The early lives of the Islanders: Stable isotope analysis of incremental dentine collagen from the prehispanic period of the Canary Islands.

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Running Title: The Early lives of the islanders from the prehispanic period of the Canary Islands.

Abstract:

Objectives: This study presents isotopic information for incremental dentine collagen and bone bulk collagen from individuals from the Canary Islands (Tenerife and Gran Canaria) to explore dietary differences during childhood life.

Materials and Methods: Eight individuals have been studied, which comprises 122 δ^{15}N and δ^{13}C incremental dentine measurements and eight bulk bone collagen analyses. A baseline of potentially consumed food sources has been developed for comparative purposes. A FRUITS model of probable contributions of each food source towards the diet of each individual has been developed. All samples but one belongs to the later period of indigenous occupation of the archipelago.

Results: The dentine collagen data are presented in correlated δ^{13}C and δ^{15}N plots per individual, showing the isotopic changes throughout time. δ^{15}N values for each individual tend to be variable whereas δ^{13}C data are generally more stable with a range of +9.1 to +14‰ for δ^{15}N and −17.4 to −20.8‰ for δ^{13}C.

Conclusion: The isotopic analysis allows for the reconstruction of 8 dietary profiles, which allow us to estimate the different dietary protein sources. The FRUITS model shows different percentages of the primary food sources for each individual. Where both δ^{13}C and δ^{15}N are elevated, this could be indicative of a higher marine contribution to the diet. There appear to be two main dietary profiles identifiable in the dataset and these may be related to changes in status or place of residence. Short-term variations in δ^{13}C and δ^{15}N and opposing co-variance of isotopic values can be indicative of nutritional stress, although metabolic changes during growth are also considered.

Keywords: Incremental dentine, stable isotopes, island archaeology, Canary Islands, Carbon, Nitrogen.

Introduction:

Human infants are born in an immature state in comparison with other mammals. A prolonged period of supported feeding is needed from birth and during infancy to ensure their survival . After that, they may experience significant fluctuations in diet through their early years to adulthood as a result of changes in social status both within and outside their family. Weaning is a process during which children move from exclusive breastfeeding through a period of mixed feeding where other foodstuffs are introduced, to the complete cessation of breastmilk consumption; when this occurs a child is deemed to have been weaned. This transition is a first biological and cultural step forward to adulthood. Therefore, archaeologists and anthropologists have sought to investigate this process in order to understand transitional periods during past life histories (See reviews: Halcrow and Tayles, 2011; Mays, Gowland, Halcrow, Murphy, 2017).

Ethnographic and historic evidence also indicates that childhood diets may differ from those of the adult population, since some dietary key components, such as ‘quality foods’ (as in both efficiency and scarcity), are sometimes restricted to the adult group. These differences between adult and child diets may be related to environmental constraints, food availability, and cultural customs . Variations in diet may also be related to movement between groups with different dietary customs such as the geographical relocation of individuals or as a change in status such as an oblate entering a monastic setting .

Island societies, regardless of inland or coastal dwelling, have a limited access to edible resources, given the fact that long range trade and mobility are conditioned by sea, and thus, specific adaptative behaviors are needed to survive and adapt through long periods of time in a relatively isolated landscape (Kirch, 2009, 1980). In such closed environments, diet can change based on social status , although sometimes children’s diets do not depend on social status, but are relatively homogeneous . The diet of the non-adult islanders should be also based on the same limited resources, although probably with different proportions of the ‘quality foods’ during each stage of development, those ‘quality foods’ most likely being the high protein sources, such as meat. Therefore, observing the evolution of the diet during childhood proves essential to explain different patterns of food consumption and possible changes happening in the early lives of these individuals.

Bioarcheological studies that can identify such transitional periods are especially important when archaeologists deal with ancient societies without written sources or first-hand information on past diets . The analysis of carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope ratios in the collagen and keratin of human tissues has allowed researchers to investigate the protein element of the diet both in individuals and at a population level. The introduction of microsampling of incrementally-forming tissues such as hair, fingernail and tooth dentine has improved temporal resolution and has led to the ability to identify variations in diet within individual life-histories. This approach to the measurement of diet within human remains offers an opportunity to investigate the early lives of archaeological societies. This method can estimate the dietary patterns during childhood (retained within dentine in the teeth) and compare this with the bone collagen values recorded in tissues that turnover during adulthood. In isolated communities, such as the Indigenous population of the Canary Islands, this method can prove an essential tool to study the differences between islanders, which lived in different environments, as they might have diets in their early lives correlated to their surroundings. Moreover, addressing the chronological variable in these communities using this technique can provide information for different dietary patterns derived from social or subsistence-related changes over time.

Archaeological background:

The Canary Islands archipelago is a group of volcanic islands located in the Macaronesian region of the Atlantic Ocean (Figure 1). They were originated in the Late Miocene due to the continued expulsion of volcanic materials (Carracedo and Troll, 2016; Schminke and Sumita, 2010). The islands are constantly affected by two major climatic influences, the Saharian winds and the Atlantic Trade winds, which both contribute to the variety of climates of this ecological region, ranging from warm, subtropical environments in its coastal areas to cold, dry climates in its high mountain areas .

The islands were first populated by farming populations from North Western Africa as evidenced by archaeological , genetic (Fregel et al., 2019; Maca-Meyer et al., 2004), and linguistic studies (Springer, 2019, 2001). The Europeans arrived in the islands in the Middle Ages and conquered the archipelago in 1496 AD (Abreu Galindo, 1977). The conquest caused a drastic reduction of the Indigenous population of the islands due to both violence and slavery. However, some survived and admixed with the new settlers, as showed by the genetic composition of the current Canarians. The modern population of the archipelago, although having a Spanish/European cultural background, show a significant genetic contribution from the Indigenous people, both inferred from uniparental and genome-wide markers (Fregel, Ordóñez, Serrano, 2021).

The prehispanic society of the Canary Islands relied on resources brought from the African continent, which were not initially available in the islands when they were settled. Some crops and vegetables were cultivated, such as barley (*Hordeum vulgare*), durum wheat (*Triticum durum*), lentils (*Lens Culinaris*), and figs (*Ficus Carica*). However, the latter has only been found in Gran Canaria . They occasionally relied on wild species such as the Mocán Fruit (*Visnea mocanera)* or the Canarian Palm Date, *(Phoenix Canariensis)* (Morales et al., 2017). Domesticated animals were farmed and consumed, mainly goat (*Capra hircus*), sheep (*Ovis aries*) and pig (*Sus scrofa*), as evidenced by the archaeological record . Gathering and fishing of marine coastal species were broadly exploited in all the islands .

