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ORIGINAL PAPER

Economic and socio-cultural consequences of changing political rule on human and faunal diets in medieval Valencia (c. fifth–fifteenth century AD) as evidenced by stable isotopes

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Abstract
This paper explores the impact of changing religious political rule on subsistence within a single city through time using stable isotope analysis of human and animal bone collagen. The diet and economy of the medieval city of Valencia (Spain) are examined over a 1000-year period during successive periods of Visigothic, Muslim and Christian rule. Bulk stable isotope analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) was carried out on 67 humans and 47 animals sampled from several archaeological sites dating between the fifth and fifteenth centuries AD. Terrestrial C_3 resources dominated the diet in all periods. However, an increase in consumption of C_4 plants (e.g. millet, sorghum) and/or marine resources is detected among individuals dating to the Islamic period. Differences in the isotopic values of humans and animals between the three periods indicate a significant dietary diversity during the Islamic phases (eleventh to thirteenth century), compared with the earlier Visigothic phase (fifth–seventh century) and the later Christian phase (fourteenth and fifteenth century). Observed diachronic changes in isotopic results provide evidence for a shift in diet and subsistence, particularly during the Muslim and later Christian periods. This is linked with change in population and economic focus. Dietary diversity among Muslim individuals is hypothesised to indicate the polyculture that was reflected in varied Islamic agricultural practices and the presence of potential migrants from elsewhere in the Islamic world.

Keywords Muslim · Christian · Visigothic · Spain · Collagen · Diet

The influence of socio-political and economic change on diet over the long term is just beginning to be directly investigated using isotope analysis. Investigations have centred on a single location, such as the city of York (Müldner and Richards 2007), or multiple sites across a large area, e.g. in Croatia (Lightfoot et al. 2012) and Mallorca (Fuller et al. 2010). Such studies have highlighted human dietary responses to these shifts. Recent work has, however, emphasised resilience and continuity in dietary practice despite dramatic shifts in socio-political circumstances, e.g. Christianisation in Poland (Reitsema et al. 2017). The present research explores the dietary impact of the major religious, socio-political, economic and population transformations that occurred over 1000 years in the medieval city of Valencia at the level of an individual. Both human and animal remains were analysed to examine aspects of day-to-day subsistence, agriculture and animal husbandry under Visigothic, Islamic and subsequent Christian control in eastern Spain.

During the medieval period, the Iberian Peninsula harboured a multi-faith society that was subject to dramatic socio-cultural, economic and demographic shifts associated with changes in religious political rule. The long and eventful

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settlement history of Valencia, a major city in Spain during the medieval period, provides the ideal opportunity to investigate the diet of its urban population over the long term in the context of these changes. In this article, we explore a period of roughly 1000 years from the fifth to the fifteenth centuries AD through the analysis of carbon (δ^{13}C) and nitrogen (δ^{15}N) isotopes in collagen from human and animal bone: these samples are taken from multiple sites across the medieval city. The application of isotopic methodologies to medieval populations is growing in Spain, with many concentrating on Islamic populations (e.g. Salazar-García et al. 2014, 2016; Pickard et al. 2017; Guede et al. 2017), status (Jiménez-Brobeil et al. 2016), the Christian North (e.g. Sirignano et al. 2014) or the interplay of faith and diet between contemporaneous populations of Christians and Muslims under later Christian rule (Alexander et al. 2015). Although others have explored diachronic changes in diet in Spain, for example following the Islamic conquest in the Balearic Islands (Fuller et al. 2010), this is the first time any bioarchaeological analysis of historic diet has investigated such an extended chronology for any major Spanish city and in particular the transition from Islamic to Christian rule.

Development of the medieval city

The city of Valencia lies on the banks of the River Turia on Spain's Mediterranean coastline (Fig. 1). Founded in 138 BC, the Roman city of *Valentia* declined in importance during the Visigothic period (fifth–eighth century) but maintained its strategic value as the see of a Bishopric and remained the administrative nucleus of a wide territory (Ribera 2006, 2008; Jiménez Salvador 2009). In AD 711, the city was taken by Muslims and became fully established with an Islamic ruler in AD 800. After Rodrigo Díaz de Vivar ('El Cid') briefly interrupted Islamic rule, Valencia was re-taken by the Almoravids in AD 1109 and remained under Islamic control (Kennedy 1996). In 1238, Valencia fell to the Aragonese King James I and was annexed to the Crown of Aragón. The city now became capital of the Kingdom of Valencia between Murcia and the Tortosa region of the Ebro valley. Throughout the thirteenth and fourteenth centuries, the city was populated by Christian immigrants from the northern territories of Aragón (Guinot 2009, p. 176). Muslims who stayed in the area moved to a *morería* or Muslim quarter established outside the walls of Valencia (Baydal and Esquilache 2014).

Economy and agriculture

Throughout the medieval period, Valencia was an important port and commercial centre. By the twelfth century, Genoese merchants used the city to export goods from al-Andalus (the

area of the Iberian Peninsula under Islamic control) to Christian ports throughout the Mediterranean (Constable 1994, p. 20). Agriculture, however, was at the heart of the region's economy and the changes to the ethnic and religious make-up of the population and shifting political power outlined above would have had a dramatic effect on agriculture, economy and diet. Agrarian transformation occurred across the Iberian Peninsula under Islamic rule. This 'agricultural revolution' (first coined as such by Watson in 1974, but see Decker 2009 and Squatriti 2014 for criticism) has been attributed to societal change and formation of a tributary economy, innovations in agricultural and hydraulic technology and the introduction of new crops, such as pomegranate, rice, cotton, sorghum and citrus fruits (Ruas et al. 2017). There is little evidence for a revolution in the archaeobotanical record so far, but the study of medieval plant remains has lagged behind that of the prehistoric periods in Spain (Peña-Chocarro et al. 2017).

The extensive irrigated area that surrounds Valencia today (known as the *Horta*) has its origins in the Islamic conquest of the eighth century (Guinot and Esquilache 2017). The development of intensive irrigation enabled the cultivation of a variety of crops at any given time and agricultural diversity in particular was a defining feature of the Islamic agrarian economy (Glick 1995). The introduction of sorghum (a C_4 crop) in particular might be visible through isotopic data if it not yet archaeologically. The later Christian conquest saw the establishment of a feudal society and the reorganisation of cultivated land (Torró 2012a, b). Irrigation was maintained; however, new systems emerged, and the *Horta* was extended, while vines and cereal crops, particularly wheat, received new emphasis. There was also an increased emphasis on stock keeping and this period in particular saw the rise of long-range transhumance (Guinot and Esquilache 2017; Guinot 2009; Torró 2009).

Zooarchaeological data from sites across the Iberian Peninsula indicate that sheep/goat were the most common species at both Islamic and Christian period sites. Variation in kill-off patterns suggests that younger meat was preferred in the Islamic period, but these animals were increasingly used for secondary resources in the Christian period (e.g. wool). Conversely, cattle seem to have undergone the reverse trend (Morales et al. 2011). Pigs have been reported at Islamic period sites, although in low frequencies compared to Christian sites (Morales et al. 2011; Grau-Sologestoa 2017). These generalisations however belie the diversity of animal management practiced in the medieval period; there is no clear 'Muslim' signal for a zooarchaeological assemblage, although an urban/rural divide does appear to exist in the data (Morales et al. 2011; Grau-Sologestoa 2017; Estaca-Gómez et al. 2018). Large-scale shifts in agriculture and stock keeping have the potential to be read from the
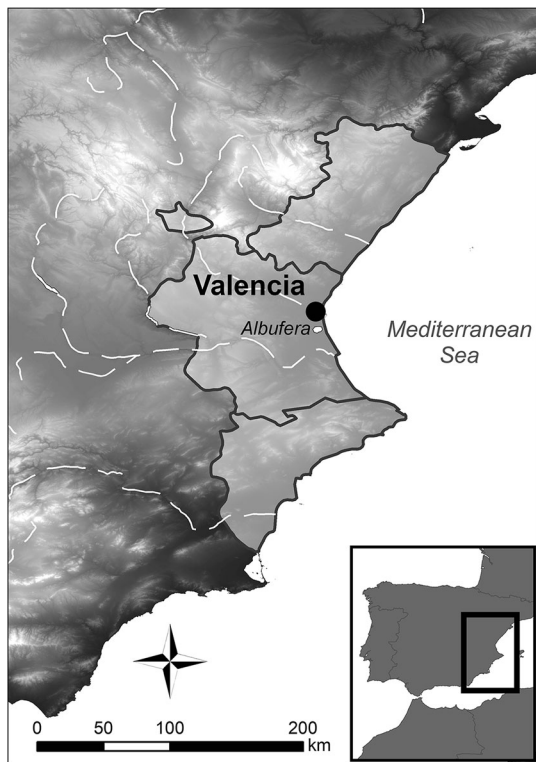
Fig. 1 Location map of Valencia. Map created with data from Natural Earth and the Shuttle Radar Topography Mission (SRTM)

isotopic data, providing direct evidence for discernible shifts in diet and economy that would be applicable at the individual and population level.

Medieval diet

A brief historical and archaeological overview of medieval diet in Spain is provided by Alexander et al. (2015) (but see also, for example, de Castro 1993; García Sánchez 1996, 2002; Adamson 2004). Wheat, a C_3 crop, was the most desirable grain, although mixed-grain bread would have been the most commonly eaten; C_4 crops such as millet (broomcorn and/or foxtail) or, from the Islamic period, sorghum, were considered secondary. These crops tended to be relied upon particularly in times of scarcity or by those of lower social status (de Castro 1993 p. 286; García Sánchez 2002, p. 279). A wide range of vegetables and fruit were also available from markets and kitchen gardens, but these contribute little in terms of the isotopic evidence considered here. Meat and dairy products made up a smaller, but important, part of the diet according to social status, geographical location/ environment and faith. Lamb and mutton were the most commonly consumed meats throughout the medieval period, and beef, chicken, pork (in the case of Christians) and game could also be found on the table (Waines 1992; de Castro 1993; García Sánchez 1996).

