A snapshot of subsistence in Iron Age Iberia: the case of La Hoya village

Teresa Fernández-Crespo[1*], Javier Ordoño[2], Amy Bogaard[1], Armando Llanos[3], Rick Schulting[1]

[1] School of Archaeology, University of Oxford, 1 South Parks Road, Oxford OX1 3TG, United Kingdom.
[2]Department of Archaeology and New Technologies, Arkikus, Pedro de Asúa 63 2 D, Vitoria-Gasteiz 01008, Spain.
[3] Instituto Alavés de Arqueología, Pedro de Asúa 2, Vitoria-Gasteiz 01008, Spain.

* Corresponding author. Research Laboratory for Archaeology and the History of Art, School of Archaeology, University of Oxford, 1 South Parks Road, Oxford OX1 3TG, United Kingdom.
E-mail: teresa.fernandez-crespo@arch.ox.ac.uk

Abstract

Excavations at the Iron Age settlement of La Hoya in north-central Iberia, which was attacked between the mid-4th and the late 3rd centuries BC, provided fossilized scenes of devastation and death but also an extraordinary opportunity to analyze lifeways. Here, we conduct stable carbon and nitrogen isotope analyses of human, animal and plant remains to reconstruct subsistence practices at that time. The results suggest a mainly C_3-based subsistence economy, focused on the cultivation of cereals and the herding of domestic animals, particularly pigs, as the archaeological data support. Although C_4 plants are less abundant, they may have played a key role in infant and child feeding practices. Inferred differences in livestock management, as well as in manuring intensity and management in relation to water resources between crops, suggest a well-established farming economy. Inter-household variability in crop-cultivation and land-use suggests household production and subsistence autonomy, and points to the existence of socio-economic inequalities within the community.

Keywords:
subsistence, isotopes, protohistory, south-west Europe

Declarations of interest: none.

1. Introduction

Archaeological sites frozen in time are rare but very valued occurrences. They permit unique access to synchronic socioeconomic information otherwise obscured by the diachronic palimpsests that usually dominate the record. The protohistoric settlement of La Hoya in northern Iberia is one of those few instances. The site was violently attacked and set on fire at some point between the mid-4th and the late 3rd centuries BC (Iron Age II, Celtiberian period). Skeletons of both people and animals found killed on the streets, houses suddenly abandoned and abundant food, crafts and personal objects left behind are clear evidence of the severity of the attack and the haste of the fight (Llanos, 1975, 1983).

Unfortunately, and despite its relatively early discovery in 1935 and excavation in 1973-1990, the site has never received the attention it warrants and much information is still pending publication. Here, we present the results of stable carbon and nitrogen isotope analyses of 19 human and 30 animal bone collagen and 31 charred plant samples from the site to explore subsistence practices in Iron Age Iberia. The majority of the samples analysed refer to the moment of the attack, and so provide a more synchronous view of diet, inferred via stable carbon and nitrogen isotopic analysis, than is usually possible. The fact that cremation was the dominant funerary treatment in Late Iron Age communities across Europe makes these paleodietary findings of crucial importance, as very few isotopic data for this period are available in the literature (e.g. Salazar-García et al., 2010). The results are compared with other archaeological sources of information to contextualize the new evidence.

2. Context

The archaeological site of La Hoya (Laguardia, Álava) is located in the Rioja Alavesa region of north-central Iberia (Fig. 1). It extends over ca. 4 ha, of which a small fraction of 6230 m^2, i.e. 15.5% of the total area, has been excavated, unearthing an impressive protohistoric settlement. This was founded in the Middle Bronze Age around the 15th century BC, and saw use during the Late Bronze Age, the Iron Age I and the Iron Age II (Celtiberian phase) (Llanos, 1983).

The privileged position of the settlement (600 masl) in the fertile valley of the Ebro River, in close proximity to Sierra de Cantabria-Toloño mountain range, was key for its development. The location granted not only access to both low and upland resources, but also to the main communication routes between the Cantabrian, Mediterranean and Inner Plateau regions. This favored the flow of people, objects and ideas and, therefore, the economic and political growth of the village. During the Iron Age II (Celtiberian period, layer A3), the village reached its greatest extension and formal complexity, with an enclosing masonry wall, paved streets, public spaces as squares, more than 300 buildings (including dwellings, shops, hybrid buildings conjoining commercial and domestic roles, and communal buildings) (Llanos, 1983), and an estimated population of ca. 1500 people (Galilea, 2003). That, together with the existence of large food surpluses (Mariezkurrena, 1990), the presence of pottery and metal production, evidence of medium- and long-distance exchange of luxury items including personal adornments and weapons, and the presence of potential warrior aristocracies deposited in the extramural cremation necropolis of Piñuelas (Llanos, 2005), suggest that the settlement was a major center for social, economic, commercial and political activities.

However, this privileged setting was a double-edged sword, as its location in the valley lowlands –contrary to most of the coeval settlements of the region, which are located on hilltops– implied weakness in its natural defenses, being particularly important in a border area where different pre-Roman ‘tribes’ (e.g. Berones, Vardulii, Vascones and Caristii) disputed control of the territory. The site was violently attacked, set on fire and abandoned at some point between the mid-4th and the late 3rd centuries BC, based on associated material culture and new radiocarbon dates on human remains (layer A3: 365–204 cal. BC, 2215 ± 20 BP, PSUAMS-3466; 361–195 cal. BC, 2195 ± 25 BP, PSUAMS-2078) (Olalde et al., 2019). The resulting material evidence provides a unique snapshot of life in the Iberian Iron Age.

3. Research approach

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of plant remains provides information on aspects of past subsistence strategies. Crop $\delta^{15}N$ values largely reflect ^{15}N of the soil in which they are grown. In particular, use of animal manure has been found to increase the $\delta^{15}N$ values of arable soils and in cereals by as much as 10‰, relating to the amount and frequency of manuring (Fraser et al., 2011), as well as to the type of organic matter compost, animal manure and household waste applied (Szpak, 2014). $\delta^{13}C$ values reflect the movement of carbon dioxide through the stomata, which in dry climates is strongly influenced by the water status of a crop during its growth period (Wallace et al., 2013), whether through direct watering or by strategic planting of relatively demanding crops in wetter soils, and by the type of landscape in which plants grow (e.g. open vs. forested areas) (e.g. Bonafini et al., 2013).

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of bone collagen in humans and animals also provides information on aspects of past diet. In Iron Age inner Iberia, where domestic C_4 plant cultivation is present from the Middle Bronze Age (Moreno-Larrazabal et al., 2015), $\delta^{13}C$ measurements can be primarily used to distinguish between C_3 and C_4 photosynthetic pathways, with the former including cereals such as wheat, oat and barley, pulses and the vast majority of edible wild plants, and the latter comprising principally millets. Bone collagen will yield values of ca. -21‰ and ca. -5‰ in pure C_3 and C_4 consumers, respectively. The situation, however, may be complicated by the fact that organisms in some freshwater systems display elevated $\delta^{13}C$ values that are intermediate between C_3 and C_4 systems (Dufour et al., 1999). Little is known concerning freshwater systems in the Ebro valley specifically, although the few modern fish that have been analyzed from the region show low rather than elevated values (Soto et al., 2011). $\delta^{13}C$ values also reflect the type of landscape in which animals graze and humans obtain their dietary resources (e.g. open vs. forested areas). $\delta^{15}N$ measurements primarily reflect trophic position in a food web (Hedges and Reynard, 2007), though again there are other factors to consider, including the consumption of manured crops (which, as mentioned above, can be inferred through the direct isotope analysis of archaeological plants) and physiological effects (e.g. illness or starvation) that may increase human stable nitrogen isotope values (e.g. Beaumont et al., 2018).

4. Material

Nineteen human bone samples have been analyzed to reconstruct Iron Age II diet. They belong to different individuals from layer A3 (Iron Age II, Celtiberian period), of which 13 correspond to potential victims of the attack. Their remains, some of which show skeletal evidence of violence (e.g. decapitations, arm amputations and other postcranial sharp force injuries), were found scattered through the streets and the floors of households (Llanos, 2005) (Fig. 2). The remaining six individuals included in the study are a selection of the 131 infants buried under the houses of La Hoya (Galilea and García, 2002). Their inclusion is intended as a pilot study on early life diets at the site, which may be expanded in the future. Since cremation was the main funerary treatment for adults, adolescents and children, infant intramural burials provide the only available human remains from normative funerary contexts.

In addition, 30 faunal bone samples, including 7 cattle (*Bos taurus*), 11 sheep/goat (*Ovis aries/Capra hircus*), 10 domestic pigs (*Sus domesticus*), 1 dog (*Canis familiaris*) and 1 chicken (*Gallus domesticus*), and 31 charred bulk plant samples, including 6 of bread wheat (*Triticum aestivum/durum*), 4 of einkorn wheat (*Triticum monococcum*), 6 of emmer wheat (*Triticum dicoccum*), 2 of spelt (*Triticum spelta*), 3 of naked barley (*Hordeum vulgare*), 2 of oat (*Avena sp.*), 3of millet (*Panicum milliaceum*) and 5 of acorn (*Quercus sp.*), have been analyzed for baseline and subsistence insights for the human assemblage.

5. Methods

5.1. Osteological analysis

Morphognostic methods were used for human age and sex estimation. Age estimation was based on a complete assessment of skeletal and dental development, maturation, wear and degeneration of all available skeletal elements (White and Folkens, 2005). Adolescent and adult sex estimation primarily made use of dimorphic pelvic features, followed by cranial morphology (Buikstra and Ubelaker, 1994; Ferembach et al., 1980).