Palaeodietary studies proposed a mixed protein diet for the ancient population of the islands, mainly based on cereals and livestock, complemented by marine foods (Arnay-de-la-Rosa et al., 2010).

It is of special importance to define the type of plants that were likely most consumed by the indigenous people of the Canary Islands to produce an accurate paleodietary reconstruction using stable isotopes. The plants that can constitute the base of a food chain can be classified according to their photosynthetic pathway in C3 (Calvin-Benson), C4 (Hatch-Slack) or CAM (Crassulacean Acid Metabolism) plants. C3 plants usually have δ^{13}C values between –33 to –23‰, whereas C4 plants, which are characteristic to arid and tropical environments have values ranging between –16 to –

9‰ (Farquhar et al., 1989). CAM plants have a variable metabolism, which causes them to have an increased range of $\delta^{13}C$ values, and, therefore, complications arise when interpreting isotopic food chains that are based on CAM plants. (Ambrose, 1987).

According to archaeobotanical data (Morales et al., 2017), the cereals brought from the north African continent would be C3 type cereals, such as the wheat and barley, no C4 African cereals, such as sorghum or millet have been found in the archaeological record of the archipelago. Moreover, the wild plants gathered by the population to complement their diet greatly differ between islands and have also been found to be mostly C3 type plants (Morales et al., 2017). Therefore, it is unlikely that C4 plants were predominant in the everyday diet of the islanders during the prehispanic period.

Archaeological data also indicate differences in the social complexity and subsistence strategies of some islands . It is noteworthy that the two major islands of the archipelago, Tenerife and Gran Canaria, exhibit significant differences in social, demographic and economic development even though the islands are ecologically similar . Gran Canaria shows a subsistence mostly based on agriculture as evidenced by the abundant archaeobotanical evidence found throughout the island (Hagenblad, Morales, Leino, Rodríguez-Rodríguez, 2017; Morales et al., 2017) and the granaries used to store the crops over the long term (Henríquez-Valido et al., 2020). Whereas Tenerife developed a subsistence model mostly based on livestock and agriculture along with gathering and marine resources exploitation. The islanders from Tenerife lived scattered throughout the island, near ravines and coastal areas (Chávez Álvarez, Pérez Caamaño, Pérez González, Soler Segura, Tejera Gaspar, 2007; Galván Santos et al., 1999; Soler Segura, Pérez Caamaño, Rodríguez Rodríguez, 2011). Moreover, the central area of the island, a large highland plateau called Las Cañadas del Teide was considered a “common space” used by the islanders (Diego Cuscoy, 1968), who would only stay in the area seasonally (Vidal-Matutano et al., 2019, Morales Mateos et al., 2021).

These different subsistence strategies shown in the archaeological record have a mild representation in the palaeodietary studies, . Given the fact that the whole plant environment is C3 based, and the marine intake preserved in the archaeological record shows consumption of low-depth fish and sporadic seashell consumption. Previous palaeodietary studies using bone collagen $\delta^{15}N$ and $\delta^{13}C$ measurements show us that the inhabitants of the archipelago relied on a mixed diet where principal protein component was obtained from terrestrial sources, although it sometimes included some marine protein (Arnay-de-la-Rosa et al., 2009; Velasco-Vázquez, 1998; Velasco-Vázquez, Arnay-de-la-Rosa, González Reimers, Hernández Torres, 1997). This slight increase in marine foods among certain groups depended on several factors, and studies have been conducted on dietary differences among islands (Arnay-de-la-Rosa et al., 2010) and time periods (Lécuyer et al., 2021; Sánchez-Cañadillas et al., 2021).

However, no information is available on whether these individuals had a different diet during their early lives than their later lives, since isotope palaeodietary studies in the Canary Islands have been restricted to adult bone collagen. High-resolution methods are needed to explore the diet of these individuals at different moments of their lives, to acknowledge questions such as breastfeeding, dietary changes through life, or the impact of metabolic conditions or sickness on their tissues.

Incremental Stable Isotope analysis for dietary reconstruction in ancient populations:

Carbon and nitrogen stable isotopes of bone collagen have been widely used for palaeodietary and paleoenvironmental reconstruction of the protein element of both faunal and human archaeological diets (Ambrose, 1993; Katzenberg and Waters-Rist, 2018; Makarewicz and Sealy, 2015). For a detailed discussion on the mechanisms by which the isotope ratios change from dietary source to the tissues of the consumer, see Lee-Thorp (2008).

In simple terms, there is a shift in the isotope ratios between the dietary source and the tissues of the consumer (a trophic level shift) caused by the preferential uptake of the lighter isotope when the body is producing proteins because this requires less energy. This process is known as fractionation. Different steps in the food chain may have different levels of fractionation, but a comparison between the isotope ratios of contemporary food sources and human tissues can allow the reconstruction of past diets . Differences between the δ^{13}C of plants with different photosynthetic pathways and between δ^{15}N and δ^{13}C of plants and animals from terrestrial and marine origins have made it possible to produce more detailed dietary histories for archaeological individuals.

Dietary changes during human development, such as breastfeeding, have been thoroughly studied. The model for the changes in δ^{15}N and δ^{13}C during breastfeeding and weaning proposed by Millard relies on an assumption that an infant is born with the same isotopic values as the mother, and that during the period of exclusive breastfeeding both δ^{15}N and δ^{13}C will rise in new tissues laid down by the infant as a result of a trophic level shift from breastmilk from the mother. This model is built upon the assumption that the infant must be growing consistently without any stunting and survives the period of growth of the tissue being analysed.

However, modern studies of hair and fingernail have shown that nutritional stress from starvation or prolonged illness can alter the δ^{15}N and δ^{13}C this has also been observed in archaeological studies where there is pathological or historical evidence for nutritional distress . Any alterations in the quality or source of maternal diet, and any interruptions in the nutrition and health of the mother or infant could change the pattern of the δ^{15}N and δ^{13}C incorporated into the proteins in the bone and dentine collagen of the infant .

δ^{15}N and δ^{13}C values observed during dentine development appears to be buffered against nutritional stress compared with bone, which will cease growing above a threshold of stress . Early studies used δ^{15}N and δ^{13}C from samples of bone collagen from infants in the archaeological record in an attempt to reconstruct weaning behaviour within past populations. Samples such as these run the risk of the "osteological paradox" by assuming that the bone of these individuals who died as infants is representative of the population and has not been subject to maternal or infant nutritional distress. Analysing the dentine, which is forming at the same age in both infants who died and who survived the weaning period in the same populations has shed light on the variations possible within a population (e.g. .