Freshwater and/or marine resources provided a valuable supplement to terrestrial resources and fish was often dried, salted, smoked or pickled (Gallart et al. 2005). Fish also served a liturgical requirement for Christians, who were obliged to avoid meat when fasting for a third of the year (Tomás 2009, p. 465). It is possible that a discernible increase in fish consumption might be detected in the later Christian population in line with religious doctrine, although alternatives, such as eggs, could have also been used instead (Gerrard 2003, p. 301). Consumption of terrestrial animal protein, marine resources and C_3 and C_4 plants, particularly if the latter were fed to animals whose products were consumed by humans, will all have an impact on the carbon and nitrogen isotope signature of consumer bone collagen.

Stable isotope analysis

In-depth reviews of stable isotopes and dietary reconstruction of archaeological populations are available elsewhere (e.g. Katzenberg 2000; Lee-Thope 2008; Schwarcz and Schoeninger 2011). In general terms, the composition of carbon and nitrogen isotopes in bone collagen is representative of a long-term average of the main protein sources of the diet in the decades before death, where protein intake is adequate (Hedges 2004; Hedges et al. 2007). The use of carbon isotopes to distinguish between the consumption of common, temperate C_3 crops and arid-adapted C_4 plants (O'Leary 1981) is notable in the context of medieval Spain where C_4 crops such as millet, sorghum and sugarcane were present. $\delta^{13}C$ values also differ between marine and terrestrial environments (Schoeninger and DeNiro 1984).

Nitrogen isotope ratios depend on the position of an organism within the food chain. It is widely accepted that $\delta^{15}N$ values increase 3–5‰ between trophic levels (Bocherens and Drucker 2003), although spacing of up to 6‰ has been suggested for humans (O'Connell, et al. 2012). There is also a slight increase in $\delta^{13}C$ values with tropic level of 0–2‰ (Bocherens and Drucker 2003). Values for $\delta^{15}N$ tend to be higher in aquatic ecosystems due to the longer length of food chains (Schoeninger et al. 1983). Therefore, although $\delta^{13}C$ values for marine and C_4 consumers can overlap, $\delta^{15}N$ values are usually able to distinguish predominantly marine from terrestrial C_4 feeders. The Mediterranean is particularly problematic in this regard because $\delta^{15}N$ values for marine and terrestrial resources are often similar (Craig et al. 2013). As a result, the identification of consumption of marine foods, as opposed to indirect consumption of C_4 crops via C_4-fed terrestrial animal protein (with corresponding higher $\delta^{15}N$ values), is not always straightforward using bulk isotope analysis due to the problem of equifinality when analysing consumer isotope values (Alexander et al. 2015).

Materials

Human populations

Human bone from 67 individuals was sampled from five sites representing six phases within and outside the medieval city walls (Table 1, Fig. 2), 10 individuals from the Visigothic period, 38 from the Islamic period and 19 from the later Christian period (see Table 1 for dates). Osteological analysis was undertaken by Alexander following established methods to ascertain adult age (ca. 18 years of age and above) based on the development and fusion of bones (Scheuer and Black 2000) and dental eruption and wear (Ubelaker 1989; Brothwell 1981). Sex was determined using standard osteological techniques outlined in Mays and Cox (2000) assessing the morphology of the pelvis and skull and the measurements of bones to support morphological examination.

Individuals were identified as Christian or Muslim from their distinctive burial rites. In general, Christians were buried supine, orientated E-W with their heads to the west, while the Muslims were buried on their right-side orientated SW-NE with their face towards Mecca (Lozoya et al. 2006). Unfortunately, no mozarab or later *mudéjar* (Muslims under Christian rule) burials were available for analysis. It should also be noted that a Jewish community was present in Valencia throughout the periods examined here, but as no Jewish burials have been analysed, there will be no discussion of this population in this paper.

Both Visigothic and selected Muslim burials were sampled from excavations in the Plaza de la Almoina, the political and religious nucleus of Valencia from the Roman period onwards. Given that this was the area of the Cathedral and Bishop's residence in the sixth and seventh centuries, the Visigothic burials sampled here have been interpreted as members of the social elite (Martin and Ribera 2006). Burials were sampled from two phases of interments representing both individual and multiple graves (Table 1). The main mosque, originally located here next to the Islamic palace (*alcázar*), was later converted into the present cathedral. The palace has an adjoining Islamic cemetery (known today as La Rauda) that was situated within the city walls, unlike other cemeteries of the period (Pascual 1989, p. 406; Ribera 2006, p. 82). Historical sources identify this cemetery as the high-status burial ground for the Taifa kingdom (Pascual and Serrano 1996). Samples taken here allow any associations between diet and status within the Islamic population of Valencia to be explored.

Further, burials of the eleventh–thirteenth-century derive from the large cemetery of Bab al-Hanax, and a smaller cemetery uncovered in Carrer Sagunt. The latter is likely to be related to a small extramural suburb and allows comparison between populations of different quarters of the city. Three Muslim burials were also sampled from a group of interments in Carrer Pintor Sorolla. These burials lay within the Islamic city walls and given that this is a practice that was prohibited under normal circumstances, it seems likely that these particular people were interred during the Christian siege of 1238.

Christian burials were sampled from two early parishes. San Andrés was one of the first parishes created after the Christians took control of the city and was one of the wealthiest during the thirteenth century (Burns 1967, p. 97; García and Ruiz 1997, p. 5). The burial ground excavated near Carrer Sant Vicent was part of a complex of a church, monastery and hospital that was established in the thirteenth century by royal patronage near the shrine dedicated to St Vincent. The monastic group that attended and administered the complex was

Table 1 Details of the human material sampled from medieval Valencia from all sites

| Site	Date (centuries) and period	No. of samples	Comments	Reference(s)
Plaza de la Almoina	Late 5th–7th Visigothic	10	Christian rite, early individual interments unfurnished (5th–6th C), later multiple interments with grave ornaments (6th–7th C). Potentially high status	Albiach et al. 1998; Álvarez and Ribera 2002
Plaza de la Almoina/La Rauda	11th–13th Islamic	7	Islamic rite, high status, graves were unfurnished, lined with mortar with evidence of gold weave in three graves	Pascual and Ribera 1990; Pascual and Serrano 1996
Carrer de Dalt 48–58/Bab al-Hanax	11th–13th Islamic	21	Islamic rite, located between two main city gates	Serrano 1997
Carrer Sagunt	11th–13th Islamic	7	Islamic rite. Cemetery may be related to the small extramural suburb of la Alcudia	Herreros 1999
Carrer Pintor Sorolla	13th Islamic	3	Islamic rite, buried within the city walls, potentially related to the Christian siege in AD 1248	García and Ruiz 1997
San Andrés/Carrer Pintor Sorolla	14th–15th Christian	4	Associated with a wealthy parish established early in the Christian medieval period	García and Ruiz 1997
Sant Vicent/Carrer Sant Vicent	14th–15th Christian	15	Associated with a church, monastery and hospital of royal foundation	Ortega and Gálego 2004
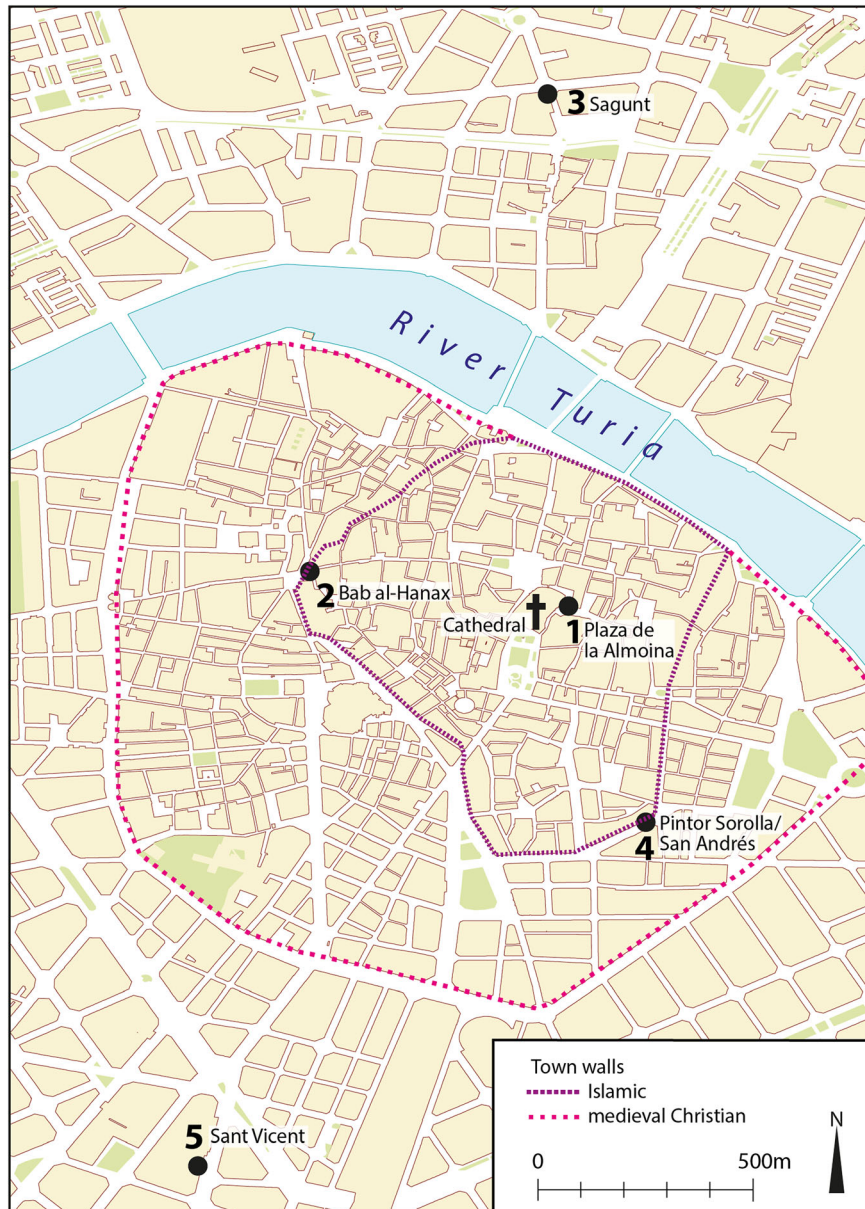
Fig. 2 Map of the modern centre of Valencia with the location of sites sampled. Drawing by A. Gutiérrez after CartoCiudad 2006–2017 CC-BY-4.0 scne.es

chosen by the king and underwent several changes including monks from the monastery of San Victorián, Mercedarians, followed by Cistercians (Burns 1967, pp. 283 and 294). The monastery served as a retirement home for civil servants, families or old soldiers, while the hospital included a hostel for the poor and infirmaries for the sick (Burns 1967, p. 285–286).