5.2. Isotope analysis

Charred plant isotope preparation was carried out following an acid-only procedure (Vaiglova et al., 2014). Sample weight was between 0.2 and 0.15 g (i.e. 7 and 12 homogenized grains per sample for C_3 cereals and millet, respectively, to obtain an average isotopic ratio of crop growing conditions (Nitsch et al., 2015), and the half of one individual nutmeat for acorns). The homogenized powders of each plant sample were weighed into tin capsules for IRMS analysis on a SerCon EA-GSL continuous flow 20/22 isotope ratio mass spectrometer coupled with an elemental analyser at the Research Laboratory for Archaeology and the History of Art (RLAHA), University of Oxford. The $\delta^{13}C$ and $\delta^{15}N$ values were measured in separate runs due to low %N in the plant samples. An alanine standard was used to correct for machine drift. For $\delta^{13}C$, two-point normalization to the VPDB scale was obtained using IAEA-CH6 and IAEA-CH7, while for $\delta^{15}N$ the standards were IAEA-600 and IAEA-N2 (cf. Coplen et al., 2006). The $\delta^{13}C$ and $\delta^{15}N$ values of carbonized plant remains were corrected for the effect of charring by subtracting 0.11‰ and 0.31‰, respectively (Nitsch et al., 2015). The $\Delta^{13}C$ values of archaeological plants were calculated from the measured $\delta^{13}C$ values ($\delta^{13}C_{plant}$) and a $\delta^{13}C_{air}$ value approximated by the $AIRCO_2$_LOESS system (Ferrio et al., 2005). The equation was defined by Farquhar et al. (1989). There are no set rules for accepting or rejecting plant isotope measurements based on their C:N ratios, as there are with collagen. In order to assess the reliability of the crop isotope measurements obtained in this study, parameters are compared to those of experimentally charred cereals (Fraser et al., 2013).

Human and animal collagen extraction was carried out following a modified Longin method (Richards and Hedges, 1999). Sample weight was between 0.5 and 0.8 g. The carbon and nitrogen isotope ratios were measured in duplicate into a SerCon EA-GSL continuous flow 20/22 isotope ratio mass spectrometer coupled with an elemental analyser at the RLAHA. Stable carbon and nitrogen isotopic compositions were corrected for machine drift relative to the VPDB and AIR scales using the abovementioned alanine standard. Measurements were adjusted using a three-point calibration comprising two in-house collagen standards and one international standard with well-characterized isotopic compositions extending beyond those of the measured samples: SEAL-1 (seal bone collagen) and COW (cow bone collagen), and IAEA-600 (caffeine), respectively. Collagen preservation quality was assessed according to several widely used criteria: collagen yield greater than 1%, carbon content between ca. 30 and 44% weight (wt%), nitrogen content between ca. 11 and 16 wt%, and atomic weight C/N ratios between 2.9 and 3.6 (Ambrose, 1990; DeNiro, 1985; van Klinken, 1999).

For both plant and collagen measurements, precision was determined to be ± 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$ on the basis of repeated measurements of calibration standards and samples.

5.3. Statistical analysis

Statistical analysis of results was performed using IBM SPSS software for Windows v17. *Z*-scores were initially calculated to detect the presence of outliers. Shapiro-Wilk tests were used to assess whether or not the data were normally distributed. For two-sample comparisons, Student's t-tests were employed when the data did not depart significantly from a normal distribution; when they did, non-parametric Mann-Whitney U-tests were used. For more than two groups, one-way ANOVA tests were conducted, since all the datasets analyzed were normally distributed with approximately equal variance. Post-hoc Tukey's HSD tests were used to detect significant differences between sample groups. Finally, Pearson's r/r^2 and Spearman's *rho* coefficients were used to assess correlations as appropriate. A significance level of 0.05 was used for all tests.

6. Results and discussion

6.1. Manuring intensity and crop management in relation to water resources, spatial variation in agricultural strategy and gathering

Plant isotope measurements (Table 1) are consistent with those obtained from modern experimentally charred cereals (Fraser et al., 2013), suggesting that the results are reliable. The $\delta^{13}C$ values are consistent with their different photosynthetic mechanisms, showing mean values of –22.8 ± 1.4‰ for C_3 plants (–22.4 ± 0.9‰ for cereals and –24.6 ± 1.9‰ for acorns) and of –10.8 ± 0.2‰ for C_4 millet grains (Fig. 3). The calculated $\Delta^{13}C$ values of wheat (bread wheat, einkorn, emmer and spelt combined) (16.0 ± 0.4‰) and barley (17.0 ± 0.6‰) suggest poor to moderate watering conditions (Wallace et al., 2013) (Fig. 4), in keeping with what would be expected if the water status of crops was mainly driven by rainfall (600-700 mm per annum at present, Ninyerola et al., 2005). However, these results do not exclude some degree of water management such as strategic growing of some crops in areas with better water supply (i.e. close to marshland or streams found near the site). Indeed, while the vast majority of the barley samples fall into the poorly watered band, half of the wheat samples fall into the moderately watered band. The better water status of wheat compared to barley may support a deliberate agricultural practice, since barley generally tolerates drier conditions better than wheat (Riehl, 2009). The remaining cereal grains (oat and millet) and the acorns (nutmeat) lack experimental studies for comparison.

The relatively high $\delta^{15}N$ values obtained suggest that wheat and barley (7.0 ± 0.8‰ and 6.8 ± 0.6‰, respectively) grew under high manuring conditions, while oat values (3.8 ± 0.4‰) had medium manuring levels (Fraser et al., 2011). Manure is a heavy and bulky resource to transport so that manuring intensity is generally directly proportional to transport distance (Styring et al., 2017). Thus, it is possible to suggest that the plots immediately surrounding the settlement area at La Hoya, where animal dung from stabled livestock and/or midden material accumulates, were preferentially devoted to wheat and barley cultivation as those cereals show higher $\delta^{15}N$ values on average. Spatially, then, it is also plausible to assume that the more variable manuring levels seen in bread wheat (6.5 ± 1.0‰), possibly the most common crop in the site, reflects a spectrum of manuring intensity radiating out from the village, from intensively managed 'infield' areas to more extensively managed fields further away from the settlement. High $\delta^{15}N$ values of millet (10.2 ± 0.4‰), the only C_4 plant analyzed, may also suggest high manuring conditions. However, as aridity can increase plant $\delta^{15}N$ values, and millet is a summer crop and there are no experimental studies for comparing manure intensity specifically for this crop, this is difficult to infer. Acorn nutmeat $\delta^{15}N$ values show high variability (3.6 ± 2.4‰), suggesting either that they were gathered from very diverse environments, or that they display high natural variability: the paucity of isotopic research on acorns prevents choosing between these alternatives, though the former seems more likely.

Finally, analyzing both intra- and inter-household variability in $\Delta^{13}C$ and $\delta^{15}N$ values of C_3 cereals reveals interesting patterns. The fact that crops recovered from each household show very low variability in both $\Delta^{13}C$ and $\delta^{15}N$ values, even including different taxa (e.g. household 304 (n = 8): $\Delta^{13}C$ 16.5 ± 0.6‰, $\delta^{15}N$ 6.8 ± 0.5‰; household 72 (n = 6): $\Delta^{13}C$ 15.7 ± 0.3‰, $\delta^{15}N$ 7.6 ± 0.5‰; household 5 (n = 4): $\Delta^{13}C$ 16.2 ± 0.2‰, $\delta^{15}N$ 6.4 ± 0.6), is worth noting. These data are consistent with the average isotope values established for single growing conditions, which fall within ± 0.5‰ for $\delta^{13}C$ and ± 1.0‰ for $\delta^{15}N$ (Nitsch et al., 2015), suggesting that individual households had access to specific arable fields (e.g. a single or various plots located at a similar distance from the village) encompassing a low spectrum of agricultural intensity. Related to this, a significant drop in cereal pollen observed at La Hoya from Iron Age I to Iron Age II has been interpreted to be the result of either a subsistence shift from farming to a more specialized pastoral economy or placement of arable plots at greater distances from the settlement in the later period (Iriarte, 2002). Such clustering also rejects the possibility that the harvest was pooled prior to storage and/or that cereal surpluses were exchanged among households, and thus supports a high degree of self-sufficiency for food production (e.g. Styring et al., 2016).

With regard to inter-household variability, one-way ANOVA tests indicate significant differences between households both in $\Delta^{13}C$ ($F_{(2, 16)} = 4.8$, $p = 0.024$) and in $\delta^{15}N$ ($F_{(2, 16)} = 7.7$,

$p = 0.005$), with no differences in variance (Levene's test: $\Delta^{13}C$, $p = 0.221$; $\delta^{15}N$, $p = 0.762$). The application of a post-hoc Tukey HSD test shows that cereal values of household 72 significantly differ from those of households 304 and 5 (household 54 was excluded from analysis for its small sample size (n = 2)), showing clearly lower $\Delta^{13}C$ and higher $\delta^{15}N$ mean values (see above). The differences are not driven by the type of crop analyzed at each household, since the three samples include a combination of different taxa (cf. Table 1), which moreover show low isotopic variability. As cereal grains recovered at La Hoya derive from a single harvest, they suggest coeval variation in crop-growing and land-use conditions between households, which may relate to the social dimension of crop-husbandry practices (e.g. Styring et al., 2016). Grains collected from household 72, one of the largest buildings in La Hoya with an area of nearly 75 m^2 (cf. Fig. 2), indicate that their cultivation may have taken place in a more intensive managed 'infield' zone, while grains from smaller households at the site (usually < 50 m^2), as households 304 and 5, may have derived from less well-manured fields at greater distances from the settlement, providing evidence of a potential relationship between household size and specific access to cultivable land. This supports the existence of socioeconomic differences between households, particularly differential access to the most productive growing areas (e.g. Bogaard et al., 2011).

6.2. Livestock management

Twenty-eight of the 30 faunal samples analyzed provided collagen yields, carbon and nitrogen percentages and C:N ratios indicating well-preserved collagen (Table 2). The remaining two (LHY21 and LHY44) exhibited %C and %N below the generally accepted limits. However, these have been retained for subsequent analyses, given that the other two criteria show values within the accepted ranges and their $\delta^{13}C$ and $\delta^{15}N$ values do not substantially differ from those samples of the same species showing acceptable collagen preservation.

The $\delta^{13}C$ and $\delta^{15}N$ ratios for herbivores are consistent with expectations for a temperate C_3 ecosystem. Cattle show mean $\delta^{13}C$ values of –21.1 ± 0.2‰ and mean $\delta^{15}N$ values of 5.0 ± 1.1‰, while ovicaprines show mean $\delta^{13}C$ values of –20.1 ± 0.5‰ and mean $\delta^{15}N$ values of 6.0 ± 1.0‰. Cattle mean $\delta^{13}C$ values are thus significantly lower (by 1‰, $U = 1.5$, $Z = 3.374$, $p = 0.001$), suggesting their grazing in more forested areas, whereas ovicaprines might have made use of more open pastures. Suids show mean $\delta^{13}C$ values of –20.4 ± 0.3‰ and mean $\delta^{15}N$ values of 5.6± 0.3‰, indicating a herbivorous diet similar to that of ovicaprines (Fig. 5), which clearly differs from Neolithic and Chalcolithic isotope data in the same region, where pigs are mostly omnivorous (Fernández-Crespo and Schulting, 2017). The isotope values of the only dog available in the sample ($\delta^{13}C$:–19.5; $\delta^{15}N$: 7.6) are consistent with the consumption of a more diverse range of foods, perhaps including domestic waste. Those of the only chicken analyzed ($\delta^{13}C$:–17.3; $\delta^{15}N$: 10.1) suggest that this bird was also fed with domestic waste and possibly foddered with C_4 millet.