In studying the dietary transitions through early development using incremental stable isotope analysis it is crucial to observe the information recorded in the skeleton and the available archaeological, environmental and historical context. Since some individuals will have experienced very similar dietary variations and may be considered a cohort in terms of their life-histories .

Objectives:

The main objective of this study is to investigate the differences between islander diets coming from different environments from the archipelago, especially focusing on the differences between coastal and inland sites. Additionally, this research also aims to study the possible weaning ages of this population and evaluate the post-weaning period using incremental dentine stable isotope analysis. This paper aims to elucidate whether incremental dentine collagen isotope analysis can discriminate a larger amount of marine component in restricted dietary profiles. This approach considers that the population buried in the high mountain area of Las Cañadas del Teide represents groups of seasonal shepherds that were most likely born in either the midlands or the coastal areas of the island. As the childhood diet after breastfeeding would ideally reflect what foodstuff was consumed at the homeland areas (midland and coastal areas), dentine incremental isotope analyses would identify if they had access to marine products from their residence areas. Moreover, this approach is also applied in several samples of Gran Canaria from inland and coastal sites to estimate the hypothetical thresholds for mixed and terrestrial diets. This approach is based in archaeological and paleodietary studies, which indicate that dietary profiles were significantly different between the coastal and inland areas of Gran Canaria (Delgado-Darias, 2001; Lécuyer et al., 2021).

The incremental data will be presented as a series of dentine profiles for each individual according to the estimated age of each increment, to study the possible changes in diet during the life of each individual and discuss the possibilities of said changes, being dietary or metabolic. Additionally, the δ^{15}N and δ^{13}C of each section will be observed as a group, to address differences between individuals.

This study also compares the incremental dentine isotopic values with the available isotopic dataset of the indigenous period of the Canary Islands. This analysis benefits from a wide isotopic baseline to develop a Bayesian statistical model to interpret the results.

Materials and Methods:

Materials:

This study includes a sample of eight lower molars (M1 and M2) and eight bone fragments of the mandibles of eight adult individuals from four burial caves from Las Cañadas del Teide, Tenerife (Caves of La Angostura, El Salitre, El portillo and Roque Blanco), and two funerary sites of Gran Canaria: El Metropole and Guayadeque (Figure 2). Sex and age were already estimated in previous studies, and while not all age-at-death estimations could be made due to poor preservation, all individuals are reported to be at least above 17 years old based on the eruption of the third molar (Arnay-de-la-Rosa et al., 2011; Santana Cabrera, Velasco-Vázquez, Rodríguez Rodríguez, 2015). Sex-specific patterning in diets among the indigenous population has been reported previously . Therefore, only male individuals were selected for this study to facilitate comparability between individuals.

The samples from Tenerife belong to individuals directly dated between the 12th to the 16th cal AD. The site of El Metropole (Gran Canaria) was directly dated in the 13th-15th cal AD (Table 1). However, there are no direct radiocarbon data for the individual from Guayadeque. Chronological data from this site ranged from the 7th cal AD to the 9th cal AD . Therefore, most samples from this study are likely placed in the the latest period of the indigenous phase.

Only well-preserved molars were selected to avoid bias related to isotopic turnover or intrusions related to dental conditions, such as tooth wear, caries, or periodontal disease.

Given the fact that the stable isotope study requires the destruction of part of the samples selected, institutions dedicated to the preservation of heritage from both Tenerife (*Museo de la Naturaleza y la Arqueología*) and Gran Canaria (*El Museo Canario*) were informed and asked to provide the samples. The researchers sent two solicitations, one to each institution, to conduct a study that was approved in a previous solicitation by the local administration (*Dirección General de Patrimonio Histórico del Gobierno de Canarias*). After the approval of both permissions, *El Museo Canario* directly provided the samples utilized, whereas for the *Museo de la Naturaleza y la Arqueología* the researchers were invited to collect the samples with the supervision and support of the museum personnel.

Method:

Bone and tooth samples were prepared at the University of Bradford Stable Isotope Laboratory (UBUSIL). A piece of 200mg bone was dry cut from the same mandibles of the sampled individuals. The tooth samples were prepared for stable isotope analysis of incremental dentine sampling following Beaumont et al. . This method consists of cutting each tooth in a longitudinal section from crown to root using a diamond saw embedded in a handheld dental tool. The developmental stage for each tooth was assigned following AlQatani, Hector, and Liversidge (2010), and the period of each increment followed Beaumont and Montgomery (2015), starting at “0” years in M1 and 2.5 years in M2 samples. Once cut, each of these sections were demineralized at 4°C in 0.5M hydrochloric acid (HCl), periodically refreshing the acid until demineralization was complete over a time period ranging from 7–14 days. Bone samples were also demineralized following the same acid bath procedure. After demineralization both bone and tooth samples were rinsed with 18.2MΩ (ultrapure) water. Tooth samples were horizontally cut into 1mm sections using a scalpel and the sections placed into labelled micro tubes along with dilute HCl at pH3 and sealed. The bone samples were placed into screw top 10ml tubes again with dilute HCl at pH3. The closed tubes were then placed into a dry block at 70°C to denature/solubilize the collagen. Upon completion the microtubes were centrifuged, the solution in the 10ml tubes was filtered and all tubes placed into a freezer at –35°C for a minimum of 12 hours before freeze drying. Finally, dried collagen was weighed, in duplicate, into tin capsules, to be measured by IRMS on a Thermo Flash 1112 EA coupled to a Thermo Delta Plus XL IRMS at UBUSIL. International standards of IAEA-N-1 Ammonium Sulfate, IAEA-600 Caffeine and IAEA-CH-3 Cellulose were used alongside in house standards of fish gel

(FG) and bovine liver standard (BLS) to ensure measurement precision, which was ± 0.2 per mil. Supplementary Table 1 contains data results and age estimations (according to Beaumont and Montgomery (2015)), δ^{13}C and δ^{15}N values for each tooth 1mm section, and bulk bone collagen, along with the quality parameters C%, N% and C:N ratio.