Faunal remains

The animal remains analysed in this study come from well-stratified refuse deposits in the Plaza de la Almoina ($n = 42$). Samples were taken from a selection of contexts dating to the Visigothic (sixth–eighth century), Islamic (eleventh–

thirteenth century) and Christian (thirteenth–sixteenth century) periods excavated between 1997 and 2001. Previously published marine fish $\delta^{13}C$ and $\delta^{15}N$ values from other medieval sites in eastern Spain, Albarracín, (Teruel) and Gandía (Valencia) (Alexander et al. 2015) were also included.

Methods

All human samples derived from adult (> 18 years) individuals (based on osteological analysis). Bone (200–500 mg) was preferentially sampled from ribs or cortical bones when ribs were unavailable. Cortical bone was chosen from animal

specimens (300–500 mg), ensuring that only one sample was taken from one individual in each context. Collagen was isolated from bone following a modified Longin (1971) method (Brown et al. 1988) as described in Alexander et al. (2015).

Collagen (0.5 mg) was analysed in duplicate EA/IRMS with a Delta XP (Thermo-Finnigan®, Bremen, Germany) mass spectrometer interfaced with a Costech ESC 4010 elemental analyser at the Alaska Stable Isotope facility (University of Alaska Fairbanks's Water and Environmental Research Centre; WERC) for humans or coupled with a Flash EA 2112 at the Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology (MPI-EVA, Leipzig, Germany), for animals. Stable isotope ratios were reported as δ values expressed as per mille (‰) deviation from the international standards VPDB (carbon) and AIR (nitrogen) following the equation ($\delta = (R_{sample} - R_{standard})$ $R_{standard}$) (Coplen 2011). For both laboratories, analytical error (calculated from repeated measurements of each sample and an in-house laboratory gelatine control from multiple extracts) was $< 0.2‰$ (1σ) for both $\delta^{13}C$ and $\delta^{15}N$. Collagen samples were exchanged between laboratories to ensure instrument consistency and as outlined in Alexander et al. (2015), a slight difference (0.6 ± 0.2‰, 1σ) was detected between $\delta^{13}C$ values at each laboratory and though is at the threshold of the minimum meaningful difference (MMD, 0.6‰) between laboratories suggested by Pestle et al. (2014), it is not at the magnitude of dietary interpretation (typically 1‰; Sealy et al. 2014).

Statistical tests were performed using PAleontological STatistics software (PAST 3.08; Hammer et al. 2001). The non-parametric Mann-Whitney U and Kolmogorov-Smirnov tests were employed, with Kruskal-Wallis tests used to assess overall variability between the three groups.

Results and data interpretation

The results are presented here alongside an initial interpretation of human diet and animal management within and between periods. The later discussion and synthesis is focused on a diachronic comparison and the wider implications of the results in terms of economy and diet under changing sociopolitical rule.

Sample preservation

Sufficient collagen (> 1% yield) was found to be preserved in all but two samples (11,025 and VCP2, Tables 2 and 3 respectively); however, all samples met published collagen quality criteria (DeNiro 1985; van Klinken 1999) and as ultrafiltration can reduce collagen yields (by up to 50%; Jørkov et al. 2007), compared to unfiltered samples, the data from the two samples with low yield were retained.

All periods

Human values for all periods ($n = 67$) range from − 19.8 to − 14.2‰ (range of 5.6‰) in $\delta^{13}C$ with a mean of − 18.0 ± 1.1‰ (1σ) and from 8.0 to 17.1‰ (range of 9.1‰) in $\delta^{15}N$ with a mean of 11.3 ± 1.5‰ (1σ). Contemporaneous animals ($n = 42$) range from − 22.3 to − 10‰ (range of 12.3‰) in $\delta^{13}C$ with a mean of − 19.1 ± 1.9‰ (1σ) and from 2.5 to 11.5‰ (range of 9‰) in $\delta^{15}N$ with a mean of 6.6 ± 2.3‰ (1σ). The human and animal stable isotope data for all periods are presented in Tables 2 and 3 respectively and plotted together in Fig. 3; summary statistics for humans and animals in each period are listed in Tables 4 and 5 respectively. Within the Christian period dataset, there is an extreme human outlier, VSVC3622, with a $\delta^{15}N$ value (17.1‰) that is more than three standard deviations (3.3) from the population mean. VSVC3622 was therefore omitted from any statistical comparisons as this individual is considered to be unrepresentative of the local population.

In general, herbivores (cattle, sheep/goat) in all periods tend to have lower $\delta^{13}C$ and $\delta^{15}N$ values than omnivores (chicken, dog, pig) (Table 5). This breadth in values for all species is indicative of a variety of geographic and environmental origins and long-term feeding strategies and must reflect the wide catchment of resources the city was drawing upon, including the possibility of the presence of non-local animals imported from further afield. No one region supplied all the city's needs.

Low $\delta^{13}C$ values for the majority of domestic animals indicate that C_3 plants were the main resource throughout the medieval period and the diets of sheep/goat, the most popular source of meat throughout this time period, are consistently C_3-based. Higher $\delta^{13}C$ values indicative of C_4 consumption, however, are seen among cattle, chickens and pigs and a dog (Table 5), indicating some presence of C_4 resources in animal diets. In the Islamic and Christian periods, the highest $\delta^{15}N$ values for herbivores overlap with humans, a relatively uncommon observation among published medieval faunal data. Given that an effort was made to sample animals older than weaning age, an enrichment of the plant baseline is the most probable explanation here. There is a complex combination of environmental (aridity, salinity) and anthropogenic influences (e.g. manuring) on $\delta^{15}N$ in food webs (Heaton 1987; Bogaard et al. 2007). Manuring was widely practiced and, even in the recent past, *corrales* or *bordas* (dedicated enclosures for the stabling and foddering of animals) were important for the production of manure to fertilise meadows and hillside terraces (Christie et al. 2004, p. 109; Montserrat and Fillat 1990, p. 58). $\delta^{15}N$ increases may also be attributed to herbivores grazing close to urban settlements in the vicinity of accumulations of human and animal nitrogenous waste (Vassberg 1974; Butzer 1988; Hedges et al. 2005; Triantaphyllou et al. 2008). Grazing of coastal areas and salt

marshes is an additional factor to be considered (Britton et al. 2008). To the south of Valencia, the Albufera is an extensive wetland with salt marshes around a lagoon (Fig. 1) used as pasture for sheep and cattle (Momblanch 2003; Torró 2012a, b). Aridity may also play a part; some parts of the Valencian region today are dry and semi-arid bioclimatic contexts, with a mean annual rainfall ranging from 500 to less than 300 mm/ year (Hidalgo et al. 2003), particularly areas to the south. Environmental evidence indicates that the Mediterranean region of the Iberian Peninsula experienced particularly dry conditions during the Medieval Warm Period (900–1300 AD) (Moreno et al. 2012).

Values for δ^{13}C and δ^{15}N for humans indicate that a C_3 terrestrial diet predominated in all periods under study. The Islamic data in particular, however, stand apart in demonstrating a variable pattern of δ^{13}C values, and a tendency towards elevated δ^{15}N values in comparison to the other periods. A Kruskal-Wallis test comparing sites medians by period for humans indicates there is no difference for δ^{13}C (H(2):3.373, $p = 0.184$) or δ^{15}N (H(2):5.922, $p = 0.051$). Kolmogorov-Smirnov tests for the distribution of isotopic values between sites, however, indicate that there is a significant difference in the distributions of values between δ^{13}C and δ^{15}N values for the Islamic period compared to both the Visigothic and Christian periods (Table S1). Examination of patterning in human data between periods needs to take into account potential shifts in the animal baseline, indicative of the environment and husbandry in each period. To that end, herbivores and humans from all periods are plotted together for comparison in Fig. 4. Offsets between humans and herbivores remain similar through all three periods (Table 6) indicating that the shift to C_4 plants in particular is broadly reflected in both animals and humans. The dietary shift exhibited in the Islamic period is therefore indicative of an economic shift towards the use of C_4 crops in both in human and animal diets rather than solely a change in human food choice. There was no difference between the sexes identified in the isotopic data from any period. The results from each period in Valencia are discussed further below including comparison with other published studies to consider whether Valencia is typical of dietary trends seen elsewhere at similar periods. Figure 5 compares the diet in Visigothic, Islamic and Christian Valencia with other published sites in eastern and southern Spain and the Balearic Islands, areas with similar climates and socio-cultural history.

Visigothic period

All animals from this period possess a C_3-based diet bar one dog (VVD1, Fig. 3, Tables 3 and 5). This dog possesses a δ^{13}C value of $-16.4‰$, which, combined with a relatively low δ^{15}N value (9‰) most probably reflects an input of C_4-based terrestrial protein in the diet. This is puzzling because dogs are often used as a proxy for human diet (see Guiry 2012), but

none of the humans sampled from this period have isotopic values indicative of C_4 consumption. Only a small number of humans have been analysed from this period, however, and given that these individuals have been identified as the social elite, they may not reflect the popular diet of the time. Dogs may also have not been fed the 'best' foods from the table. Analyses of further humans and animals from this period are needed to investigate this more thoroughly.

