−18.94	7.57	5.85	15.72	44.19	3.28	*Ovis*
AH56	−18.91	8.03	2.06	14.78	41.76	3.30	*Ovis*
AH64	−18.77	9.15	5.36	15.48	43.44	3.28	*Ovis*
AH55	−18.76	8.04	1.56	15.47	44.21	3.33	*Ovis*
AH60	−18.74	7.79	4.01	15.78	44.56	3.30	*Ovis*
AH61	−18.70	8.65	4.67	15.80	44.28	3.27	*Ovis*

Table 2 (*continued*)

Lab no.	δ^{13}C	δ^{15}N	% collagen	% N	% C	C:N	Genus
AH69	−18.66	8.61	3.90	15.12	42.71	3.30	*Ovis*
AH62	−18.59	8.19	9.54	15.44	43.01	3.25	*Ovis*
AH76	−18.51	9.89	2.87	15.77	44.37	3.29	*Ovis*
AH68	−18.43	9.01	5.68	15.69	43.80	3.26	*Ovis*
AH58	−18.30	8.88	5.10	15.69	43.95	3.27	*Ovis*

Percentage carbon (% C) and nitrogen (% N) and the atomic ratio C:N are also given to demonstrate good preservation.

so again these are plotted together. These individuals range in carbon from −19.56 to −17.67‰ (1.89‰ difference) and in nitrogen from 4.48 to 9.89 (5.41‰ difference). These data illustrate far less isotopic variation (assumed as indicating dietary variation) and very little contribution from C_4 plants in the diet of any of the animals sampled compared with the samples from Çatalhöyük since nearly all values are lower than −18‰ δ^{13}C which is our cut off for C_4 consumption. Samples were taken from all subphases of the Level 2 exposure (2A to 2G) and no diachronic variation was observed Fig. 4 shows caprines plotted by level. The *Bos* spp. values are very variable (Table 2) with δ^{13}C values between −19.98 and −15.32‰ (4.66‰ variation) and δ^{15}N values between 6.92 and 11.5‰ (4.58‰ variation). A large contribution from C_4 plants in a few individuals is evidenced (Fig. 5), suggesting a larger environmental range covered by these animals than for caprines.

4. Discussion

In our opinion these data can best be explained in terms of early herding practices or management of caprine populations in Central Anatolia. We suggest that at Çatalhöyük the dramatic change from a diet essentially uniform in both δ^{13}C and δ^{15}N values between individual animals in Pre Level XII C and D to a pattern of individually variable diet, which occurs from Pre Level XII B onwards, represents a transition in herding strategies from smaller to larger scale practices. An independent samples *t*-test confirms significant variation both in δ^{13}C ($t = -4.253$, df $= 54.04$, $P < 0.001$) and in δ^{15}N ($t = -3.108$, df $= 42.27$, $P = 0.003$). We suggest that caprine diet became more variable because flocks were herded over a wider geographic range incorporating multiple environmental zones with large differences in δ^{13}C and δ^{15}N values, and that the ways in which animals were pastured are likely to have varied considerably among contemporary flocks. This larger scale strategy, of sending separate flocks to different areas, may have been more organised and dictated by task scheduling and exploitation of particular ecozones. Such tasks involving resources such as plant exploitation have been found to have occurred at some distance from the site including wheat and barley agriculture (Fairbairn et al., 2002) and collection of structural timber (Asouti, 2005). Other anthropogenic causes of nitrogen isotope variation include manuring which would raise δ^{15}N values in plants (Bogaard et al., 2007) and could be passed onto animals. At present, there is no evidence for this practice at Çatalhöyük and the growing of crops is also postulated to be in areas at some distance from the site, which are unlikely to have been used as grazing areas. Finally, such practices also cause only increases in the δ^{15}N values of the plant biomass, whereas these animals show lighter as well as heavier δ^{15}N values over time which suggests that manuring cannot be used to explain the variation seen here.

At Aşıklı Höyük, these data suggest that the proto-domestic caprines did not graze in areas where C_4 plants were encountered as such steppic highlands or grasslands. This is puzzling

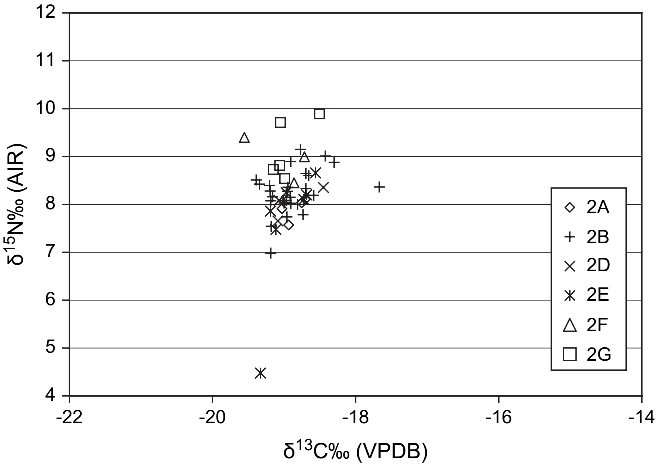

Fig. 4. Asikli Hoyuk level 2 exposure: stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope values of caprine bone collagen plotted by occupational phase. 2A represents the latest deposits and 2G the earliest.