Bayesian modelling using FRUITS:

This study modelled the percentage of dietary inputs in the studied individuals using FRUITS (Food Reconstruction Using Isotopic Transferred Signals) software (Fernandes, Millard, Brabec, Nadeau, Grootes, 2014). The model includes an isotopic baseline on isotope signatures of modern and archaeological animal and plant remains published in previous studies from the Canary Islands (Supplementary Table 2). Modern samples were corrected to mitigate the Suess effect (+1.5 δ^{13}C‰) following established procedures (Böhm et al., 2002; Eerkens et al., 2021; Marino and McElroy, 1991). Likewise, two samples were converted from muscle/body tissue to bone collagen following the procedure of Bownes, Ascough, Cook, Murray, and Bonsall (2017) (–2.7δ^{13}C‰, +0.4 δ^{15}N‰). This approach differentiated three main dietary sources: herbivore/omnivore animals, C3 domesticated plants (cereals) and marine contribution, C4 plants were not included since they have not been found in the archaeological record of the archipelago. The model includes the macronutrient (energy and protein) portion of each source following Varalli et al. (2021). This approach involves offsets from proteins and energy from each dietary source and increment averages from consumer/consumed trophic relations obtained from literature (Fernandes, Grootes, Nadeau, Nehlich, 2015; Hedges and Reynard, 2007; Styring et al., 2017). However, caution must be advised when interpreting information outputs from FRUITS, since it has been recently demonstrated that dietary estimates using this software are derived from the fallibilities of the sampling and the collagen-to-diet offsets introduced in the application (Schulting, R.J., MacDonald, R., Richards, M.P., 2022).

Results:

Sample quality control:

All analysed samples have a carbon to nitrogen (C:N) ratio between 3.2 and 3.4, which fits into the category of acceptable C:N ratio for archaeological samples (2.9–3.6) (DeNiro, 1985, van Klinken, 1999). Likewise, all samples %C wt and %N wt falls within the recommended range (15–47% for carbon and 5–17% for nitrogen), except for the samples from the dentine data of both TENC-05 and TENC-06 (both from the same burial site of *Roques Blancos*) which show %C wt amounts of 49 – 50% and %N wt amounts of 16–17 %. These quantities do not greatly exceed the established standards (Ambrose and Norr, 1993; Ambrose, 1990) and have an accepted C:N ratio (3.3–3.4). However, caution must be applied when interpreting results from those two sequences. A total of 146 isotopic measurements were obtained, which amounts for 8 full incremental dentine sequences and 8 bone collagen analysis from the mandibles of the same individuals sampled for incremental dentine analysis.

δ^{13}C and δ^{15}N incremental results:

Dentine sections have been plotted longitudinally to observe specific changes during development. All M1 sections (TENC-03, TENC-05, TENC-06) have a first increment with higher δ^{15}N values than the rest of their sections, and later, they present an observable decrease in δ^{15}N values during subsequent sections, which corresponds to the weaning period, albeit TENC-06 has an increase in both δ^{15}N and δ^{13}C values during a single section. We can assume a completed weaning for TENC-03 at approximately 1.2 years, and for TENC-06 at approximately 3 years. TENC-05 is not suitable for weaning assessment since the third increment has values anomalous from the rest of the profile. All M2 samples seem to have completed their weaning, albeit sample GRAN-02 has a constant decrease in δ^{15}N up until approximately six years, which could or could not be related to weaning. Therefore, in this sample, weaning seems to have been completed at age around 2.5–3 years.

It is important to note that each dentine increment represents an average of about 7-9 months of life: this means that any δ^{15}N and δ^{13}C values in the first increment of an M1 represent a mean from just pre- birth to an age at which exclusive breastfeeding will cease. Thus, any δ^{15}N values will be lower than at the peak of exclusive breastfeeding. Where the δ^{15}N values are higher than the 1.5‰ above the weaned diet, these data suggest that there is some recycling of body tissues in the infant caused by physiological stress (undernutrition or infection for example). This would explain the second peak seen in the δ^{15}N profile of TENC-05 (Feuillâtre, Beaumont, Elamin, 2022).

Both M1 and M2 samples display a wide range of δ^{15}N values, being especially high in TENC-03, TENC-04 and GRAN-01, two samples from the same cave of *La Angostura*, and the sample from *El Metropole*, whose δ^{15}N values are our threshold for an observable amount of marine contribution in the diet. These δ^{15}N values are higher than bone collagen values from coastal populations from Gran Canaria (Lécuyer et.al, 2021) (Supplementary Table 2), therefore, δ^{15}N values above 12 δ^{15}N‰ should be taken into account, since they are similar to individuals considered as having a noticeable marine intake in their diets from the Canary Islands (Sánchez-Cañadillas et. al, 2021). Further, δ^{13}C values display a similar tendency on the whole dentine section (Figures 3 and 4), which correlates with values of C3 plant consumers.

Differences and similarities in incremental dentine profile:

As shown in Figures 3 and 4, there is a similar pattern of δ^{15}N values in three individuals, TENC-01, TENC-02 and GRAN-02, which consists in a noticeable (~ 1.5 ‰) nitrogen decline after the weaning period, which persists up until the increment corresponding to age 8, in which the δ^{15}N values increase. This pattern contrasts with four other individuals, comprising TENC-03, TENC-04, TENC-05, and GRAN-01, which is a group of samples with relatively homogeneous isotopic values during the whole subadult period. TENC-06 also presents similarities with both patterns since the curve shows a first decrease in δ^{15}N during the possible weaning period (the first sections, corresponding from ages between 0–2.5 age), a posterior plateau of both δ^{15}N (10–10.5 ‰) and δ^{13}C (–20 to –20.5 ‰) values, and an continued increase in δ^{15}N (11–12 ‰) values at the interval corresponding with age 6 until the end of the curve.

Some of the individuals (TENC-03, TENC-06, GRAN-02) have dentine collagen profiles that include what has been labelled as *opposing co-variance* (identified as “the famine pattern”), characterized by an extreme increase in δ^{15}N values opposed with a relative decrease in δ^{13}C values during the same increments (Beaumont and Montgomery, J., 2016, . This might imply that childhood nutritional stress is overlying the weaning curve. There is, however, a lack of visible osteological stress markers such as linear enamel hypoplasia or *cribra orbitalia* . The observable co-variance in between δ^{15}N and δ^{13}C values is not happening at the same age on each sampled tooth. TENC-03 has an opposing co-variance pattern in between 1.8 to 3.1 years, TENC-06 between 4.4 and 5.6 years, and GRAN-02 between 3.4 and 6.2 years.

As observed in Figure 5, almost all the δ^{13}C values of our plotted dentine samples fall within the range of –19.0‰ δ^{13}C and –20.5‰ δ^{13}C. The standard deviation of our whole δ^{13}C data is 0.4‰: Lovell, Nelson, and Schwarcz proposes that a standard deviation of 0.3‰ or less is characteristic of an homogeneous dietary profile. Therefore, discrete dietary differences in the food chain, especially in the samples with more positive values than –19.0‰ δ^{13}C are exceptions to this dietary homogeneity. δ^{15}N values, as shown in Figure 6, are heterogeneous and present different curves for each individual.