While the results for humans in the Visigothic period are more tightly clustered than later periods (Fig. 3), the two phases of burial fall into two distinct groups (Fig. 6). Burials of the later sixth and seventh centuries are slightly enriched in ^{13}C and ^{15}N and this is statistically significant for δ^{13}C values (Mann-Whitney $U = 2.5$, $p = 0.032$), although not for δ^{15}N values (Mann-Whitney $U = 22$, $p = 0.056$). While the sample is small, the significant difference in δ^{13}C values is of interest when related to burial practice among these individuals. The earlier burials follow the preceding Hispano-Roman burial tradition with single interments, an absence of grave goods and tiles covering the grave. The later burials, on the other hand, tend to be multiple interments with artefacts (amber pendants, coins and silver objects) and walled tombs, possibly representing family mausolea (Ribera 2008). These changes also correlate with morphological differences observed between the skeletons buried in these two phases: individuals of the later phase are of higher stature and greater robusticity (Martin and Ribera 2006). These findings may reflect an increasing Germanic influence in this quarter of the city and it is recorded, for example, that there was an Arian bishop in the city in AD 589 (Martin and Ribera 2006; Ribera 2008). The isotopic patterning seen here could therefore be a reflection of shifting dietary practice in line with a change in population, although the limited sample size prevents further interpretation.

More broadly, the Valencian Visigothic data are comparable to sixth- and seventh-century 'Late Roman' individuals from Tossal de les Basses in Alicante (Salazar-García et al. 2016) and fourth–seventh-century Late Antique/Early Byzantine individuals from Ibiza (Fuller et al. 2010) in Fig. 5. Of these two, the values for Valencia are remarkably similar to Tossal de les Basses, indicating that diets in these two places were comparable, with C_3-based diets for humans at both sites.

Islamic period

Among the animal data from the Islamic period, both cattle and chickens stand out for their wide range in δ^{13}C values (4.3‰ and 7.9‰ respectively, Table 5) indicative of diverse feeding strategies in both species. Some individuals possess low δ^{13}C values indicative of C_3 consumption whereas others have values reflecting a significant proportion of C_4 plants in their diets, including one chicken (VMGa2) with an extreme

Table 2 Stable carbon and nitrogen isotope data for human bone collagen from all sites (F=female, M=male)

Period	Site	Skeleton	Element	Sex	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	C (%)	N (%)	C/N	% Col.
Visigothic	Almoina 8	10602[b]	Rib	?F	−18.5	11.3	43.0	15.5	3.2	10.9
Christian	Almoina 8	10572	Femur	F	−18.5	10.7	42.7	15.5	3.2	6.3
(5th–7th C)	Almoina 8	10603[b]	Femur	?M	−18.6	11.4	41.4	13.8	3.5	1.1
	Almoina 8	10562	Rib	?M	−18.6	11.3	42.6	15.3	3.2	1.4
	Almoina 11	10940	Rib	?F	−18.7	10.5	43.1	15.6	3.2	11.2
	Almoina 11	10835	Rib	F	−18.6	9.5	40.2	14.6	3.2	1.5
	Almoina 11	7602[b]	Rib	F	−18.0	11.3	43.0	15.7	3.2	10.3
	Almoina 11	11,025	Rib	M	−18.7	10.6	33.0	11.8	3.3	0.8[a]
	Almoina 11	10689[b]	Rib	M	−18.1	10.9	42.3	15.2	3.2	4.2
	Almoina 11	10694[b]	Rib	M	−18.0	10.8	43.6	16.0	3.2	1.3
Islamic	Almoina 1	1281	Rib	?	−18.1	10.7	45.5	15.8	3.4	6.5
(11th–13th C)	Almoina 1	1356	Rib	?	−16.3	16.6	45.8	17.2	3.1	9.6
	Almoina 1	1428	Rib	?	−17.8	11.6	46.0	16.9	3.2	8.3
	Almoina 1	1363	Rib	F	−17.0	13.8	46.1	16.9	3.2	4.7
	Almoina 1	1295	Rib	F	−18.9	11.4	46.8	16.6	3.3	6.7
	Almoina 1	1344	Femur	M	−17.3	14.2	46.0	16.6	3.2	2.1
	Almoina 1	1095	Rib	M	−15.8	12.2	51.2	18.3	3.3	2.0
	Carrer de Dalt 48–58	1434	Femur	?	−19.8	9.7	42.8	15.2	3.3	1.1
	Carrer de Dalt 48–58	1568	Femur	?F	−18.1	11.5	36.7	13.1	3.3	1.0
	Carrer de Dalt 48–58	2375	Femur	?F	−16.6	12.1	45.4	16.4	3.2	4.3
	Carrer de Dalt 48–58	1354	Rib	?F	−17.7	10.3	49.7	17.8	3.3	3.9
	Carrer de Dalt 48–58	1632	Rib	F	−18.8	10.1	45.6	16.3	3.3	3.5
	Carrer de Dalt 48–58	2094	Rib	F	−19.3	11.0	46.7	17.3	3.2	1.9
	Carrer de Dalt 48–58	1941	Femur	F	−19.2	10.8	47.4	15.3	3.6	2.2
	Carrer de Dalt 48–58	2036	Rib	F	−18.8	10.3	48.3	17.1	3.3	2.0
	Carrer de Dalt 48–58	1419	Femur	F	−19.2	10.8	48.4	16.8	3.4	2.1
	Carrer de Dalt 48–58	2549	Rib	F	−18.4	10.5	49.4	18.8	3.1	8.0
	Carrer de Dalt 48–58	2544	Rib	F	−15.8	11.5	49.4	17.4	3.3	1.6
	Carrer de Dalt 48–58	1565	Femur	?M	−17.3	12.2	40.7	14.8	3.2	1.5
	Carrer de Dalt 48–58	1330	Femur	?M	−18.8	10.5	42.1	14.8	3.3	2.2
	Carrer de Dalt 48–58	2369	Femur	?M	−17.6	10.6	43.7	16.5	3.1	3.2
	Carrer de Dalt 48–58	2292	Rib	?M	−18.6	9.9	46.0	17.3	3.1	9.5
	Carrer de Dalt 48–58	2193	Femur	M	−18.3	9.3	44.0	16.4	3.1	2.8
	Carrer de Dalt 48–58	1945	Femur	M	−19.1	10.3	45.4	16.2	3.3	2.3
	Carrer de Dalt 48–58	1366	Femur	M	−19.0	11.2	45.5	15.8	3.3	1.3
	Carrer de Dalt 48–58	2011	Femur	M	−18.5	11.0	47.0	17.8	3.1	2.0
	Carrer de Dalt 48–58	2536	Rib	M	−18.8	11.4	48.6	18.3	3.1	8.5
	Carrer de Dalt 48–58	2132	Rib	M	−18.9	10.7	49.1	16.6	3.5	2.9
	Carrer Pintor Sorolla	1809	Rib	?F	−16.3	11.8	39.7	14.0	3.3	2.8
	Carrer Pintor Sorolla	1807	Rib	F	−15.2	12.3	44.0	15.9	3.2	4.2
	Carrer Pintor Sorolla	1805	Rib	M	−16.6	12.0	46.9	16.7	3.3	3.3
	Carrer Sagunt	1217	Rib	?M	−16.7	12.0	42.4	15.3	3.2	6.4
	Carrer Sagunt	1586	Rib	?M	−16.9	12.0	44.4	15.4	3.4	3.6
	Carrer Sagunt	1117	Rib	F	−15.8	11.7	41.7	14.9	3.3	12.3
	Carrer Sagunt	1192	Rib	F	−17.6	14.5	44.4	15.7	3.3	4.7
	Carrer Sagunt	1399	Rib	F	−17.1	13.4	48.0	17.4	3.2	14.5
	Carrer Sagunt	1290	Humerus	M	−17.9	12.2	41.5	14.3	3.4	9.1
	Carrer Sagunt	1331	Rib	M	−14.2	11.0	48.2	17.1	3.3	2.9

Table 2 (continued)

Period	Site	Skeleton	Element	Sex	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	C (%)	N (%)	C/N	% Col.
Christian	San Andrés IPSOS47	1585	Rib	F	− 18.2	11.2	34.6	11.6	3.5	2.6
(14th–15th C)	San Andrés IPSOS47	1466	Rib	F	− 18.1	11.7	44.7	16.4	3.2	8.1
	San Andrés IPSOS47	1549	Rib	F	− 18.1	11.3	48.1	17.4	3.2	4.6
	San Andrés IPSOS47	1649	Rib	F	− 18.4	10.5	49.3	17.1	3.4	2.3
	Carrer Sant Vicent 134	3048	Rib	?	− 18.5	11.3	46.4	16.9	3.2	11.1
	Carrer Sant Vicent 134	3277	Rib	?F	− 19.3	9.3	40.5	14.4	3.3	4.3
	Carrer Sant Vicent 134	3274	Rib	?F	− 17.3	11.6	49.1	17.8	3.2	10.9
	Carrer Sant Vicent 134	3054	Rib	F	− 18.3	10.3	49.0	17.9	3.2	12.7
	Carrer Sant Vicent 134	3280	Rib	F	− 18.7	8.4	49.5	17.1	3.4	6.0
	Carrer Sant Vicent 134	3283	Rib	?M	− 18.8	8.0	45.4	16.0	3.3	3.0
	Carrer Sant Vicent 134	3325	Rib	?M	− 18.4	11.6	45.7	16.2	3.3	5.0
	Carrer Sant Vicent 134	3289	Rib	?M	− 18.9	10.1	46.5	16.7	3.3	4.0
	Carrer Sant Vicent 134	3070	Rib	M	− 18.5	11.3	38.1	13.1	3.4	3.7
	Carrer Sant Vicent 134	3051	Rib	M	− 18.8	11.1	40.7	14.2	3.3	7.7
	Carrer Sant Vicent 134	3244	Rib	M	− 16.8	10.6	44.3	15.5	3.3	2.8
	Carrer Sant Vicent 134	3334	Rib	M	− 18.1	11.3	45.1	16.4	3.2	9.1
	Carrer Sant Vicent 134	3677	Rib	M	− 19.1	9.1	47.9	17.2	3.2	5.0
	Carrer Sant Vicent 134	3220	Rib	M	− 18.5	10.9	48.3	17.9	3.2	10.1
	Carrer Sant Vicent 134	3622	Rib	M	− 18.7	17.1	41.6	13.8	3.5	5.9

[a] Yield < 1% but data retained

[b] These burials are thought to date to the late 5th–early 6th century

δ^{13}C value of − 10‰. The same C_3/C_4 patterning among cattle was found in the rural Muslim settlement of Gandía in a later period (Alexander et al. 2015). In line with the evidence presented here, species of millet are mentioned among the grains used to fatten both cattle and chickens by the agronomist Ibn al-Awwam in his twelfth-century *Treatise on Agriculture* (Ibn al-Awwam 1802). In north-west Spain, ethnographic evidence demonstrates that millet is still traditionally used for foddering animals, particularly stabled cattle and chickens (Moreno-Larrazabal et al. 2015).