6.3. Human subsistence

The 19 human samples analyzed provided collagen yields, carbon and nitrogen percentages and C:N ratios indicating well-preserved collagen (Table 3). Mean $\delta^{13}C$ and $\delta^{15}N$ values are –18.0 ± 1.0‰ and 11.3 ± 1.8‰, ranging from –16.2‰ to –19.7‰ and from 8.9‰ to 14.9‰, respectively. Such high variability is clearly driven by the notably higher mean carbon (+1.7‰) and nitrogen (+3.6‰) isotope values of infants and young children compared to those of adults, adolescents and perinatal individuals ($\delta^{13}C$: $t = 5.433$, df = 17, $p < 0.001$; $\delta^{15}N$: $t = 8.135$, df = 17, $p < 0.001$), which cluster reasonably tightly (cf. Fig. 5). The fact that perinatal individuals' values are similar to those of adults and adolescents (but different to the infants and children) is consistent with the former still reflecting their mothers' isotope signals, as a result of dying at or shortly after birth, i.e., before being breastfed, as is supported by their lower $\delta^{15}N$ values.

The higher $\delta^{15}N$ values of infants and young children can be explained by the nursing signal, raising infants approximately a trophic level (ca. 3-4‰) above their mothers (e.g. Herrscher et al., 2017). The mean difference of 1.7‰ in $\delta^{13}C$, however, is too high to be exclusively due to breastfeeding, which would usually result in an increase of ca. 1‰ at most (e.g. Fuller et al., 2006), and suggests the existence of age-related dietary differences. These differences could be explained by the greater consumption of C_4 cereals by infants and young children, which combined with continued nursing would elevate both carbon and nitrogen isotope values, resulting in the aforementioned correlation. It is likely that millet, which has been identified in the archaeological record of La Hoya and is thought to be a significant crop in Iberia since the Middle Bronze Age (Moreno-Larrazabal et al., 2015), was introduced during the weaning process as easily digested porridge made through cooking grains in water or milk (Table 4). This would provide a nutritious, easily digestible weaning food for children (WHO, 2009). Similar infant feeding practices have been documented in other regions and periods, including Neolithic China (Yi et al., 2018), Bronze Age Greece (Nitsch et al., 2017), Roman Egypt (Dupras et al., 2001) and modern Africa (Pelto et al., 2003).

The significant positive correlation ($r^2 = 0.811$, $p < 0.001$; $rho = 0.850$, $p < 0.001$) observed in the human carbon and nitrogen isotope values is partly driven by the difference between infants and young children and the other age categories, but it still remains if the former are excluded ($r^2 = 0.471$, $p = 0.007$; $rho = 0.642$, $p = 0.013$). This suggests some differential consumption of millet among adolescents and adults, whose isotopic signals are consistent with mainly C_3 plant-based diets. Contribution of domestic C_3 plants is expected to have principally come from wheat and barley, which are abundant in the palaeobotanical record of the site and may have been used for the production of bread and of alcoholic beverages (Dietler, 1990).

In addition to the domestic cereals, a range of wild vegetables, tubers, fungi and nuts (e.g. acorns, hazelnuts, walnuts and chestnuts) could have been exploited directly by humans, as well as featuring indirectly through the diets of animals, particularly those of pigs. Pliny the Elder pointed out the particular importance of acorns in the subsistence of northern Iberian Iron Age populations, whose flour was commonly used to make bread (Torres-Martínez, 2003). Pulses such as pea, bean and vetch are also expected to have contributed to diets. However, there is virtually no information on legume macro-remains recovered either in this settlement or in nearby coeval sites, though they are known to have featured in other Iberian regions during the Iron Age (e.g. Alonso, 2008) and in Roman and later cuisines (e.g. Peña-Chocarro et al., 2019). Forest fruits and berries (e.g. apple, pear, wild cherry, whitebeam, rowan, hawthorn, elderberries, blackberries, etc.) would have provided dietary diversity (Zapata, 2000), though with generally low protein content they would not be expected to contribute significantly to stable isotope measurements in bone collagen.

Animal contribution to diet would have consisted mainly of meat and dairy products from cattle and ovicaprines, and meat from pigs. The consumption of animal products is supported by the identification of palmitic acids, which are abundant in meat and dairy products, in eight of nine pottery Celtiberian vessels studied at La Hoya (López-de-Heredia, 2014). Unfortunately, stable isotope results do not allow the assessment of which of those three main taxa contributed more to human diet, since they show overlapping values similar to those of herbivores. However, zooarchaeological analysis of Iron Age II faunal assemblages from layer A3 suggests the predominance of cattle (NISP = 2399, 34.8 %) –in terms of meat weight and dairy– and pigs (NISP = 3109, 45.2 %), while ovicaprines held a secondary position (NISP = 1210, 17.6 %) (Mariezkurrena, 1990). This contrasts to the preceding Iron Age I (layers B2 and B1) where cattle (NISP = 1486, 30.4 %) and ovicaprines (NISP = 1860, 38.1 %) were predominant, with pigs of less importance (NISP = 1058, 21.6 %) (Fig. 6). This marked shift from sheep and goat to pig may be linked to the aforementioned change in crop cultivation (Iriarte, 2002), possibly as a response to the population growth inferred for the Iron Age II period (Galilea, 2003).

Other domestic animals comprising horses and chickens, and wild ungulates including red deer, wild goat, roe deer and wild boar, do not seem to have played a significant role in diet, based on their minimal presence in the zooarchaeological record (<3% combined). Isotope results do not show any clear indications that freshwater resources contributed significantly to human diet either (if so, more depleted $\delta^{13}C$ and enriched $\delta^{15}N$ values would be expected), which is consistent with the absence of fish remains and of specialized fishing technology at the site. However, the identification of palmitoleic acids derived from fish fats in one of the abovementioned nine Celtiberian vessels from La Hoya (López-de-Heredia, 2014), suggests some occasional consumption below a level that would be detectable in human isotope signals. Species as trout, barbell, common carp, crayfish or freshwater mussels, all abundant in local rivers, could have been exploited. Given the site's considerable distance from the sea (> 100 km), the lack of evidence for any regular contribution of marine resources is unsurprising.

7. Conclusion

The large village of La Hoya was violently attacked, set on fire and abandoned at some point between the mid-4th and the late 3rd centuries BC, providing a unique snapshot of Iron Age subsistence in northern Iberia. Adolescent and adult diets seem to be relatively homogeneous, focusing on C_3 cereals, such as wheat and barley, together with some wild plants (e.g. acorns) and meat from cattle, pig, and ovicaprines, as well as dairy. Infant and young children diets show evidence for higher consumption of C_4 cereals (i.e. millet), probably used as complementary food during weaning (i.e. porridge). Inferred differences in manuring intensity and management in relation to water resources between crops, together with variation in livestock management strategies, suggest a fully developed agropastoral economy capable not only of feeding a large population, but also of generating surpluses, which may have favored economic specialization and social complexity. There are indications of inter-household differences within the settlement, with crops from the largest dwelling perhaps showing preferential access to infields, which points to the existence of potential socio-economic differences among the community.

Acknowledgements

We are grateful to Dr P. Ditchfield for mass spectrometry technical support, to J. Aguirre and J. Fernández Bordegarai for access to the samples, and to the Basque Government for sampling permission. We would also like to thank the reviewers for their useful suggestions. Funding: This research was supported by the Museums and Archaeology Service of the Diputación Foral de Álava, Spain (Project title 'La Hoya: Reconstrucción de la dieta y modos de subsistencia a través de isótopos estables de carbono y nitrógeno', 2017, to T.F-C. and J.O.); and the British Academy, United Kingdom (Newton International Fellowship, NF170854, 2018, to T.F-C.).

References

Alonso, N., 2008. Crops and agriculture during the Iron Age and late antiquity in Cerdanyola del Vallès (Catalonia, Spain). *Veg. Hist. Archaeobot*. 17(1), 75-84.

Ambrose, S. H., 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *J. Archaeol. Sci.* 17, 431-451.

Beaumont, J., et al., 2018. Comparing apples and oranges: Why infant bone collagen may not reflect dietary intake in the same way as dentine collagen. *Am J Phys Anthropol.*167(3), 524-540.

Bonafini, M., Pellegrini, M., Ditchfield, P., Pollard, A. M., 2013. Investigation of the ‘canopy effect’ in the isotope ecology of temperate woodlands.*J. Archaeol. Sci.* 40(11), 3926-3935.

Bogaard, A., Krause, R., Strien, H. C., 2011. Towards a social geography of cultivation and plant use in an early farming community: Vaihingen an der Enz, south-west Germany. *Antiquity* 85, 395-416.

Buikstra, J. E., Ubelaker, D. H., 1994. *Standards for data collection from human skeletal remains*. Arkansas archaeological survey research series 44.Arkansas Archaeological Survey Press, Fayetteville.

Coplen, T. B., Brand, W. A., Gehre, M., Gröning, M., Meijer, H. J., Toman, B., Verkouteren, R. M., 2006. New guidelines for δ^{13}C measurements. *Anal. Chem*. 78, 2439-2441.

DeNiro, M., 1985.Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction.*Nature* 317, 806-809.

Dietler, M., 1990. Driven by drink: The role of drinking in the political economy and the case of Early Iron Age France. *J. Anthropol. Archaeol.*9, 352-406.

Dufour, E., Bocherens, H., Mariotti, A., 1999. Paleodietary implications of isotopic variability in Eurasian lacustrine fish.*J. Archaeol. Sci.* 26, 617-627.

Dupras, T. L., Schwarcz, H. P., Fairgrieve, S. I., 2001. Infant feeding and weaning practices in Roman Egypt. *Am. J. Phys. Anthropol*. 115, 204-211.