δ^{13}C and δ^{15}N baseline and island comparison:

Both δ^{13}C and δ^{15}N data were obtained for bulk bone collagen and dentine collagen. Mean dentine values from each individual have been plotted against a proposed baseline from the Canary Islands using already published animal and plant data from both archaeological and modern samples (Supplementary Table 2). To avoid data bias due to breastfeeding in M1 samples and potential early life nutritional stress, data from sections corresponding to the age interval between 0 –2.5 years have been removed (Garland and Reitsema, 2018), and thus, mean δ^{13}C and δ^{15}N from the incremental dentine analyses represents the post-weaning period (Table 2) (Figure 7).

Upon observation of each of the dentine mean values and our proposed baseline, there is an observable difference between the isotopic values of our studied sample (Figure 7). There is a range of individuals that have δ^{15}N values between +11.5 and +13.5 ‰ and δ^{13}C values between -19.5 and -19 ‰, these samples have been proposed as having a protein-mixed diet, having a certain marine input as opposed to the rest of the samples, that would have a predominantly terrestrial diet. This hypothesis is based on cautionary criteria of considering certain δ^{13}C values as characteristic of a larger “marine contribution” in diet (Montgomery et al., 2013) and recent studies made in the archipelago that propose a similar range of isotopic values as characteristic of a certain marine input in the diet of the islanders (Lecuyer et al.,2021).

The δ^{13}C and δ^{15}N values follow a normal distribution (Curt = 0.43 and Curt = 0.43, respectively). A Pearson’s correlation coefficient was made for both isotopes (p=0.000), indicating that both carbon and nitrogen isotope values are not correlated. A Student-T test was performed between the values of our proposed “mixed-diet” group (n=62) and the “terrestrial-diet” group (n=60). As shown in Table 3, there is a significant difference for δ^{13}C (p=0.000) and δ^{15}N (p=0.000) values between both groups, which suggests that this dataset comprises two different dietary profiles.

Food source percentages using Bayesian modelling:

Supplementary Table 3 shows the estimates (Mean% and sd% of diet) of each food source calculated using FRUITS with both mean dentine values and bulk bone isotopic data. The FRUITS model has been programmed with no prior information and with the inclusion of a single prior that acknowledges terrestrial contribution over marine contribution. Figure 8 shows the boxplots of the food source contribution from each studied individual during their early lives (minus breastfeeding), the upper graphs include the information from the model without priors, whereas the lower graphs are the same data with the specified priors. Samples deemed as having a mixed diet with higher marine inputs highlighted in blue.

The mean dentine profiles of TENC-03, TENC-04 and GRAN-01 (both samples from *La Angostura* and the sample from *El Metropole*) have more than 20% of their diet based on marine elements according to this model. Samples TENC-02 and TENC-06 have the lowest marine consumption intake on both mean dentine and bulk bone collagen isotope values.

Discussión:

Dietary changes through non-adult growth of the population from the Canary Islands:

While each of the eight dentine profiles shown in this article is different enough to be assessed individually, certain considerations can be identified regarding the early lives of the individuals studied. Weaning does not seem to follow a specific pattern for the studied population, the limited (n=3) M1 sample allow an investigation of potential "weaning curves" from birth in only three individuals (TENC-03, TENC-05, TENC-06), and one of the individuals is an outlier (TENC-06). In all three, there is the possibility that the trophic level shift seen in δ^{15}N from the breastmilk (in modern individuals 1–1.5‰ has been overlaid by increased δ^{15}N caused by undernutrition or stress. This is further corroborated by the lack of a corresponding pattern in the δ^{13}C. The patterns in the dentine profile suggest a period of opposing covariance. Some of the M2 samples show a decrease in δ^{15}N values around the increments corresponding with ages above 2.5 years. Specifically, TENC-02, GRAN-01 and GRAN-02 have decreasing δ^{15}N values at the beginning of their incremental sequence, with GRAN-02 δ^{15}N values continuing higher until around age 6 if only δ^{15}N values are observed (Figures 3 and 4). However, there must be an expected increase in δ^{13}C as more foods are incorporated into the child's diet to compliment the progressive withdrawal from breastmilk (Fuller et al., 2006, 2003).

This is the case for samples TENC-03, TENC-04 and TENC-05 that have some sections with more positive δ13C values than −19‰ δ13C, which has been proposed as a conservative value for acknowledging some contribution of marine food into the diet of prehistoric populations (Montgomery et al., 2013). However, this is not the case for all the samples, as there is only find an increase of δ^{13}C values at the same increment in which the δ^{15}N values decrease in TENC-06, GRAN-01, and GRAN-02 (Figure 4). Furthermore, we cannot rule out the possibility of GRAN-02 having a different diet than GRAN-01 due to this sample being from an earlier period (Lécuyer, et al. 2021)

Thus, weaning does not seem to have followed a specific pattern in our studied population, being a process completed at an age interval from 2 to 4 years old, which is consistent with the average weaning age for both prehistoric and preindustrial populations (Tsutaya and Yoneda, 2013).

The sample TENC-05 yielded a significant shift in both $\delta^{15}N$ and $\delta^{13}C$ values during just one increment of the whole section. Since contamination or deterioration can be ruled out based on collagen quality criteria, this case presents a controversial result as this fluctuation seems too drastic and different from the overall sequence. If not anomalous, these isotope values suggest a specific change in the life of this individual. $\delta^{15}N$ values have been demonstrated to shift during disease or whole body catabolic protein state derived from starvation , although this sample does not show an opposing co-variance pattern, which is related to famine in other studies (Walter et al., 2020). This acute increment could also be related to the transition of this individual to a coastal area during his early life, and a marine-only feeding during that age, as the $\delta^{15}N$ and $\delta^{13}C$ values are characteristic of a marine diet (Montgomery et al., 2013). After that increment, however, the isotope values demonstrate that the individual acquired a similar pattern to the other individuals.

Dietary changes or metabolic process?

Dentine incremental isotope values display a relative homogeneity between individuals of each group after weaning. This also consists of covariations of $\delta^{13}C$ and $\delta^{15}N$ tendencies as consequence of food intake fluctuations . It is noteworthy that $\delta^{15}N$ values may also increase as result of metabolic processes during this developmental stage, but the preferential contribution of growth and diet to the $\delta^{15}N$ values remains obscure. While recent studies propose that $\delta^{15}N$ variations linked to pubertal growth are inversely proportional to growth rate, other studies argue that it is expected to find a gradual increase in $\delta^{15}N$ values with age as the anabolic growth implies a net tissue gain in the body . There is a finely nuanced argument surrounding the effect of rapid growth on $\delta^{15}N$ values measured in dentine collagen: if the individual has sufficient dietary protein, then there should be a net fall in these values. However, and particularly in archaeological populations, there may be dietary stress that causes a recycling of the body tissues during rapid growth, which results in a measurable increase in the $\delta^{15}N$ measured.