Human data from Islamic Valencia exhibit a strikingly wide range in both δ^{13}C (5.5‰) and δ^{15}N (7.0‰, Table 4). When the isotopic data is plotted (Fig. 3), a core group of individuals show δ^{13}C and δ^{15}N values (− 19.0 to −18.0‰ and 10 to 12‰ respectively) indicative of a predominantly terrestrial, C_3-based diet. Isotopic values for the reminder of the sampled individuals suggest the consumption of marine fish and/or C_4 protein (directly and/or indirectly). As previously noted, it is difficult to disentangle the consumption of marine fish rather than C_4 resources in the Mediterranean environment, although trends are discernible that could indicate the consumption of one over the other. One group of individuals possess increasingly higher δ^{13}C values >− 18‰ but relatively constant δ^{15}N values of around 12‰, indicating input of C_4 resources, whereas other individuals exhibit

considerable enrichment in ^{15}N (δ^{15}N values of up to ~ 17‰) coupled with corresponding higher δ^{13}C values (− 18 to − 16‰) suggesting marine protein consumption.

This variability is also visible by site (Fig. 7), suggesting that a range of dietary resources was available across the city and between communities. Only the individuals from the Bab al-Hanax cemetery plot in a relatively cohesive group with some individuals tailing out towards higher δ^{13}C values. For the most part, this population may represent locals of middling status who subsisted mainly on C_3 terrestrial foods.

Burials from Carrer Sagunt, associated with the artisan suburb of la Alcudia outside the city, are especially notable for their extremely variable δ^{13}C and δ^{15}N values; these individuals have some of the highest δ^{15}N values exhibited by the population. The three individuals from Carrer Pintor Sorolla, believed to date to the late thirteenth-century siege, all show higher δ^{13}C values indicative of C_4 protein consumption. High-status burials from La Rauda are again highly variable, with some plotting with the majority in Carrer de Dalt, whereas others possess higher δ^{13}C and δ^{15}N values. The latter group may have consumed a greater proportion of marine resources (> 50% for individual VRM1356 following Richards et al. 2006); alternatively, these individuals may have originated elsewhere.

Table 3 Full δ^{13}C and δ^{15}N results for medieval animal bone collagen from Valencia. Those marked by a dot (•) are marine fish (Alexander et al. 2015)

Sample	S-EVA	Site	Period	Species	δ^{13}C$_{VPDB}$ (‰)	δ^{15}N$_{AIR}$ (‰)	C (%)	N (%)	C/N	% Col.
VVC1	13616	Almoina 8	6th–8th	Cow	−20.1	3.7	42.9	15.5	3.2	3.8
VVC2	13576	Almoina 8	6th–8th	Cow	−18.6	3.9	42.6	15.2	3.3	1.9
VVD1	13571	Almoina 8	6th–8th	Dog	−16.4	9.0	40.7	14.9	3.2	2.9
VVG1	13559	Almoina 8	6th–8th	Goat	−18.9	3.7	42.8	15.4	3.2	4.9
VVO1	13612	Almoina 8	6th–8th	Sheep	−20.5	6.1	43.1	15.7	3.2	3.1
VVO2	13569	Almoina 8	6th–8th	Sheep/goat	−19.4	5.7	42.6	15.6	3.2	5.7
VVO3	13560	Almoina 8	6th–8th	Sheep	−20.1	7.4	43.6	15.9	3.2	9.8
VVO4	13566	Almoina 8	6th–8th	Sheep	−20.0	5.2	42.2	15.4	3.2	4.0
VVP1	13570	Almoina 8	6th–8th	Pig	−19.0	8.4	42.4	15.1	3.3	4.8
VVP2	13564	Almoina 8	6th–8th	Pig	−18.5	7.2	41.6	15.0	3.2	2.4
VVP3	13565	Almoina 8	6th–8th	Pig	−19.4	8.5	40.1	14.5	3.2	2.6
VVR1	13615	Almoina 8	6th–8th	Rabbit	−22.3	3.7	44.0	15.5	3.3	5.9
VMC1	7895	Almoina 8	10th–13th	Cow	−18.8	7.0	36.9	13.5	3.2	1.0
VMC2	7893	Almoina 8	10th–13th	Cow	−16.8	7.0	40.5	15.0	3.2	4.2
VMC3	7919	Almoina 10	10th–13th	Cow	−18.4	8.5	34.2	12.6	3.2	1.4
VMC4	7905	Almoina 10	10th–13th	Cow	−20.1	2.5	42.0	15.0	3.3	2.8
VMC5	7918	Almoina 8	10th–13th	Cow	−15.8	5.9	43.8	16.3	3.1	5.6
VMGa1	13607	Almoina 10	10th–13th	Chicken	−17.9	11.4	43.2	15.5	3.2	12.3
VMGa2	13608	Almoina 10	10th–13th	Chicken	−10.0	11.5	43.4	15.6	3.3	7.8
VMO4	7917	Almoina 8	10th–13th	Sheep/goat	−20.4	9.7	42.2	15.3	3.2	1.7
VMO5	7901	Almoina 8	10th–13th	Sheep/goat	−19.7	5.5	43.8	16.0	3.2	2.0
VMO6	7916	Almoina 10	10th–13th	Sheep/goat	−19.4	3.8	40.1	14.9	3.1	3.5
VMO1	7910	Almoina 10	10th–13th	Sheep	−19.3	2.8	38.3	13.9	3.2	1.0
VMO2	7894	Almoina 8	10th–13th	Sheep	−20.3	8.0	42.2	15.6	3.2	3.9
VMO3	7909	Almoina 10	10th–13th	Sheep	−19.0	9.6	37.7	13.8	3.2	1.3
VMS1	7896	Almoina 8	10th–13th	Sheep	−18.9	7.1	43.9	16.1	3.2	1.0
VMS2	7897	Almoina 10	10th–13th	Sheep	−18.6	5.3	42.6	15.5	3.2	5.6
VMP1	7915	Almoina 8	10th–13th	Pig	−19.5	7.7	41.4	15.0	3.2	1.6
VCC1	7914	Almoina 9–10	13th–16th	Cow	−20.6	6.0	43.1	15.8	3.2	2.2
VCC2	7902	Almoina 8	13th–14th	Cow	−19.9	9.0	44.5	16.4	3.2	3.5
VCO1	7920	Almoina 9–10	13th–16th	Sheep/goat	−20.4	4.3	44.6	16.4	3.2	3.2
VCO4	–	Almoina 9–10	13th–16th	Sheep/goat	−19.3	5.2	42.0	15.3	3.2	6.2
VCO2	7903	Almoina 8	13th–14th	Sheep	−20.6	8.0	41.6	15.4	3.2	3.4
VCO3	7907	Almoina 9–10	13th–16th	Sheep/goat	−19.5	3.0	42.2	15.4	3.2	3.4
VCS1	7898	Almoina 8	13th–14th	Sheep	−19.3	4.9	39.3	14.5	3.2	2.1
VCS2	7913	Almoina 8	13th–14th	Sheep	−20.0	7.7	39.6	14.4	3.2	1.5
VCS3	7899	Almoina 9–10	13th–16th	Sheep	−20.7	5.7	35.1	12.8	3.2	1.8
VCP1	7911	Almoina 9–10	13th–16th	Pig	−19.6	9.6	41.4	15.1	3.2	3.0
VCP2	7904	Almoina 8	13th–14th	Pig	−18.3	8.8	26.2	9.5	3.2	0.4[a]
VCP3	7900	Almoina 9–10	13th–16th	Pig	−19.6	8.0	40.1	14.6	3.2	1.0
VCP4	7906	Almoina 9–10	13th–16th	Pig	−17.0	8.8	39.7	14.7	3.2	1.8
VCR1	7912	Almoina 8	13th–14th	Rabbit	−21.8	4.6	25.1	8.9	3.3	1.6
ABF1•	7889	Albarracín	10th–12th	*Mugilidae*	−10.1	8.1	44.1	16.2	3.2	3.9
ABF3•	7890	Albarracín	10th–12th	*Argyrosomus*	−10.8	10.4	42.7	16.3	3.0	16.2
ABF4•	7891	Albarracín	10th–12th	*Dicentratchus*	−11.2	12.6	42.7	16.1	3.1	4.1
ABF5•	7888	Albarracín	10th–12th	*Mugilidae*	−9.4	9.5	45.9	16.6	3.2	3.8
ABF6•	7892	Albarracín	10th–12th	*Dicentratchus*	−11.4	12.5	44.8	16.6	3.2	6.2
GBF1•	7887	Gandía	15th–16th	*Galeorhinuseus*	−12.4	9.9	42.9	15.3	3.3	4.6

[a] Yield < 1% but data retained

The presence of non-locals may explain the variation in the population overall. As a successful port, Valencia was at the centre of political, familial, trade and travel links between al-Andalus and the Maghreb during the eleventh to thirteenth centuries (Glick 2005, p. 357). The people buried at La Rauda are believed to have been those related either politically or by kinship to the Almoravid and Almohad rulers of Valencia and it is very probable that some of these elites may have originated from areas such as the Almohad capital of Marrakesh on the edge of the Sahara in North Africa (Boone and Benco 1999; Torró 2009b). Written records indicate that both members of the nobility and inhabitants of other cities in the Valencian territory were buried at Bab al-Hanax (Pascual and Serrano 1996, p. 232). There were continuous waves of Berber immigrants from North Africa into al-Andalus throughout the Islamic period and their frequency increased from the tenth century onwards (Guichard 2000). Slaves would have also been a major presence in Valencia

during this period. The presence of, and access to, black slaves in al-Andalus purportedly goes back to the eleventh century and is associated with Islamic penetration of sub-Saharan areas and the arrival of the Almoravid and Almohad dynasties from North Africa (Constable 1996, p. 269). It may be that some of the individuals identified with relatively high δ^{15}N

Fig. 3 Stable carbon and nitrogen isotope data for animal and human bone collagen for each period, Visigothic (**a**), Islamic (**b**) and Christian (**c**)

and δ^{13}C values originated from the Maghreb. Substantial enrichment in ^{15}N of consumer bone collagen has been reported from arid areas such as Dakheleh Oasis in the Sahara (δ^{15}N values from around 15 to 18‰, Schwarcz et al. 1999; Dupras and Schwarcz 2001) and δ^{13}C values, similar to those exhibited here, have been reported in human collagen samples from archaeological populations from North Africa, for example from Sudanese Nubia (Turner et al. 2007).