Farquhar, G. D, Ehleringer, J. R., Hubick, K. T., 1989.Carbon isotope discrimination and photosynthesis.*Annu. Rev. Plant Physiol. Plant Mol. Biol.* 40, 503-537.

Ferembach, D., Schwidetzky, I., Stoukal, M., 1980.Recommendations for age and sex diagnosis of skeletons.*J. Human Evol.*9, 517-549.

Fernandes, R., Nadeau, M. J., Grootes, P. M., 2012. Macronutrient-based model for dietary carbon routing in bone collagen and apatite. *Archaeol. Anthropol. Sci*. 2012 (4), 291-301.

Fernández-Crespo, T., Schulting, R. J., 2017. Living different lives: early social differentiation identified through linking mortuary and isotopic variability in Late Neolithic/ Early Chalcolithic north-central Spain. *PLoS ONE* 12(9), e0177881.

Ferrio, J. P., Araus, J. L., Buxó, R., Voltas, J., Bort, J., 2005. Water management practices and climate in ancient agriculture: inferences from the stable isotope composition of archaeobotanical remains. *Veg. Hist. Archaeobot*. 14, 510-517.

Fraser, R. A., et al., 2011. Manuring and stable nitrogen isotope ratios in cereals and pulses: towards a new archaeobotanical approach to the inference of land use and dietary practices. *J. Archaeol. Sci.* 38, 2790-2804.

Fraser, R. A., Bogaard, A., Schäferb, M., Arbogast, R., Heaton, T. H. E., 2013. Integrating botanical, faunal and human stable carbon and nitrogen isotope values to reconstruct land use and palaeodiet at LBK Vaihingen an der Enz, Baden-Württemberg. *World Archaeol.*45, 492-517.

Fuller, B. T., Fuller, J. L., Harris, D. A., Hedges, R. E. M., 2006. Detection of breastfeeding and weaning in modern human infants with carbon and nitrogen stable isotope ratios.*Am. J. Phys. Anthropol.* 129(2), 279-293.

Galilea, F., 2003. La demografía en el poblado berón de La Hoya (Laguardia-Álava). *Estudios de Arqueología Alavesa* 20, 117-133.

Galilea, F., García, A., 2002. Enterramientos infantiles en el poblado protohistórico de la Hoya (Laguardia, Álava). *Estudios de Arqueología Alavesa* 19, 150-162.

Hedges, R., Reynard, L., 2007.Nitrogen isotopes and the trophic level of humans in archaeology.*J. Archaeol. Sci.* 34, 1240-1251.

Herrscher, E., Goude, G., Metz, L., 2017. Longitudinal study of stable isotope compositions of maternal milk and implications for the palaeodiet of infants.*Bull. Mém. Soc. Anthropol. Paris* 29, 131-139.

Iriarte, M. J., 2002. Antropización del paisaje y economía de producción entre los siglos XV y IV a. C. El entorno vegetal del yacimiento de La Hoya (Laguardia. Álava). *Estudios de Arqueología Alavesa* 19, 163-190.

Llanos, A., 1975. Excavaciones arqueológicas en el poblado de la Edad del Hierro de La Hoya (Laguardia, Álava): I, II y III campañas. *Noticiario Arqueológico Hispánico (Prehistoria)* 4, 273-288.

Llanos, A., 1983. *La Hoya, un poblado del primer milenio antes de Cristo*. Diputación Foral de Álava, Vitoria-Gasteiz.

Llanos, A., 2005. *Mil años de vida en el poblado berón de La Hoya (Laguardia, Álava). Guía del yacimiento y del museo*. Diputación Foral de Álava, Vitoria-Gasteiz.

López-de-Heredia, J., 2014. *La cerámica de la Segunda Edad del Hierro en el País Vasco: Estudio Tecnológico, funcional y social*. PhD. Thesis. University of the Basque Country, Vitoria-Gasteiz.

Mariezkurrena, K., 1990. Caza y domesticación durante el Neolítico y Edad de los Metales en el País Vasco. *Munibe (Antropologia-Arkeologia)* 42, 241-252.

Moreno-Larrazabal, A., Teira-Brión, A., Sopelana-Salcedo, I., Arranz-Otaegui, A., Zapata, L., 2015. Ethnobotany of millet cultivation in the north of the Iberian Peninsula. *Veg. Hist. Archaeobot.*24(4), 541-554.

Ninyerola, M., Pons, X., Roure, J. M., 2005. *Atlas Climático Digital de la Península Ibérica. Metodología y aplicaciones en bioclimatología y geobotánica*. Universidad Autónoma de Barcelona, Bellaterra.

Nitsch, E. K., Andreou, S., Creuzieux, A., Gardeisen, A., Halstead, P., Isaakidou, V., Karathanou, A., Kotsachristou, D., Nikolaidou, D., Papanthimou, A., Petridou, C., Triantaphyllou, S., Valamoti, S. M, Vasileiadou, A., Bogaard, A., 2017. A bottom-up view of food surplus: using stable carbon and nitrogen isotope analysis to investigate agricultural strategies and diet at Bronze Age Archontiko and Thessaloniki Toumba, northern Greece. *World Arch.* 49(1), 105-137.

Nitsch, E. K., Charles, M., Bogaard, A., 2015. Calculating a statistically robust $\delta^{13}C$ and $\delta^{15}N$ offset for charred cereal and pulse seeds. *Sci. Technol. Archaeol. Res.* 1, 1-8.

O'Connell, T., Kneale, C. J., Tasevska, N., Kuhnle, G. G. C., 2012. The diet-body offset in human nitrogen isotopic values: A controlled dietary study. *Am. J. Phys. Anthropol*. 149(3), 426-434.

Olalde, I., Mallick, S., Patterson, N., Rohland, N., Villalba-Mouco, V., Silva, M., Dulias, K., Edwards, C. J., Gandini, F., Pala, M., Soares, P., Ferrando-Bernal, M., Adamski, N., Broomandkhoshbacht, N., Cheronet, O., Culleton, B. J., Fernandes, D., Lawson, A. M., Mah, M., Oppenheimer, J., Stewardson, K., Zhang, Z., Jiménez Arenas, J. M., Toro Moyano, I. J., Salazar-García, D. C., Castanyer, P., Santos, M., Tremoleda, J., Lozano, M., García Borja, P., Fernández-Eraso, J., Mujika-Alustiza, J. A., Barroso, C., Bermúdez, F. J., Viguera Mínguez, E., Burch, J., Coromina, N., Vivó, D., Cebrià, A., Fullola, J. M., García-Puchol, O., Morales, J. I., Oms, F. X., Majó, T., Vergès, J. M., Díaz-Carvajal, A., Ollich-Castanyer, I., López-Cachero, F. J., Silva, A. M., Alonso-Fernández, C., Delibes de Castro, G., Jiménez Echevarría, J., Moreno-Márquez, A., Pascual Berlanga, G., Ramos-García, P., Ramos-Muñoz, J., Vijande Vila, E., Aguilella Arzo, G., Esparza Arroyo, A., Lillios, K. T., Mack, J., Velasco-Vázquez, J., Waterman, A., Benítez de Lugo Enrich, L., Benito Sánchez, M., Agustí, B., Codina, F., de Prado, G., Estalrrich, A., Fernández Flores, A., Finlayson, C., Finlayson, G., Finlayson, S., Giles-Guzmán, F., Rosas, A., Barciela González, V., García Atiénzar, G., Hernández Pérez, M. S., Llanos, A., Carrión Marco, Y., Collado Beneyto, I., López-Serrano, D., Sanz Tormo, M., Valera, A. C., Blasco, C., Liesau, C., Ríos, P., Daura, J., de Pedro Michó, M. J., Diez-Castillo, A., A., Flores Fernández, R., Francès Farré, J., Garrido-Pena, R., Gonçalves, V. S., Guerra-Doce, E., Herrero-Corral, A. M., Juan-Cabanilles, J., López-Reyes, D., McClure, S. B., Merino Pérez, M., Oliver Foix, A., Sanz Borràs, M., Sousa, A. C., Vidal Encinas, J. M., Kennett, D. J., Richards, M. B., Alt, K. W., Haak, W., Pinhasi, R., Lalueza-Fox, C., Reich, D., 2019.The genomic history of the Iberian Peninsula over the past 8000 years. *Science* 361, 1230-1234.

Pelto, G. H., Levitt, E., Thairu, L., 2003. Improving feeding practices: Current patterns, common constraints, and the design of interventions. *Food Nutr. Bull*. 24(1), 45-82.

Peña-Chocarro, L., Pérez-Jordá, G., Alonso, N., Antolín, F., Teira-Brión, A., Tereso, J. P., Montes-Moya, E. M., Reyes, D. L., 2019. Roman and medieval crops in the Iberian Peninsula: A first overview of seeds and fruits from archaeological sites. *Quat. Int*. 499, 49-66.

Richards, M. P., Hedges, R. E. M., 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic Coast of Europe. *J. Archaeol. Sci.* 26, 717-122.

Riehl, S., 2009. Archaeobotanical evidence for the interrelationship of agricultural decision-making and climate change in the ancient Near Eart.*Quat. Int.* 197, 93-114.

Salazar-García, D. C., Vives-Ferrándiz, J., Fuller, B. T., Richards, M.P., 2010. Alimentación estimada de la población del Castellet de Bernabé (SS. V-III A.C.) mediante el uso de ratios de isótopos estables de C y N. *Saguntum* 9, 313-322.

Soto, D. X., Wassenaar, L. I., Hobson, K. A., Catalana, J., 2011. Effects of size and diet on stable hydrogen isotope values (δD) in fish: implications for tracing origins of individuals and their food sources. *Can. J. Aquatic Sci.* 68(11), 2011-2019.

Styring, A. K., Charles, M., Fantone, F., Hald, M. M., McMahon, A., Meadow, R. H., Nicholls, G. K., Patel, A. K., Pitre, M. C., Smith, A., Sołtysiak, A., Stein, G., Weber, J. A., Weiss, H., Bogaard, A., 2017. Isotope evidence for agricultural extensification reveals how the world's first cities were fed. *Nature Plants* 3, 17076.

Styring, A. K., Maier, U., Stephan, E., Schlichtherle, H., Bogaard, A., 2016. Cultivation of choice: new insights into farming practices at Neolithic lakeshore sites. *Antiquity* 90, 95-110.

Szpak, P., 2014. Complexities of nitrogen isotope biogeochemistry in plant-soil systems: implications for the study of ancient agricultural and animal management practices. *Plant Physiol.* 5, 288.