The results of the Canarian sample indicate that there is an increase in $\delta^{15}N$ values after the individual reaches certain age, observable in, TENC-04, TENC-05, TENC-06, and GRAN-01 at 6-7 years, and in TENC-01, TENC-02, and GRAN-02 at around 9-11 years. These two age groups correlate to the differential diets proposed in this paper.

This increase then could be related either to dietary changes due the inclusion of higher trophic foodstuff into the diet or the metabolic changes associated with growth affecting $\delta^{15}N$ values positively. Cocozza et al. (2021) argued that an observable change could be seen in $\delta^{15}N$ after age seven years old in their study. This was interpreted as an increase in social status in children in a Romano-British population, and therefore could also be an indicator of a new social status (adulthood) in this studied population.

It is also noteworthy to account for the possibility of an earlier maturation happening in this specific population, which probably had scarcity in food variety and edible resource amounts. This increase in $\delta^{15}N$ values could be the result of trade-off during the child's development, which would happen earlier in the individuals with a mixed diet, as the necessity to incorporate certain foodstuffs into the child's diet could be motivated by a lack of other edible resources preferred by these groups.

However, more data are needed to corroborate these assumptions and create a broader hypothetical framework on δ^{15}N values, growth and maturation.

Terrestrial and mixed diets in the sampled dentine sections:

There is a trophic relationship between the sample δ^{15}N values and the herbivore and omnivore available isotopic data (Figure 7). A stepwise trophic enrichment in bone collagen between consumers and protein food sources is expected to be between 3-5‰ (De Niro and Epstein, 1981). Some individuals from this sample present δ^{15}N values above this trophic level enrichment (6–7‰). Their diet may have an additional nitrogen source such as a sporadic consumption of fish and/or molluscs. The δ^{13}C and δ^{15}N values are consistent with previous stable isotope work on bulk collagen and incremental dentine analyses done in medieval religious contexts . Both studies propose an increase in marine foods for certain individuals based on values like those of the "mixed-diet" feeders from our study.

The primary source of dietary protein has been suggested to be mainly terrestrial in the whole archipelago, except for the case of the site of *La Lajura*, in El Hierro Island (Arnay-de-la-Rosa et al., 2010). Likewise, δ^{13}C values are predominantly related to a C3 plant environment both in our sample and in all previous studies done in the archipelago . If the marine contribution to the diet was higher, it would be expected to find higher values in δ^{13}C isotopes due to the marine carbon reservoir being added to the consumers' tissues, as is the case of isotopic studies done on islanders from the Pacific . Islander's diets show that animal food consumption is not wholly derived from either marine or terrestrial inputs, but proportions of both protein sources . Therefore, establishing an expected contribution of each food source consumed proves essential to study differences in these isolated environments.

Bayesian analysis has contributed to clarify which individuals from this sample may have a higher input of marine foods in their diets. Dentine samples TENC-03, TENC-04, TENC-05 and GRAN-01 appear as having more than 18% of their diet based on marine contribution according to this model, which supports the observation based on the incremental dentine profiles. FRUITS models assume that the individual has a "healthy" dietary input, and therefore does not acknowledge nutritional stress (Cheung and Szpak, 2021). Moreover, the model will always discriminate a certain amount of the diet to each of the sources (Fernandes et al., 2015). This model acknowledges each food source type found in the archaeological record of the Canary Islands, those being the terrestrial and marine species found at sites, and the C3 cereals cultivated. Therefore, the output resulting from this model is a hypothetical dietary estimation acknowledging the consumption of these sources.

Furthermore, the indigenous population occupied the islands during more than one thousand years (Velasco et al., 2019), and while their diet was likely based on the same resources, it probably was not homogeneous in the proportions of those resources. Small differences are expected to appear depending on islands (Arnay-de-la-Rosa et al., 2010), time periods (Lécuyer et al., 2021, Sánchez-Cañadillas et al., 2021), or even local differences on each island, as evidenced by this study. This study has focused on the later period, albeit with one sample belonging to a funerary context with a wide timeframe, that being GRAN-02 (*Guayadeque*), the differences of this profile compared with GRAN-01 (*El Metropole*) could be both related to local variations (terrestrial vs. mixed-diet) and chronological variations (different centuries). FRUITS proves a useful tool to address these small differences in the contribution of each food component in the overall diet, and it should be considered as an exploratory tool in future stable isotopic studies in the Canary Islands.

Ultimately, the findings of this study reveal two dietary patterns in the individuals from Tenerife and Gran Canaria. The first profile, corresponding to a "terrestrial" diet, would be characterized by a trophic decrease in δ^{15}N after weaning ends, with consequently lower than average δ^{15}N up until the adulthood period. Whereas a "mixed" dietary profile would be characterised by the prevalence of a homogeneous, or even positive δ^{15}N curve during the whole dentine profile. As Lécuyer et al. (2021) demonstrated for the island of Gran Canaria, the most likely scenario regarding the diet of the indigenous population of the archipelago is the consumption of different proportions of the same resource package. These different proportions could vary across time, and this could explain the differences between GRAN-01 and GRAN-02. Incremental dentine has contributed to discriminating which individuals could have a higher marine input in their diet than the rest. This marine input, however, was never larger than the terrestrial one.

Conclusions:

This study presents the first incremental dentine isotopic analysis in the Canary Islands, focused on the late period of the two major islands from the archipelago. This study has provided new information on the weaning ages, post-weaning period and possible access to foodstuffs in a selection of samples from male individuals from the late prehispanic period of the Canary Islands.

The δ^{15}N values on the first section of the M1 sequences have shown the weaning ages of this population, which are varied, but happened during the 2-to-4-year age period. This pattern is consistent with pre-industrial populations according to previous incremental dentine studies.

This study also enabled us to observe access to foodstuffs in the period after weaning, and evaluate if regional and chronological differences affected diet, effectively establishing a difference between the late period coastal mixed diet (*El Metropole*) and the earlier midland diet (*Guayadeque*). These two profiles from Gran Canaria were compared with the late period of the neighbor island of Tenerife, which resulted in the conclusion that some individuals buried in the high mountain of Tenerife had a dietary profile that correlates closely with coastal dietary profiles, while other cave burials correlate with midland profiles. Las Cañadas del Teide, however, is most likely a seasonally-occupied territory, thus the population are not the ideal population to study different diets related to geographical origin. While incremental dentine analysis can provide useful to study child growth in the Canary Islands, archaeological sampling methods should focus on studying populations that represent specific geographical areas, to establish concrete profiles of terrestrial or mixed diets during childhood and childhood-to-adulthood transition.