In the wider context, this variability in isotopic values, particularly for δ^{13}C, is also a feature of published isotopic values for Islamic populations in other parts of Spain (Fig. 5). This is often due to the presence of specific outliers increasing the standard deviation of these populations, particularly in those cases with smaller samples, e.g. La Torrecilla, Granada (Jiménez-Brobeil et al. 2016). In the tenth–thirteenth-century Islamic population from Can Fonoll, Ibiza, there was a wide range of δ^{13}C values, but only four individuals had values above − 16‰ indicative of significant input of C$_4$ resources and these were therefore interpreted as migrants (Pickard et al. 2017). In Valencia, by contrast, many individuals exhibit increased δ^{13}C values and although the presence of migrants is highly likely, individual choice or restriction in diet cannot be ruled out.

Local socioeconomic factors must therefore also be considered, where low status individuals and/or slaves may have relied on C$_4$ grain in particular. On the other hand, individuals with higher δ^{13}C values may be local migrants from rural areas where C$_4$ grain was utilised more widely. Isotopic evidence points to a rural-urban divide where later medieval Islamic communities from rural contexts exhibit higher δ^{13}C values indicative of C$_4$ signatures (Fig. 5), e.g. La Torrecilla (Jiménez-Brobeil et al. 2016), Benipeixcar (Alexander et al. 2015) and El Raval (Salazar-García et al. 2014).

Christian period

Animal data for the Christian period indicates a return to a predominantly C$_3$-based diet, although no chickens and only two cows were sampled from contexts dating to this period (Fig. 3, Table 5). Perhaps more samples of these species in particular would reveal further diversity. Data for pigs are most notable among the animal data for this period, demonstrating more enrichment in ^{15}N in comparison to earlier periods (minimum δ^{15}N value 8‰, maximum δ^{15}N value 9‰, $n = 4$, Table 5). This is perhaps indicative of more intensive husbandry and inclusion of animal protein in the diet of pigs that may signal a renewed importance for animal for the Christian populace. One pig (VCP4, Table 3) is also enriched in ^{13}C, with a δ^{13}C value of − 17.0‰. This suggests the input of a source of ^{13}C-enriched carbon in the diet, probably from C$_4$-derived protein rather than marine sources as the pigs have lower δ^{15}N values than the majority of humans (Fig. 3).
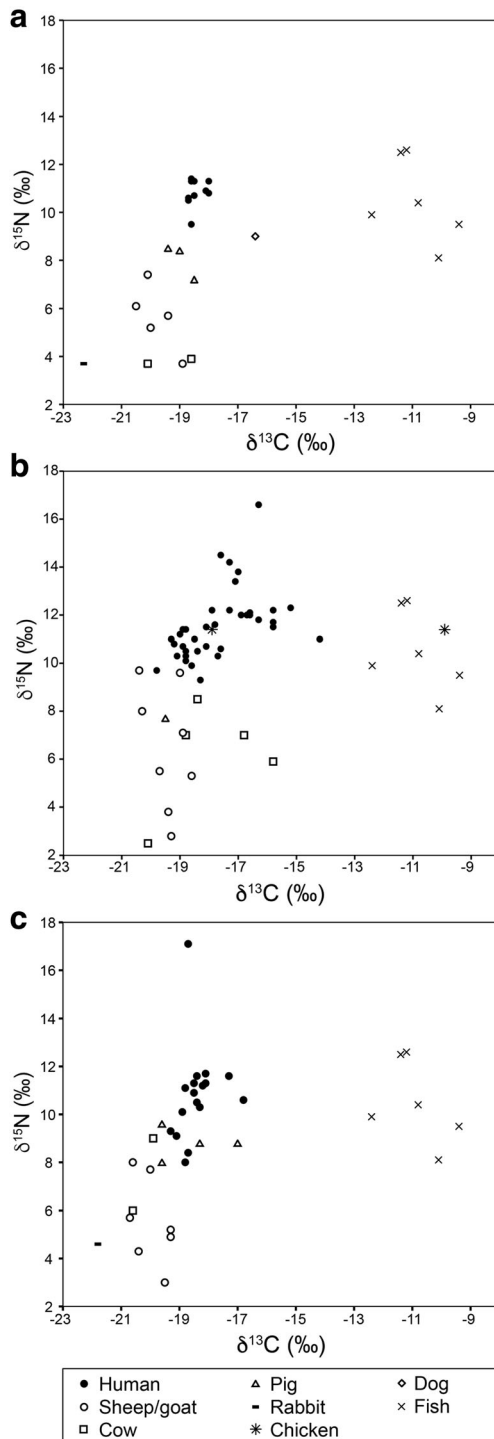
Table 4 Summary stable carbon and nitrogen isotope data for human bone collagen from all sites in each period

Period (centuries)	n	$\delta^{13}C_{VPDB}$ (‰)				$\delta^{15}N_{AIR}$ (‰)			
		Min	Max	Range	Mean ± 1	Min	Max	Range	Mean ± 1
Visigothic, 5th–7thC	10	− 18.7	− 18.0	0.7	− 18.4 ± 0.3	9.5	11.4	1.9	10.8 ± 0.6
Islamic, 11th–13thC	38	− 19.8	− 14.2	5.6	− 17.7 ± 1.3	9.3	16.6	7.3	11.5 ± 1.4
Christian, 14th–15thC	19	− 19.3	− 16.8	2.5	− 18.4 ± 0.6	8	17.1	9.1	10.9 ± 1.9

Human individuals from the later medieval Christian Valencia (Table 4) display a relatively narrow range (2.5‰) in $\delta^{13}C$ values but a wide range (9.1‰) in $\delta^{15}N$, due to the presence of an extreme outlier from Carrer Sant Vicent, VSVC3622 (Table 2). The $\delta^{13}C$ and $\delta^{15}N$ values for the majority indicate a C_3 terrestrial-based diet with animal protein deriving from herbivores and little contribution from pigs, which have values similar to the humans themselves (Fig. 3, human $\delta^{15}N$ values are on average only 1.8‰ higher in than the mean for pigs). However, there may be an additional source of ^{13}C-enriched carbon and ^{15}N-enriched nitrogen in the diet of some individuals, perhaps from C_4 fed pork or marine sources.

Inter-site comparison in Valencia is limited by San Andrés being represented by just four individuals (Fig. 8). One group of four individuals from the Sant Vicent cemetery are identifiable as possessing $\delta^{15}N$ values that are on par with some of the higher herbivore values. Their consumption of animal protein was therefore limited, and they were probably poor people housed by the hospital at the Sant Vicent complex.

The outlier from Carrer Sant Vicent, VSVC3622, with a remarkably high $\delta^{15}N$ value of 17‰ lacks a corresponding enrichment in ^{13}C, which rules out the consumption of marine fish. This extreme $\delta^{15}N$ value is unlikely to represent a local who consumed freshwater fish, given that the value is higher than even Mesolithic individuals who are hypothesised to have primarily subsisted on freshwater fish from the Danube (Bonsall et al. 2004). A recent study of an Islamic population from Aragón (eighth–tenth century), however, showed similar $\delta^{15}N$ values (mean of 15‰) correlated with a C_3 carbon value (mean − 19.1‰) so that such signatures are possible in some areas of Spain (Guede et al. 2017). Although data from later Christian periods are lacking from that area, northern Aragón is a possible place of origin that ties with population movement during the initial phase of Christian control and repopulation of Valencia. However, any other area with high aridity and C_3 crops remains a possibility.

Across the Valencian region (Fig. 5), there is a greater reliance of on C_4 plants exhibited by the broadly contemporaneous Christian population from Gandía and the *mudéjar*

Table 5 Summary $\delta^{13}C$ and $\delta^{15}N$ data for animals for each period in medieval Valencia

Period (centuries)	Species	n	$\delta^{13}C_{VPDB}$ (‰)				$\delta^{15}N_{AIR}$ (‰)			
			Min	Max	Range	Mean ± 1σ[a]	Min	Max	Range	Mean ± 1σ[a]
Visigothic, 5th–7thC	Cow	2	− 20.1	− 18.6	1.5	− 19.3	3.7	3.9	0.2	3.8
	Ovicaprid	5	− 20.5	− 18.9	1.6	− 19.8 ± 0.6	3.7	7.4	3.8	5.6 ± 1.4
	Pig	3	− 19.4	− 18.5	0.8	− 19.0 ± 0.4	7.2	8.5	1.4	8.0 ± 0.8
	Rabbit	1	–	–	–	− 22.3	–	–	–	3.7
	Dog	1	–	–	–	− 16.4	–	–	–	9.0
Islamic, 11th–13thC	Cow	5	− 20.1	− 15.8	4.3	− 18.0 ± 1.7	2.5	8.5	6.0	6.2 ± 2.3
	Ovicaprid	8	−20.4	− 18.6	1.8	− 19.5 ± 0.6	2.8	9.7	6.9	6.5 ± 2.6
	Pig	1	–	–	–	− 19.5	–	–	–	7.7
	Chicken	2	− 17.9	− 10	7.9	–	11.4	11.5	0.1	11.4
Christian, 14th–15thC	Cow	2	− 20.6	− 19.9	0.7	− 20.2	–	–	–	7.5
	Ovicaprid	7	− 20.7	− 19.3	1.4	− 20.0 ± 0.6	3.0	8.0	5.0	5.5 ± 1.8
	Pig	4	− 19.6	− 17.0	2.6	− 18.6 ± 1.2	8.0	9.6	1.6	8.8 ± 0.7
	Rabbit	1	–	–	–	− 21.8	–	–	–	4.6