Torres-Martinez, J. F., 2003. Recursos naturales y economía de los cántabros de la Edad de Hierro. *Complutum* 14, 169-196.

Vaiglova, P., et al. 2014. An integrated stable isotope study of plants and animals from Kouphovouno, southern Greece: a new look at Neolithic farming. *J. Archaeol. Sci*. 42: 201-215.

van Klinken, G. J., 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *J. Archaeol. Sci.* 26(6), 687-695.

Wallace, M., et al., 2013. Stable carbon isotope analysis as a direct means of inferring crop water status and water management practices. *World Archaeol.*45(3), 338-409.

White, T.D., Folkens, P.A., 2005. *The human bone manual*.Academic Press, San Diego.

WHO, 2009. *Infant and young child feeding: Model chapter for textbooks for medical students and allied health professionals*. World Health Organization, Geneva.

Yi, B., Liu, X., Yuan, H., Zhou, Z., Chen, J., Wang, T., Wang, Y., Hu, Y., Fuller, B. T., 2018. Dentin isotopic reconstruction of individual life histories reveals millet consumption during weaning and childhood at the Late Neolithic (4500 bp) Gaoshan site in southwestern China. *Int. J. Osteoarch*. 28(6), 636-644.

Zapata, L., 2000. La recolección de plantas silvestres en la subsistencia mesolítica y neolítica. Datos arqueobotánicos del País Vasco. *Complutum* 11, 157-169.

Table 1. Charred plant $\delta^{13}C$ and $\delta^{15}N$ values from La Hoya, layer A3.

ID	Inventory no.	Unit square	Household	Taxon	No. grains	%C	%N	C:N	$\delta^{13}C$ (‰) (VPDB)[1]	$\delta^{15}N$ (‰) (AIR)[2]	$\Delta^{13}C$ (‰)[3]
LHY50	N1.V18.A3.304.S1.x180.y310.z172.TM.1	V18	304	*Triticum monococcum*	7	58.5	3.7	18.9	-22.4	6.3	16.3
LHY51	N1.V18.A3.304.S1.x180.y310.z172.TM.2	V18	304	*Triticum monococcum*	7	64.1	3.7	21.8	-21.9	7.2	15.7
LHY52	N1.V18.A3.304.S1.x180.y310.z172.TD.1	V18	304	*Triticum dicoccum*	7	57.1	4.5	14.6	-22.6	7.0	16.5
LHY53	N1.V18.A3.304.S1.x180.y310.z172.TD.2	V18	304	*Triticum dicoccum*	7	65.3	4.2	18.5	-22.3	7.5	16.2
LHY54	N1.V18.A3.304.S1.x180.y310.z172.TA/D.1	V18	304	*Triticum aestivum/durum*	7	66.7	4.0	18.4	-22.2	7.3	16.1
LHY55	N1.V18.A3.304.S1.x180.y310.z172.TA/D.2	V18	304	*Triticum aestivum/durum*	6	61.8	4.3	13.6	-22.6	6.3	16.5
LHY56	N1.V18.A3.304.S1.x180.y310.z172.H.1	V18	304	*Hordeum vulgare*	5	61.3	3.3	21.7	-23.5	6.4	17.4
LHY57	N1.V18.A3.304.S1.x180.y310.z172.H.2	V18	304	*Hordeum vulgare*	5	56.0	3.0	21.4	-23.4	6.5	17.4
LHY58	N2.Y21.A3.72.A1.x205.y230.z165.TM.1	Y21	72	*Triticum monococcum*	7	63.5	3.9	18.2	-21.7	7.9	15.6
LHY59	N2.Y21.A3.72.A1.x205.y230.z165.TM.2	Y21	72	*Triticum monococcum*	7	60.4	3.7	20.6	-21.7	7.1	15.5
LHY60	N2.Y21.A3.72.A1.x205.y230.z165.TD.1	Y21	72	*Triticum dicoccum*	7	61.6	3.6	20.6	-22.3	7.4	16.2
LHY61	N2.Y21.A3.72.A1.x205.y230.z165.TD.2	Y21	72	*Triticum dicoccum*	7	66.0	4.1	18.8	-21.6	7.3	15.4
LHY62	N2.Y21.A3.72.A1.x205.y230.z165.TS.1	Y21	72	*Triticum spelta*	7	68.7	3.6	21.3	-22.0	8.5	15.9
LHY63	N2.Y21.A3.72.A1.x205.y230.z165.TS.2	Y21	72	*Triticum spelta*	7	57.9	4.4	15.9	-21.6	7.5	15.5
LHY64	N2.Y21.A3.72.A1.x205.y230.z165.H.1	Y21	72	*Hordeum vulgare*	2	82.6	3.5	32.9	-22.4	7.5	16.3
LHY65	N4.A5.A3.5.S1.x350.y250.z60.TD.1	A5	5	*Triticum dicoccum*	7	59.0	4.3	16.0	-22.3	6.7	16.2
LHY66	N4.A5.A3.5.S1.x350.y250.z60.TD.2	A5	5	*Triticum dicoccum*	7	57.9	3.4	19.8	-22.5	6.6	16.3
LHY67	N4.A5.A3.5.S1.x350.y250.z60.TA/D.1	A5	5	*Triticum aestivum/durum*	7	60.3	3.5	20.2	-22.6	6.9	16.5
LHY68	N4.A5.A3.5.S1.x350.y250.z60.TA/D.2	A5	5	*Triticum aestivum/durum*	7	71.1	3.3	24.7	-22.1	5.6	16.0
LHY69	N5.F7.A3.R54.s1.¿?.TA/D.1	F7	54	*Triticum aestivum/durum*	7	64.4	4.2	17.5	-21.6	7.7	15.5
LHY70	N5.F7.A3.R54.s1.¿?.TA/D.2	F7	54	*Triticum aestivum/durum*	7	58.4	4.0	16.5	-21.6	5.1	15.4
LHY71	LHY.Sector1.V5.x0.y250.z65.M1	V5	37	*Panicum milliaceum*	12	35.9	4.3	11.0	-10.8	9.8	4.4
LHY72	LHY.Sector1.V5.x0.y250.z65.M2	V5	37	*Panicum milliaceum*	12	38.3	4.1	11.4	-10.9	10.6	4.5
LHY73	LHY.Sector1.V5.x0.y250.z65.M3	V5	37	*Panicum milliaceum*	12	39.3	4.2	11.4	-10.6	10.3	4.1
LHY74	Nº659.Granoincinerado.36.2.2.A.1	-	-	*Avena sp.*	5	62.0	4.2	18.7	-24.5	3.5	18.4
LHY75	Nº659.Granoincinerado.36.2.2.A.2	-	-	*Avena sp.*	5	67.0	4.1	21.3	-25.0	4.1	19.0
LHY76	LHY.Sector5.Q.1	-	-	*Quercus sp.*	1	65.0	1.9	40.0	-22.6	5.8	16.4
LHY77	LHY.Sector5.Q.2	-	-	*Quercus sp.*	1	59.2	1.2	58.3	-24.2	2.0	18.2
LHY78	LHY.Sector5.Q.3	-	-	*Quercus sp.*	1	49.9	1.6	36.9	-27.2	5.5	21.3
LHY79	LHY.Sector5.Q.4	-	-	*Quercus sp.*	1	63.7	1.9	39.0	-25.8	0.2	19.8
LHY80	LHY.Sector5.Q.5	-	-	*Quercus sp.*	1	50.7	1.8	33.0	-23.2	4.3	17.1

[1] Values corrected for the effect of charring by subtracting 0.11‰ (Nitsch et al., 2015).
[2] Values corrected for the effect of charring by subtracting 0.31‰ (Nitsch et al., 2015).
[3] Values calculated using the equation defined by Farquhar et al. (1989), and both the measured $\delta^{13}C$ values ($\delta^{13}C_{plant}$) and a $\delta^{13}C_{air}$ value of –6.48‰ approximated by the AIRCO$_2$_LOESS system (Ferrio et al., 2005).

Table 2. Faunal δ[13]C and δ[15]N values from La Hoya, layer A3.