The food baseline of the indigenous period of the Canary Islands is still scarce. Further research must be done to provide a more accurate framework to consider the isotopic values of the different foodstuffs and their impact into the isotope ranges of human samples. It is noteworthy to highlight that the Canaries are an isolated territory that depended on the same range of foods during its approximately 1500 years of indigenous occupation. Bayesian modelling of dietary inputs would greatly improve reducing the uncertainties linked to this approach by determining the percentage of marine diet of each individual or group, and to determine which range of δ^{13}C and δ^{15}N values must be used as threshold for an observable marine contribution in diet, as opposed to almost entirely terrestrial diets.

This study allowed us to improve the understanding of the weaning and post-weaning diet of the indigenous population of the Canary Islands. The isotope values demonstrate two different patterns of child feeding in the late period of the indigenous period. Moreover, the identification of coastal dietary profiles of some individuals buried on the highlands allows for the interpretation that some of these individuals grew up relatively close to the coast and had a specific diet during their childhood.

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References:

Abreu Galindo, J. de, (1977). Historia de la conquista de las siete islas de Canaria. Goya Artes Gráficas.

Alberto Barroso, V., (2004). De carne y hueso: la ganadería en época prehispánica. *El Pajar Cuad. Etnografía Canar.* 18, 4–8.

AlQatani, S.J., Hector, M.P., Liversidge, H.M., (2010). The London atlas of human tooth development and eruption. *Am. J. Phys. Anthropol.* 142, 481–490.

Ambrose, S., (1993). Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations, in: Sandford, M. (Ed.), Investigations of Ancient Human Tissue: Chemical

Analyses in Anthropology, Food and Nutrition in History and Anthropology. Routledge, pp. 59–130.

Ambrose, S., Norr, L., (1993). Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. In: Lambert J.B., Grupe G. (eds) Prehistoric Human Bone. Springer, Berlin, Heidelberg.

Ambrose, S.H., 1987. Chemical and Isotopic techniques of Diet Reconstruction in Eastern North America, in: Keegan, W. (Ed.) *Emergent Horticultural Economies of the Eastern Woodlands. Southern Illinois University*, pp. 87–108.

Ambrose, S.H., (1990). Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. *J. Archaeol. Sci*. 17, 431–451.

Armit, I., Shapland, F., Montgomery, J., Beaumont, J., (2015). Difference in Death? A Lost Neolithic Inhumation Cemetery with Britain's Earliest Case of Rickets, at Balevullin, Western Scotland. *Proc. Prehist. Soc*. 81, 199–214.

Arnay-de-la-Rosa, M., Gámez-Mendoza, A., Navarro-Mederos, J.F., Hernández-Marrero, J.C., Fregel, R., Yanes, Y., Galindo-Martín, L., Romanek, C.S., González-Reimers, E., (2009). Dietary patterns during the early prehispanic settlement in La Gomera (Canary Islands). *J. Archaeol. Sci*. 36, 1972–1981.

Arnay-de-la-Rosa, M., González-Reimers, E., Yanes, Y., Romanek, C.S., Noakes, J.E., Galindo-Martín, L. (2011). Paleonutritional and paleodietary survey on prehistoric humans from Las Cañadas del Teide (Tenerife, Canary Islands) based on chemical and histological analysis of bone. *J. Archaeol. Sci*. 38, 884–895.

Arnay-de-la-Rosa, M., González-Reimers, E., Yanes, Y., Velasco-Vázquez, J., Romanek, C.S., Noakes, J.E., (2010). Paleodietary analysis of the prehistoric population of the Canary Islands inferred from stable isotopes (carbon, nitrogen and hydrogen) in bone collagen. *J. Archaeol. Sci.* 37, 1490–1501.

Beaumont, J., (2020). The Whole Tooth and Nothing but the Tooth: Or why Temporal Resolution of Bone Collagen May Be Unreliable. *Archaeometry* 62, 626–645.

Beaumont, J., Atkins, E.-C., Buckberry, J., Haydock, H., Horne, P., Howcroft, R., Mackenzie, K., Montgomery, J., (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, 524–540.

Beaumont, J., Bekvalac, J., Harris, S., Batt, C.M., (2021). Identifying cohorts using isotope mass spectrometry: the potential of temporal resolution and dietary profiles. *Archaeometry* 63, 1024–1041.

Beaumont, J., Geber, J., Powers, N., Wilson, A., Lee-Thorp, J.A., Montgomery, J., (2013). Victims and Survivors: Stabe Isotopes used to identify migrants from the Great Irish Famine to 19th century Londond. *Am. J. Phys. Anthropol*. 150, 87–98.

Beaumont, J., Gledhill, A., Lee-Thorp, J.A., Montgomery, J., J., (2013). Childhood diet: A closer examination of the evidence from dental tissues using stable isotope analysis of incremental human dentine. *Archaeometry* 55, 277–295.

Beaumont, J. and J. Montgomery (2018). Messages from the mouth: life histories recorded in the teeth. Lost Lives , New Voices. C. Gerrard, P. Graves, A. Millard, R. Annis and A. Caffell. Oxford, Oxbow Books: 88-91.

Beaumont, J., Montgomery, J., (2016). The Great Irish Famine: Identifying Starvation in the tissues of Victims using Stable Isotope Analysis of Bone and Incremental Dentine Collagen. *PLoS ONE* 1–21.

Beaumont, J., Montgomery, J., (2015). Oral histories: a simple method of assigning chronological age to isotopic values from human dentine collagen. *Ann. Hum. Biol*. 42, 497–414.

Beaumont, J., Montgomery, J., Buckberry, J., Jay, M., (2015). Infant Mortality and Isotopic Complexity: New Approaches to Stress, Maternal Health, and Weaning. *Am. J. Phys. Anthropol*. 157, 441–457.

Bell, L.S., Cox, G., Sealy, J., (2001). Determining isotopic life history trajectories using bone density fractionation and stable isotope measurements: A new approach. *Am. J. Phys. Anthropol*. 116, 66–79.

Böhm, F., Haase-Schramm, A., Eisenhauer, A., Dullo, W.-C., Joachimski, M.M., Lehnert, H., Reitner, J., (2002). Evidence for preindustrial variations in the marine surface water carbonate system from coralline sponges. *Geochem. Geophys. Geosystems* 3, 1–13.

Bownes, J.M., Ascough, P., Cook, G., Murray, I., Bonsall, C., (2017). Using stable isotopes and a bayesian mixing model (FRUITS) to investigate diet at the early Neolithi site for Carding Mill Bay, Scotland. *Radiocarbon* 54, 1275–1294.