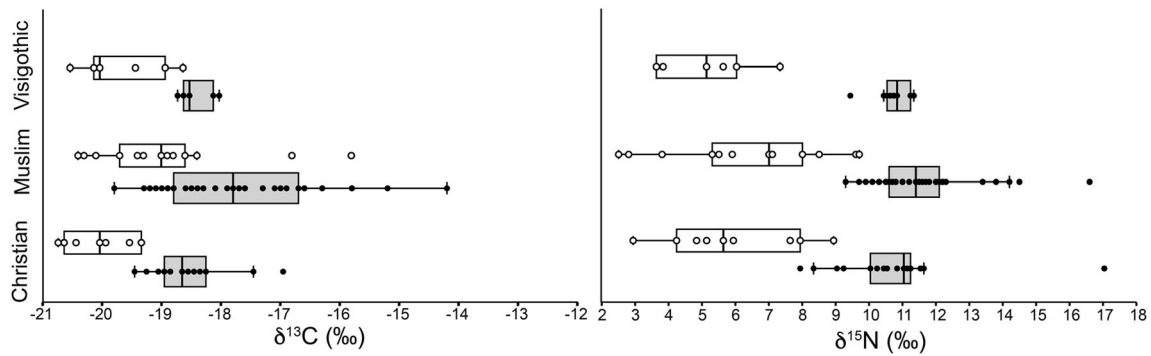[a] Standard deviation only calculated for three or more samples

Fig. 4 Stable carbon and nitrogen isotope data for herbivore (cattle, sheep/goat, white boxes) and human (grey boxes) bone collagen plotted by period as box and jitter plots. The boxes indicate the inter-quartile range (IQR), the whiskers comprise the values that are with 1.5× the IQR and the dots beyond these are outliers. Sample numbers: herbivores 7, 13, 9 and humans 10, 38, 18, for Visigothic, Islamic and Christian respectively

populations of Benipeixcar and El Raval (Alexander et al. 2015; Salazar-García et al. 2014) in comparison to the inhabitants of Christian Valencia. This may again reflect a difference between urban and rural subsistence in this later phase. During the thirteenth and fourteenth centuries, the city of Valencia itself had authority over cereal production and distribution (Barrio 2009, p. 63) but in times of shortage of wheat grain was imported from outside the kingdom (García Marsilla 1993, p. 7). Because of this, it is highly probable that the availability of wheat in the more rural areas was limited to those who could afford it. The bulk of the populace would have had to (or chosen to) rely on grains produced locally, including millet or sorghum.

Discussion and synthesis

Although sample sizes are relatively small for the Visigothic and, to some extent, later Christian periods, the consistency of the core isotopic data for all periods (~ − 19 to − 17‰ δ^{13}C, ~ 10 to 12‰ δ^{15}N, Fig. 3) and the stark contrast we see in the Islamic period in particular lends support to our interpretations.

Diachronic trends

The diet for the majority of the sampled population was characterised by a reliance on terrestrial C_3 resources which

Table 6 Herbivore-human average offsets for mean δ^{13}C and δ^{15}N for all periods, Visigothic (5th–7th centuries), Islamic (11th–13th centuries) and Christian (14th and 15th centuries)

| Period	n (cattle/sheep/goat)	n (human)	Δ^{13}C	Δ^{15}N
Christian	9	19	1.6	4.9
Muslim	11	38	1.2	5.2
Visigothic	7	10	1.2	5.7

is similar throughout all three periods under discussion. Despite this, significant shifts in subsistence occurred between each phase, which can be linked to cultural and socioeconomic changes in the historic record. The Islamic period is noteworthy for a wide variation in isotopic values and the greater reliance on C_4 crops compared to the periods both before and after.

The variability in subsistence exhibited by the Islamic population may reflect an increased non-local presence in the population, made visible by migrants from more arid areas where C_4 crops were cultivated, such as the Maghreb. When Christians took control of much of the Iberian Peninsula from the thirteenth century onwards, there was some reorientation of trade towards northern Christian Europe although some trade links between the Sultanate of Granada and the Islamic Maghreb did continue, if diminished (Constable 1994; Ferrer 2012). This change in trade may have had an impact on the origin of travellers, merchants and traders present in the city. The presence of African slaves, however, continued into the Christian period and Valencia became the principal port for the import and export of slaves in the western Mediterranean (Montalvo 2000; Mummey and Reyerson 2011; Ferrer 2012).

The shift towards the greater use of C_4 crops among local humans and animals in the Islamic period is another factor behind diversity in isotopic values that may be linked to the use of crops such as sorghum (Watson 1974; Squatriti 2014). In a recent survey of available archaeobotanical data for the Iberian Peninsula, it was reported that evidence for millets has been recorded on many medieval sites particularly in the west/north-west and the north-east although the archaeobotanical evidence from Valencia itself is extremely patchy and does not extend into the Christian period (Peña-Chocarro et al. 2017). Sorghum is yet to be identified at any site, although evidence has been found in medieval France and North Africa (Peña-Chocarro et al. 2017). It is not until the Christian period (fourteenth and fifteenth centuries) that we have historical records confirming the presence of C_4 crops such as sorghum in the *Horta* of Valencia, where a white form was used primarily for

Fig. 5 Mean values for stable carbon and nitrogen isotope data for human bone collagen for the later medieval period published from southern and eastern Spain and Ibiza. Error bars represent ± 1σ. References: Gandía and Benipeixcar (Alexander et al. 2015), El Raval (Salazar-García et al. 2014), Tossal de les Basses (Salazar-García et al. 2016), La Torrecilla and Seville Royalty (Jiménez-Brobeil et al. 2016), Can Fonoll (Pickard et al. 2017), Es Soto and S'Hort des Llimoners (Fuller et al. 2010)
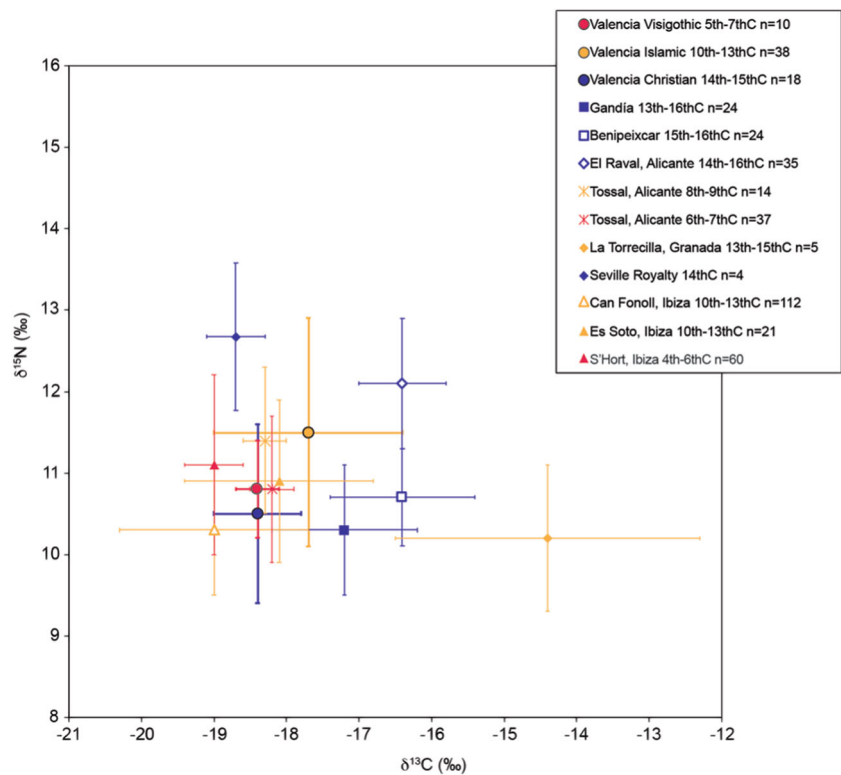
human consumption, and a red variety was used as a fodder for cattle and poultry (Rubio 1995, p. 169). Focus on wheat as the most profitable commercial crop, however, meant that summer grains such as millet and sorghum may have been more limited for the tenants of the irrigated *Horta* (Torró 2009a). The lower $\delta^{13}C$ values exhibited by humans and animals in the Christian population confirm a decrease in C_4 plant consumption, perhaps reflecting a decline in millet and sorghum cultivation during this period.

Socio-cultural factors may have also combined with these economic circumstances. Following the thirteenth-century Christian conquest, the newly arrived population would have comprised of settlers from northern Christian kingdoms, principally Aragón, who were encouraged to migrate by the offer of reduced taxes and enhanced privileges (Burns 1975; Ruiz 2014). Written sources suggest that C_4 plants were regarded as minority crops in these regions (Aguilera 1991, p. 9; Glick 1982, p. 82), although isotopic data does reveal a reliance on millet in other areas of northern Spain such as Galicia (Kaal et al. 2016; López-Costas and Müldner 2016) and the Basque Country (Quirós Castillo 2013). As a result, the consumption of C_4 crops such as sorghum may have decreased after the Christians took control, at least among the urban population (Rubio 1995, p. 162).