ID	Inventory no.	Unit square	Household	Species	Element	Age	%Col	%C[1]	%N[1]	C:N	δ[13]C (‰) (VPDB)	δ[15]N (‰) (AIR)
LHY20	BOS.1	-	-	*Bos taurus*	Long bone	Adult	7.1	38.3	13.6	3.3	-20.6	6.2
LHY21	BOS.3	E25	55	*Bos taurus*	Rib	Adult?	2.2	*24.6*	*8.5*	3.4	-21.1	5.7
LHY22	BOS.4	A29	-	*Bos taurus*	Femur	Adult	2.3	44.0	14.7	3.5	-21.1	6.0
LHY23	BOS.5	A27	-	*Bos taurus*	Femur	Nonadult	4.1	37.6	13.0	3.4	-21.1	5.7
LHY24	BOS.6	Z27	-	*Bos taurus*	Femur	Adult	10.3	40.1	14.4	3.2	-21.3	3.6
LHY25	BOS.7	Y3	38	*Bos taurus*	Long bone	Adult?	6.2	42.1	14.8	3.3	-21.2	4.1
LHY26	BOS.8	D41	75	*Bos taurus*	Long bone	Adult	14.4	42.9	15.4	3.2	-21.1	3.9
LHY27	OVIS/CAPRA.1	C37	-	*Ovis aries / Capra hircus*	Mandible	Adult?	7.2	42.2	15.2	3.2	-19.3	6.1
LHY28	OVIS/CAPRA.2	A21	27	*Ovis aries / Capra hircus*	Mandible	Adult?	14.1	44.1	15.9	3.2	-20.0	6.2
LHY29	OVIS/CAPRA.3	V3	-	*Ovis aries / Capra hircus*	Mandible	Adult/senile	13.6	43.6	15.8	3.2	-20.4	6.1
LHY30	OVIS/CAPRA.4	Y2	-	*Ovis aries / Capra hircus*	Mandible	Adult	6.2	43.4	15.4	3.3	-20.0	4.6
LHY31	OVIS/CAPRA.5	E25	55	*Ovis aries / Capra hircus*	Mandible	Adult/senile	5.2	38.9	13.8	3.3	-19.8	4.4
LHY32	OVIS/CAPRA.6	A31	-	*Ovis aries / Capra hircus*	Mandible	Adult/senile	4.0	42.0	14.8	3.3	-19.4	7.3
LHY33	OVIS/CAPRA.7	Z27	-	*Ovis aries / Capra hircus*	Mandible	Adult?	5.3	38.6	13.6	3.3	-20.6	6.2
LHY34	OVIS/CAPRA.8	C9?	-	*Ovis aries / Capra hircus*	Mandible	Nonadult	10.2	41.7	15.1	3.2	-20.4	6.8
LHY35	OVIS/CAPRA.9	-	-	*Ovis aries / Capra hircus*	Mandible	Adult	9.3	43.1	15.5	3.2	-21.0	6.8
LHY36	OVIS/CAPRA.10	A29	-	*Ovis aries / Capra hircus*	Calcaneus	Adult	5.3	42.9	15.4	3.3	-20.1	4.7
LHY37	OVIS/CAPRA.11	V3	-	*Ovis aries / Capra hircus*	Metatarsal	Adult?	2.7	29.6	10.5	3.3	-20.5	6.3
LHY38	SUS.1	A37	61	*Sus domesticus*	Mandible	Nonadult	3.3	34.5	11.9	3.4	-20.9	5.5
LHY39	SUS.2	Z37	61	*Sus domesticus*	Mandible	Adult	5.3	42.6	14.9	3.3	-20.3	5.9
LHY40	SUS.3	Z35	61	*Sus domesticus*	Mandible	Adult	6.1	40.0	14.3	3.3	-20.4	5.7
LHY41	SUS.4	X35	61	*Sus domesticus*	Mandible	Nonadult	5.3	42.4	15.0	3.3	-20.3	5.9
LHY42	SUS.5	C37	20	*Sus domesticus*	Mandible	Adult	2.0	30.1	10.3	3.4	-20.2	5.2
LHY43	SUS.7	C37	20	*Sus domesticus*	Mandible	Adult	2.1	36.8	12.9	3.3	-20.1	6.2
LHY44	SUS.8	C7	20	*Sus domesticus*	Mandible	Nonadult	1.5	*22.7*	*7.8*	3.4	-21.0	5.3
LHY45	SUS.9	C41	20	*Sus domesticus*	Mandible	Adult	3.3	34.0	12.1	3.3	-20.4	5.8
LHY46	SUS.SN.1	F15	-	*Sus domesticus*	Maxilla	Adult	2.3	33.1	11.8	3.3	-20.4	5.6
LHY47	SUS.SN.2	A27	-	*Sus domesticus*	Mandible	Adult	6.2	36.5	12.9	3.3	-20.1	5.3
LHY48	CANIS	F17	57	*Canis familiaris*	Mandible	Adult	3.0	37.8	13.3	3.3	-19.5	7.6
LHY49	GALLUS	X19	29	*Gallus domesticus*	Long bone	Adult	3.3	44.7	15.5	3.4	-17.3	10.1

[1] Anomalous %C and %N are shown in italics.

Table 3. Human $\delta^{13}C$ and $\delta^{15}N$ values from La Hoya, layer A3.

ID	Inventory no.	Unit square	Household	Context	Element	Age[1]	Sex[2]	%Col	%C	%N	C:N	$\delta^{13}C$ (‰) (VPDB)	$\delta^{15}N$ (‰) (AIR)
LHY1	ACC-51, ACC-74	A17-Z19	22	Attack	Scaphoid	IA	M?	3.4	36.2	12.9	3.3	-18.7	9.6
LHY2	ACC-73	Y19	-	Attack	Skull	YA (ca. 30)	M	7.1	43.0	14.8	3.4	-18.8	10.3
LHY3	ACC-108	B33	-	Attack	Sacrum	YA (ca. 35)	M	5.6	45.1	15.6	3.4	-18.6	11.9
LHY4	ACC-142	B37	-	Attack	Skull	MA	F	5.1	37.2	13.2	3.3	-18.3	10.0
LHY5	ACC-136	C37	-	Attack	Mandible	MA (45-55)	F	4.0	39.4	13.8	3.3	-18.6	9.6
LHY6	ACC-112, ACC-158	F15	-	Attack	Skull	J (12-15)	F?	2.4	33.8	11.7	3.4	-19.0	10.2
LHY7	LHY.X16.x130.y270.z267	X16	-	Attack	Coxal	J (15-19)	M	5.9	43.7	15.7	3.3	-17.5	11.0
LHY8	LHY.A3.Y16.x390.y345.z250	Y16	-	Attack	Humerus	IA	?	4.3	45.3	15.7	3.4	-18.4	11.1
LHY9	ACC-87, LHY.29A.125.C, LHY.79(A3.A27.x300.y289.z108)	A27-A29	-	Attack	Vertebra	IA	M	8.4	43.3	15.5	3.3	-18.3	10.2
LHY10	LHY.A3.x163.y53.z10	?	-	Attack	Humerus	IA	?	1.5	32.7	11.4	3.3	-19.7	8.9
LHY11	ACC-63	Y9	-	Attack	Skull	IA	?	6.9	45.2	15.6	3.4	-18.9	10.1
LHY12	ACC-129	X35	61	Attack	Skull	C (ca. 3)	?	2.4	37.1	12.9	3.4	-17.5	13.6
LHY13	ACC-13	A15	10	Attack	Skull	I (6±3 months)	?	6.9	36.1	13.1	3.2	-16.2	14.5
LHY14	INH-97	F21	48	Infant burial	Mandible	P	?	3.2	41.9	14.7	3.3	-18.6	9.9
LHY15	INH-163	X25	41	Infant burial	Skull	I (0-6 months)	?	11.7	44.9	16.0	3.3	-16.2	14.9
LHY16	INH-175	Y22	-	Infant burial	Skull	I (9±3 months)	?	7.0	37.3	13.3	3.3	-17.3	13.6
LHY17	INH-186	F29	63	Infant burial	Tibia	P	?	12.8	40.0	14.2	3.3	-17.8	10.6
LHY18	INH-235	Y12	95	Infant burial	Skull	P	?	16.3	42.2	14.9	3.3	-17.5	12.0
LHY19	INH-244	V6	100	Infant burial	Skull	I (6±3 months)	?	9.0	45.8	16.3	3.3	-16.8	13.2

[1]P = perinatal, I = infant, C = child, J = adolescent, YA = young adult, MA = mature adult, IA = indeterminate adult.
[2]M = male; M? = probable male; F = female; F? = female; ? = indeterminate.

Table 4. Summary of mean human, animal and plant $\delta^{13}C$ and $\delta^{15}N$ values, by species					
Species (age)	n	$\delta^{13}C$ (‰) (VPDB)		$\delta^{15}N$ (‰) (AIR)	
		$\bar{x}$	σ	$\bar{x}$	σ
Human (perinatal)	3	-18.0	0.6	10.8	1.0
Human (infant)	5	-16.8	0.6	14.0	0.7
Human (adolescent)	2	-18.2	1.0	10.6	0.6
Human (adult)	9	-18.7	0.5	10.2	0.8
Bos taurus	7	-21.1	0.3	5.0	1.1
Ovis aries/ Capra hircus	11	-20.1	0.5	5.9	1.0
Sus domesticus	10	-20.4	0.3	5.6	0.3
Canis familiaris	1	-19.5	-	7.6	-
Gallus domesticus	1	-17.3	-	10.1	-
Triticum sp.	18	-22.1	0.4	7.0	0.8
Hordeum vulgare	3	-23.1	0.6	6.8	0.6
Avena sp.	2	-24.7	0.4	3.8	0.4
Panicum milliaceum	3	-10.8	0.2	10.2	0.4
Quercus sp.	5	-24.6	1.9	3.6	2.4

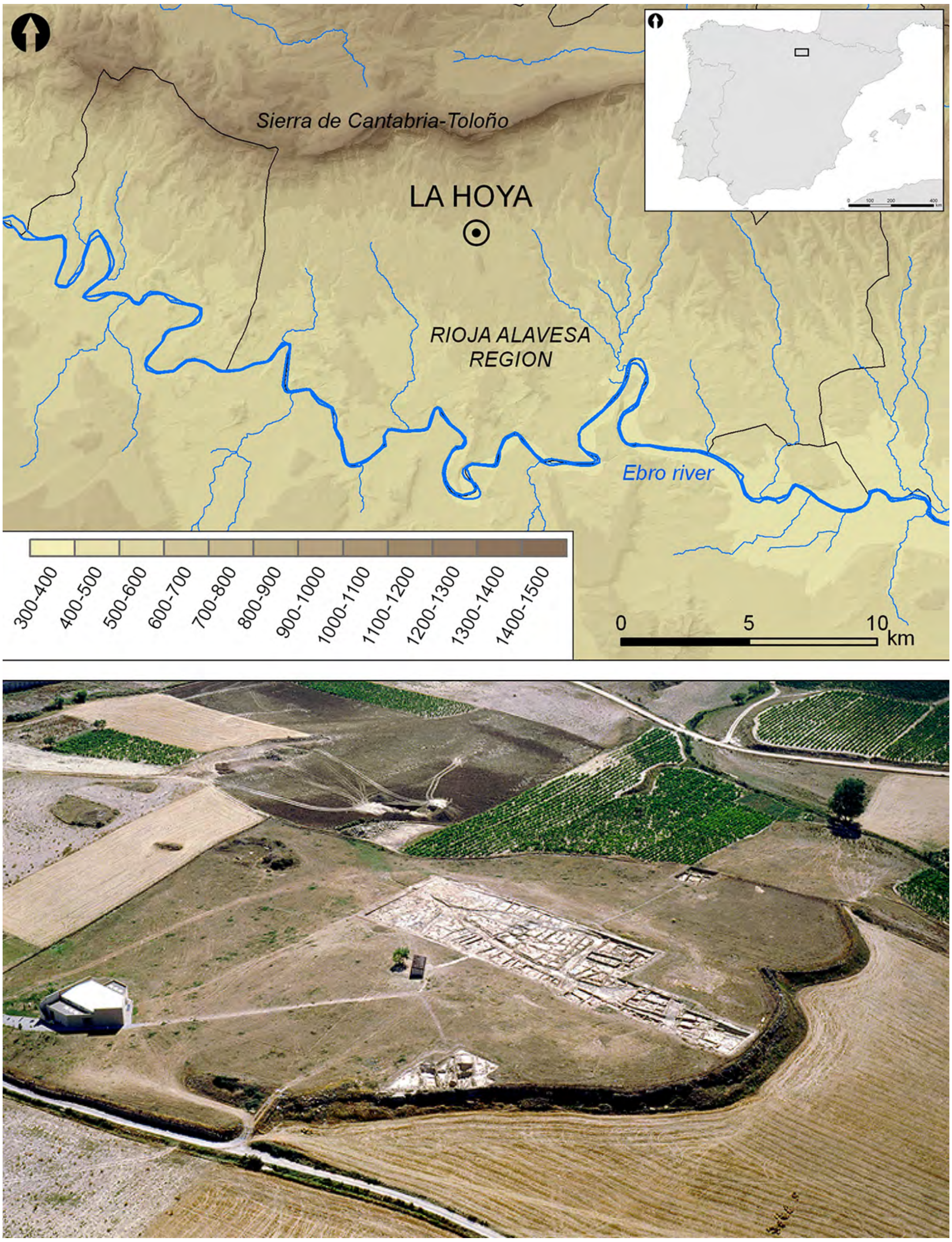

Fig. 1. Map showing the location of La Hoya in the Rioja Alavesa region, north-central Iberia, and aerial photography of the site taken from NE to SW (Llanos, 2005)**.**