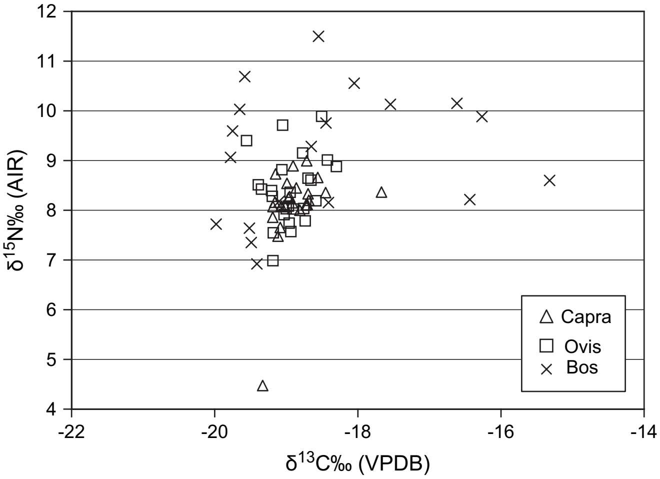

Fig. 5. *Capra*, *Ovis* and *Bos* stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope values of bone collagen from Aşıklı Höyük.

since C_4 plants were apparently present in Cappadocia because they have been detected from isotope analysis of Aşıklı Höyük *Bos* spp. specimens (Fig. 5 and Table 2). Additionally, examination of the plant assemblage for the Aşıklı Höyük region confirms the presence of C_4 plants in the area (Pearson, 2004; van Zeist and de Roller, 1995). Therefore, we suggest that caprine population at Aşıklı Höyük was restricted from C_4 plants in some fashion. Finally, the *Bos* spp. specimens are from wild cattle and thus provide a picture of carbon and nitrogen isotopic values expected of free-ranging ruminants in this region.

We therefore consider two extreme scenarios involving either true wild or fully domestic caprine populations. If the Aşıklı Höyük assemblage were a true wild population, the isotopic evidence suggests that multiple populations of sheep and goats exploited during the Level 2 occupation of Aşıklı Höyük (~400 years) had the same diet, with uniform $\delta^{13}C$ values. This is despite the fact that C_4 plants seem to be present in the diet of wild cattle. This suggests that caprines avoided C_4 plants in their diet (unlikely), were grazing in areas without C_4 plants such as a hilly environment, or were forcibly restricted from their diet, implying human intervention. Alternatively, if the assemblage represents a proto-domestic or fully domesticated population, as argued by Buitenhuis (1997), the isotope values are uncharacteristically narrow when compared with other Neolithic sites of south-central Anatolia. In light of Aşıklı Höyük's early date, this uniformity probably represents the beginnings of a management strategy which involved keeping animals nearby perhaps as a single flock, and would only later diversify into what is seen at Çatalhöyük where multiple flocks were taken to different areas probably at greater distances from the sites.

5. Conclusion

At Çatalhöyük, where the caprine assemblage has been identified as morphologically domestic, the diet is broad and varied. In comparison, at Aşıklı Höyük, a site of caprine proto-domestication uncharacteristically uniform isotope values are found for individuals within the sampled population. This has been possible to detect because of the mixed biomass of C_3 and C_4 plants present in south-central Anatolia during the Neolithic. The movement of flocks at a distance from sedentary habitation has been previously explored (Köhler-Rollefson, 1992) with reference to moving large populations of potentially destructive animals away from surrounding plant resources routinely exploited by the site's inhabitants. While we are not yet able to determine the type of mobility and distance of herding in operation at Çatalhöyük, we do argue that the increasing scale of food production, of which caprine pastoralism was a dominant feature, required modification from a small- to large scale process and that this was best achieved at some distance from expanding communities during the early Neolithic in Anatolia. Whatever the scenario at Aşıklı Höyük, we suggest that the increase in diet range seen in action at Çatalhöyük reflects an increase in the significance of pastoralism with herders moving separate flocks over more extensive territories around villages thus becoming more likely to encounter multiple isotopically distinctive plant biomasses. This may well have involved a separation of pastoral and other activities and created more specific roles for herders within certain communities in Neolithic Anatolia.

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