The growing picture of diet in southern and eastern regions of Spain (Fig. 5) suggests that, despite millet being present in the Iberian Peninsula since the Middle Bronze Age (Buxó and Piqué 2008), C_4 crops only rose in importance as a food

source in these areas during the period of Islamic rule. This is evidenced in the comparatively low $\delta^{13}C$ values seen so far in Late Antique/Visigothic populations and may not have occurred immediately after the Islamic conquest as the largely C_3 diet of the earlier eighth- and ninth-century site in Alicante site attests (Salazar-García et al. 2016). Although C_4 crops continued to be grown under later Christian rule, their
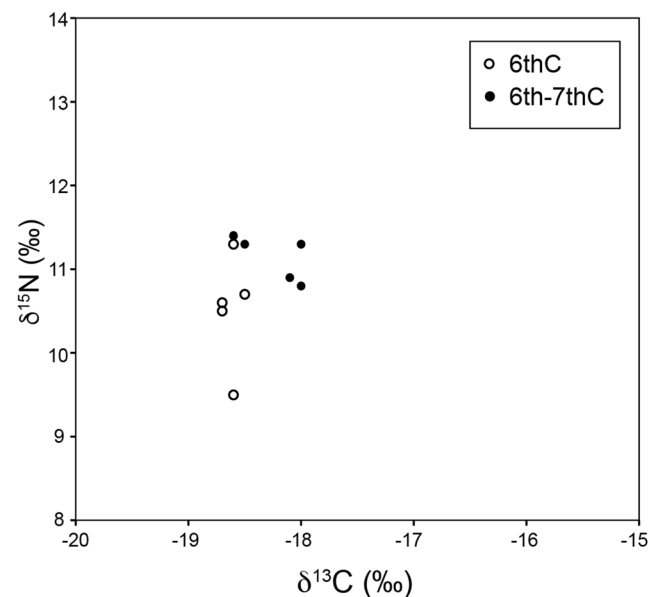

Fig. 6 Stable carbon and nitrogen isotope data for human bone collagen from the Visigothic period (5th–7th century) separated by phase
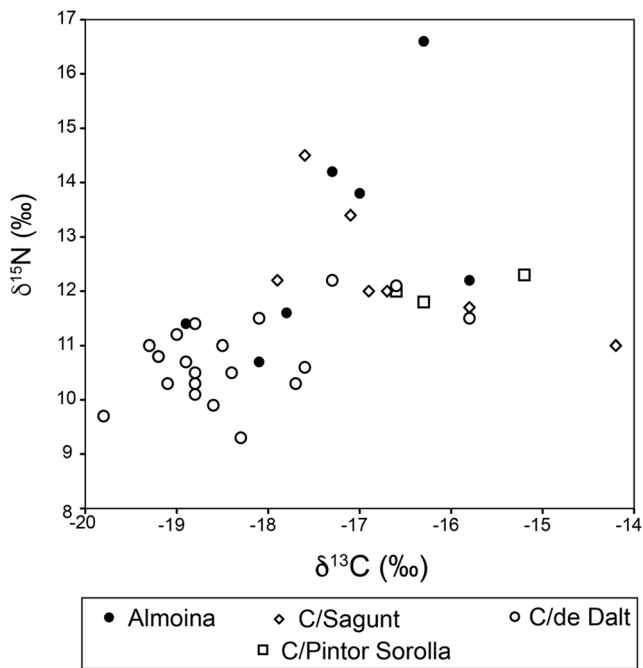
Fig. 7 Stable carbon and nitrogen isotope data for human bone collagen from the sites of Almoina, Carrer Sagunt, Carrer Pintor Sorolla and Carrer de Dalt (Bab al-Hanax) in the Muslim period (11th–13th century)

the Islamic period. For example, transhumant cattle and sheep flocks driven between summer and winter grazing lands would have effectively fed on C_3 pastures all year round which may have led to a decline in C_4 fodder fed to local sedentary animals. This would particularly have been the case at times of the year when there was only poor-quality local pasture available. To determine whether the differences in livestock practices suggested here are truly significant, further samples would need to be analysed from different quarters of the city and be combined with zooarchaeological study.

Although the isotopic data indicate the potential for certain individuals to have consumed marine resources in the Islamic period, the lack of evidence for significant marine fish consumption for the later Christian period is somewhat surprising, particularly given that fish would have fulfilled a liturgical requirement. Port archives of the fifteenth century indicate the importance of fishing to the city, mentioning the availability of 27 different types of marine and freshwater fish (Guiral 1989, p. 381). Fresh fish either originated from the Mediterranean or from brackish lagoons such as the Albufera; sardines in particular were a cheap fish that could be afforded by those of little wealth in Valencia during this period (Granero and Amparo 1962; Gallart et al. 2005; García Marsilla 1993). The dietary contribution of low trophic level marine fish and minor quantities of marine and especially brackish resources is, however, difficult to detect using isotopic analysis, particularly for the Mediterranean (Garvie-Lok 2001; Hedges 2004; Triantaphyllou et al. 2008). There is only one published instance of increased fish consumption in the later medieval period in the
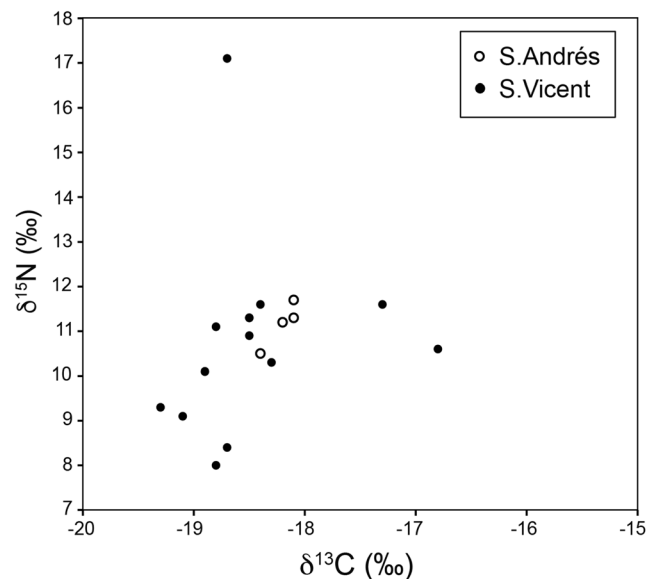
importance was diminished and seems firmly associated with the lower social orders and rural populations.

Despite faunal data exhibiting high variation in all periods, shifts in isotopic values were detected, indicating a baseline economic shift and husbandry between all three periods. While there may have been much continuity in husbandry between periods, the *scale* of agriculture and animal husbandry differed with changing production strategies and reorganisation of agricultural landscapes, particularly during the later Christian period (Torró 2012b; Lopez and Retamero 2017). As mentioned above, there was a shift in economic strategy towards a more intensive focus on economic crops and an emphasis on animal livestock and long-range transhumance (Montalvo 1992; Trillo San José 1999; Malpica 2012). It is in the later Christian period that large sheep flocks were driven through the peninsula from Aragón and Castile to the lowland pastures of southern Valencia (Klein 1920; Butzer 1988; Montalvo 1992). Similarly, cattle ranching had developed earlier in the northern Christian kingdoms and was introduced to Valencia in the thirteenth century. Herds from Valencia were driven to grazing pastures some 170 km to the south at Elche (O'Callaghan 1975, p. 478; Montalvo 1992, p. 169). This change towards large-scale animal husbandry in the Christian period may serve to lessen the variability in livestock practices and homogenise dietary signals among livestock when compared to

Fig. 8 Stable carbon and nitrogen isotope data for human bone collagen from San Andrés and Sant Vicent sites in the Christian period (14th and 15th century)

Mediterranean, from fifteenth-century Rome, where the consumption of traded Atlantic fish has been hypothesised (Salamon et al. 2008). Valencia and Alicante served as redistribution centres for fish caught in Galicia and being transported inland to Castile and Aragón (Ferreira 1988), although high trophic level Atlantic fish with corresponding higher δ^{15}N values (e.g. López-Costas and Müldner 2016) do not appear to have been a major component in the diet. The isotopic results particularly for the later Christian period in Valencia might be sufficient to question how far marine resources contributed to the local diet in the city.

It is notable that no differentiation in diet was detected between sexes at any period, something which is not reported universally in stable isotope studies of medieval populations. This may be due to a lack of dietary differentiation despite the differing roles of males and females purported for medieval Muslim and Christian societies, where women were typically associated with food preparation and domestic tasks (Shatzmiller 1994; Ward 2002). On the other hand, this may simply reflect the broad nature of isotopic evidence for diet and/or the small sample sizes often involved in such comparisons.

Conclusion

Diet in Valencia over 1000 years is characterised by significant isotopic variability between Visigothic, Muslim and later medieval Christian individuals, revealing distinct dietary regimes between these culturally contrasting phases of medieval Valencia. Diachronic trends in the data support historical evidence for a significant change in diet and subsistence, particularly during the Muslim and later Christian periods. Differences in both human and animal data between periods are the result of a complex interplay of factors including socioeconomic shifts and developing travel and trade routes.

Although many individuals in the Islamic period have isotopic values which are similar to those exhibited by individuals in the earlier Visigothic period, there is a far greater range in the δ^{13}C and δ^{15}N values of the Muslim population. This may be due to an increased number of migrants from areas with distinctive enrichment of foods in ^{13}C and ^{15}N such as the Maghreb, to which Valencia was politically and culturally aligned in this period. This diversity in values also almost certainly reflects the variety in choice or access to isotopically distinct foods at this time, as wells as the introduction of new crops, an emphasis on polyculture and the balance of local herding and cereal farming in the region. The growth of urban Valencia under Islamic rule may also have encouraged diversification, particularly the introduction of C_4 crops to the diets of both humans and animals. These foodstuffs are traditionally associated with lower status social groups and have the effect of increasing the isotopic 'visibility' of socioeconomic differences among the populations sampled here, although issues around the detection of marine protein consumption obscure a clear interpretation.

A reduction in observed dietary diversity in the Christian period may be linked with a change in economic focus, both in terms of the reorganisation of trade routes but also agriculture and animal husbandry. The transition to Christian feudal rule emphasised commercial crops and flocks, potentially homogenising isotopic values, although rural and urban differences in the use of C_4 crops remained. Given the reorientation of trade routes, people from the medieval Islamic world with dietary isotopic signatures indicative of C_4 consumption and/or living in arid environments were less likely to be present in the city.

The potential for differential consumption of marine fish complicating the subsistence patterns interpreted here cannot be disregarded although identifying this with bulk isotope analysis is confounded by the C_4 animal protein/Mediterranean fish phenomenon. In the future, techniques utilising compound-specific analysis of bone collagen amino acid δ^{13}C could be implemented to identify diets with high marine protein input (Corr et al. 2005). These developing techniques, combined with a thorough regional review of existing medieval archaeozoological and archaeobotanical datasets, offer the best prospect for the future.

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