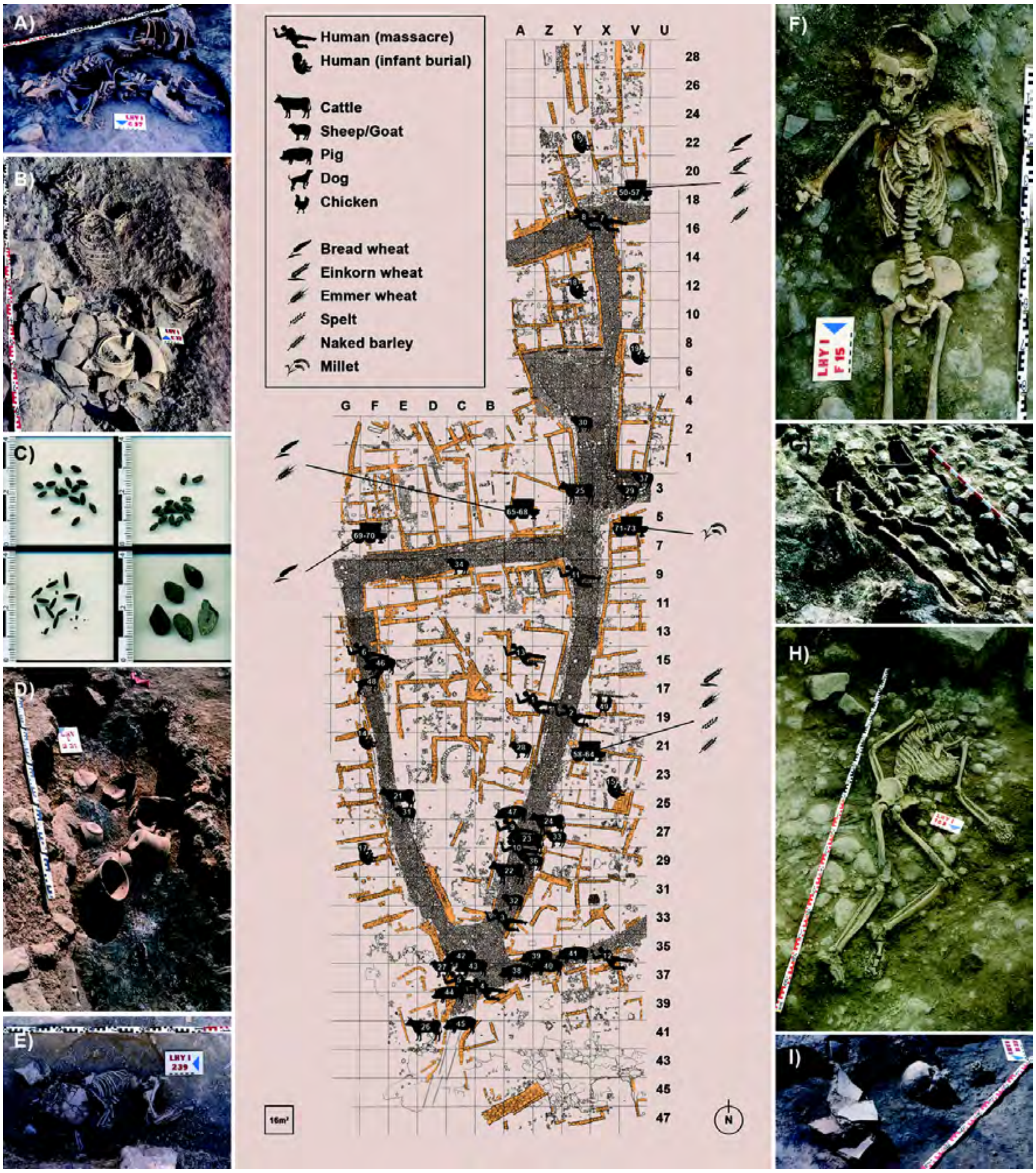

Fig. 2. **Map of Sector III, layers A3/A2 (Iron Age II / Celtiberian period), of La Hoya**. The locations of the majority of the human skeletons studied and of the human, faunal and plant samples used for isotope analyses are shown for reference. The map is accompanied on both sides by pictures of scenes of killing and devastation and of diverse material evidence recorded during excavation (Llanos, 2005), which are related to or coeval with the attack suffered by the village between the mid-4th and the late 3rd centuries BC. *A)* and *B)* complete skeletons of two pigs (LHY42 and LHY43) and vessel remains found on the floor of the village's main square (excavation square C37); *C)* example of charred plant remains found in abandoned vessels (top left: einkorn wheat / *Triticum monococcum*; top right: emmer wheat / *Triticum dicoccum*; bottom left: oat / *Avena sp*.; bottom right: acorn / *Quercus sp*.); *D)* vessels found in a house that was burnt down (household 89, square B31); *E)* infant burial found below the floor of household 305 (square Y24); *F)* skeleton of a young adolescent (LHY6) found on the street in square F15, with amputated right arm; *G)* skeleton of a young adult male (LHY2) showing right arm amputation as well as signs of burning, found on the street in square Y19; *H)* skeleton of a decapitated young adult male with postcranial mutilation, found on the street in square B33; *I)* isolated skull found on the floor of the village's main square (excavation square B37) (Fernández-Crespo et al., 2019).

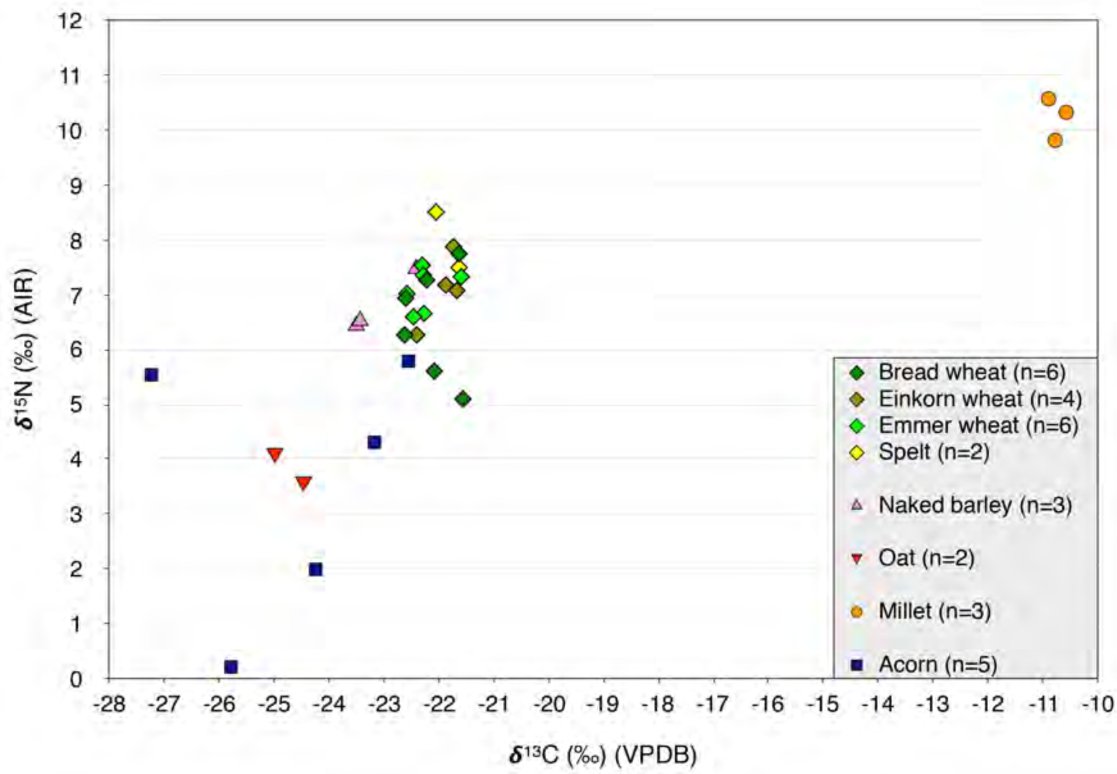

Fig. 3. **Dispersion of δ^{13}C and δ^{15}N isotope results obtained for La Hoya's plant samples**. The δ^{13}C and δ^{15}N values have been corrected for the effect of charring on carbonized plant remains by subtracting 0.11‰ and 0.31‰, respectively, from their determined measurements (Nitsch et al., 2015).

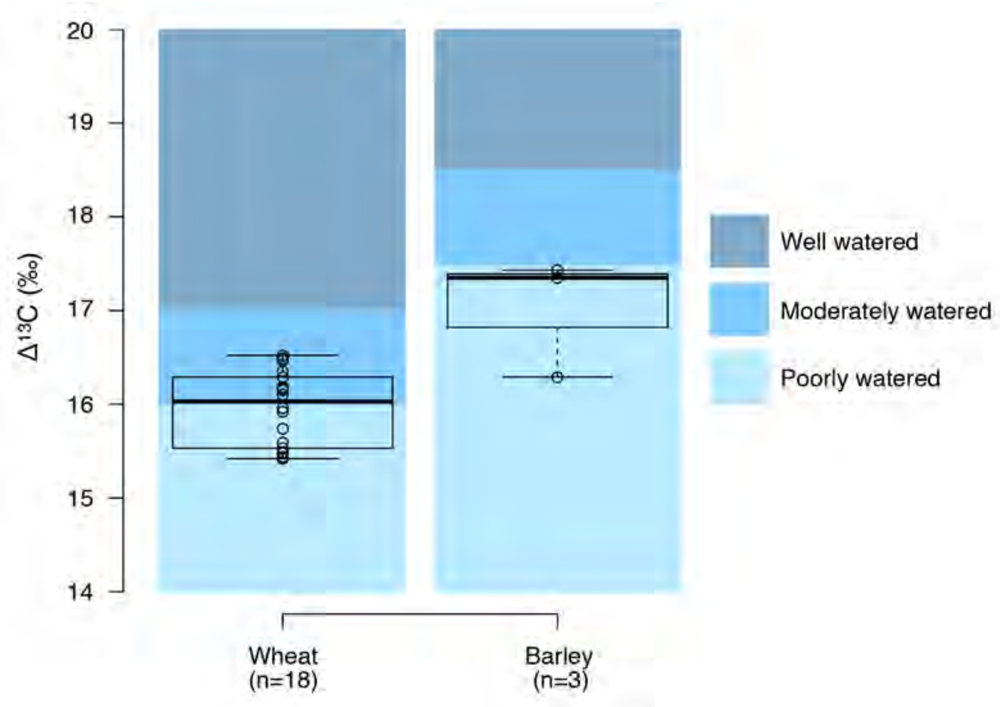

Fig. 4. **Boxplot of Δ^{13}C values of wheat (bread wheat, einkorn, emmer and spelt combined) and barley**. Experimental values for wheat and barley watering conditions (Wallace et al., 2013) are shown for comparison.

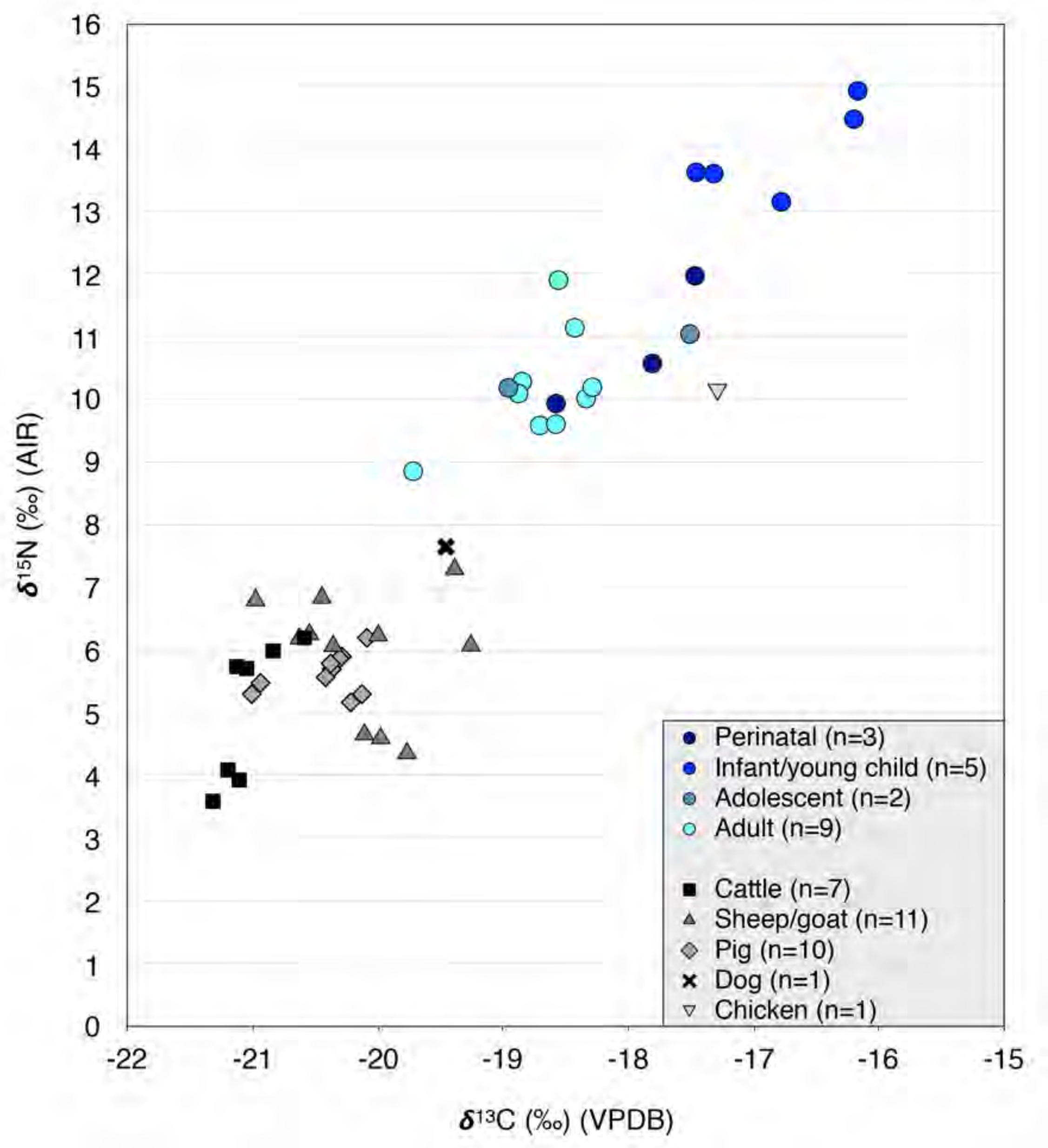

Fig. 5. **Dispersion of human and faunal $\delta^{13}C$ and $\delta^{15}N$ values of La Hoya.**

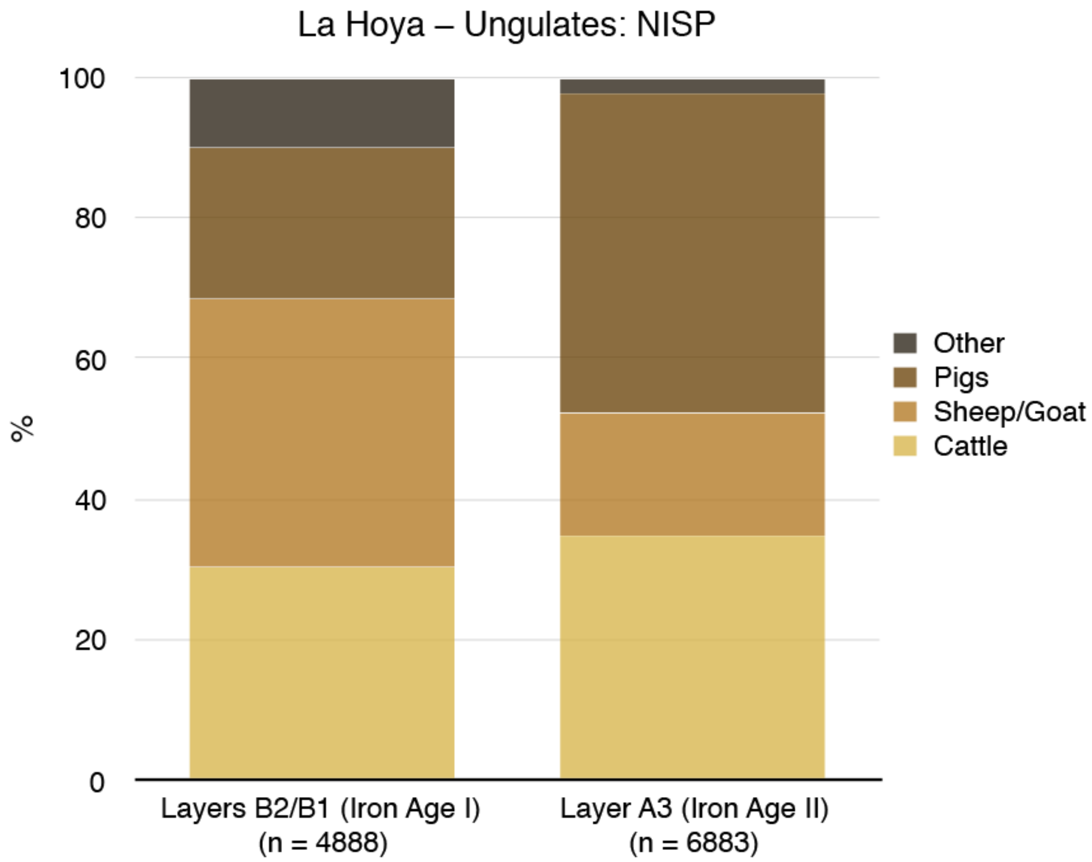

Fig. 6. Number of Identified Specimens (NISP) of the ungulate remains recovered from La Hoya Iron Age I and Iron Age II phases (data obtained from Mariezkurrena, 1990).

Figure captions

Fig. 1. Map showing the location of La Hoya in the Rioja Alavesa region, north-central Iberia, and aerial photography of the site taken from NE to SW (Llanos, 2005).

Fig. 2. Map of Sector III, layers A3/A2 (Iron Age II / Celtiberian period), of La Hoya. The location of the majority of the human skeletons studied and of the human, faunal and plant samples used for isotope analyses is shown for reference. The map is accompanied on both sides by pictures of scenes of killing and devastation and of diverse material evidence recorded during the excavation of the site (Llanos, 2005), which are related or coeval to the attack suffered by the village between the mid-4th and the late 3th centuries BC.

Fig. 3. Dispersion of $\delta^{13}C$ and $\delta^{15}N$ isotope results obtained for La Hoya's plant samples. The $\delta^{13}C$ and $\delta^{15}N$ values have been corrected for the effect of charring on carbonized plant remains by subtracting 0.11‰ and 0.31‰, respectively, from their determined measurements (Nitsch et al., 2015).

Fig. 4. Boxplot of $\Delta^{13}C$ values of wheat (bread wheat, einkorn, emmer and spelt combined) and barley. Experimental range values for wheat and barley watering conditions (Wallace et al., 2013) are shown at the background for comparison.

Fig. 5. Dispersion of human and faunal $\delta^{13}C$ and $\delta^{15}N$ values of La Hoya. Human values are distributed by age.

Fig. 6. Number of Identified Specimens (NISP) of the ungulate remains recovered from La Hoya Iron Age I and Iron Age II phases, displayed as percentages (data obtained from Mariezkurrena, 1990).