Carracedo, J.C., Troll, V., (2016). The Geology of the Canary Islands. Elsevier, Digital Publishing.

Chávez Álvarez, E., Pérez Caamaño, F., Pérez González, E., Soler Segura, J., Tejera Gaspar, A., (2007). Los guanches en Guía de Isora. Arqueología, territorio y sociedad. Biblioteca de Estudios Isoranos, Guía de Isora.

Cheung, C., Szpak, P., (2021). Interpreting Past Human Diets Using Stable Isotope Mixing Models. J. Archaeol. Method Theory 28, 1106–1142.

Craig-Atkins, E., Towers, J., Beaumont, J., (2018). The role of infant life histories in the construction of identities in death: An incremental isotope study of dietary and physiological status among children afforded differential burial. *Am. J. Phys. Anthropol*. 167, 644–655.

Cocozza, C., Fernandes, R., Ughi, A., Groß, M., Alexander, M., (2021). Investigating infant feeding strategies at Roman Bainesse through Bayesian modelling of incremental dentine isotopic data. *Int. J. Osteoarchaeol*. 31, 429–439.

D'Ortenzio, L., Brickley, M., Schwarcz, H., Prowse, T., (2015). You are not what you eat during physiological stress: Isotopic evaluation of human hair. *Am. J. Phys. Anthropol*. 157, 374–388. https://doi.org/10.1002/ajpa.22722

de Luca, A., Boisseau, N., Tea, I., Louvet, I., Robins, R.J., Forhan, A., Charles, M.-A., Hankard, R., (2012). δ15N and δ13C in hair from newborn infants and their mothers: a cohort study. *Pediatr. Res.* 71, 598–604.

Delgado-Darias, T., (2001). Los antiguos canarios a través de sus dientes, 1st ed. El Museo Canario, Las Palmas de Gran Canaria.

DeNiro, M.J., Epstein, S., (1981). Influence of Diet in the Distribution of Nitrogen Isotopes. *Geochim. Cosmochim. Acta* 45, 341–351.

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

Dettwyler, K.A., (1989). Styles of Infant Feeding: Parental/Caretaker Control of Food Consumption in Young Children. *Am. Anthropol*. 91, 696–703.

DeWitte, S.N., Stojanowski, C.M., (2015). The Osteological Paradox 20 Years Later: Past Perspectives, Future Directions. *J. Archaeol. Res*. 23, 397–450.

Diego Cuscoy, L., (1968). Los Guanches: Vida y Cultura del Primitivo Habitante de Tenerife. San Cristobal de La Laguna.

Eerkens, J., Canale, L., Bartelink, E., Canzonieri, C., Miszaniec, J., Morales, J., (2021). Stable isotopes demonstrate the importance of freshwater fisheries in Late Holocene native Californian diets in the California Delta. *J. Archaeol. Sci. Rep.* 38, 103044.

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.

Fernandes, R., Grootes, P.M., Nadeau, M.-J., Nehlich, O., (2015). Quantitative Diet Reconstruction of a Neolithic Population Using a Bayesian Mixing Model (FRUITS): The Case Study of Ostorf (Germany). *Am. J. Phys. Anthropol*. 158, 325–340.

Fernandes, R., Millard, A., Brabec, M., Nadeau, M.-J., Grootes, P.M., (2014). Food Reconstruiction Using Isotopic Transferred Signals (FRUITS): A Bayesian Model for Diet Reconstruction. *PLoS ONE* 9.

Fernández-Palacios, J.M., De Nicolas, (1995). Altitudinal pattern of vegetation variation on Tenerife. *J. Veg. Sci*. 183–190.

Feuillâtre, C., Beaumont, J., Elamin, F., (2022). Reproductive life histories: can incremental dentine isotope analysis identify pubertal growth, pregnancy and lactation? *Ann. Hum. Biol*. 49, 171–191.

Fregel, R., Ordoñez, A., Santana-Cabrera, J., Cabrera, V.M., Velasco-Vázquez, J., (2019). Mitogenomes Illuminate the Origin and Migration Patterns of the Indigenous People of the Canary Islands. *PLoS ONE* 1–24.

Fregel, R., Ordóñez, A.C., Serrano, J.G., (2021). The demography of the Canary Islands from a genetic perspective. *Hum. Mol. Genet.* 30, R64–R71.

Fuller, B. T., Fuller, J.L., Sage, N.E., Harris, D.A., O'Connel, T.C., Hedges, R.E.M., (2005). Nitrogen Balance and δ15N: Why You're Not What You Eat During Nutritional Stress. *Rapid Commun. Mass Spectrom.* 19, 2497–2506.

Fuller, B.T., Molleson, T.I., Harris, D.A., Gilmour, L.T., Hedges, R.E.M., (2006). Isotopic Evidence for Breastfeeding and Possible Adult Dietary Differences from Late/Sub-Roman Britain. *Am. J. Phys. Anthropol*. 129, 45–54.

Fuller, B.T., Richards, M.P., Mays, S.A., (2003). Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy. *J. Archaeol. Sci.* 30, 1673–1684.

Fulminante, F., (2015). Infant Feeding Practices in Europe and the Mediterranean from Prehistory to the Middle Ages: A Comparison between the Historical Sources and Bioarchaeology. *Child. Past* 8, 24–47.

Galván Santos, B., Hernández Gómez, C., Alberto Barroso, V., Barro Rois, A., Machado Yanes, M. del C., Eugenio Florido, C.M., Matos Lorenzo, L., Velasco-Vázquez, J., Machado Yanes, M. del C., Rodríguez-Rodríguez, A., Febles, J.V., Rivero, D., (1999). Poblamiento prehistórico en la costa de Buenavista del Norte (Tenerife).: El conjunto arqueológico Fuente-Arenas. *Investig. Arqueol*. 9–258.

Garland, C.J., Reitsema, L.J., (2018). Variation In Early Life Diet and Stress During Early Spanish Colonization: A Life History Perspective From Individuals Interred at the Fallen Tree Mortuary Site (9LI8) on St. Catherine Island, Georgia. Early Ga. 46, 51–79.

Guatelli-Steinberg, D., (2015). Dental Stress Indicators from Micro- to Macroscopic, in: A Companion to Dental Anthropology. John Wiley & Sons, Ltd, pp. 450–464.

Hagenblad, J., Morales, J., Leino, M.W., Rodríguez-Rodríguez, A., (2017). Farmer fidelity in the Canary Islands revealed by ancient DNA from prehistoric seeds. *J. Archaeol. Sci.* 78, 78–87.

Halcrow, S.E., Tayles, N., (2011). The Bioarchaeological Investigation of Children and Childhood, in: Social Bioarchaeology. John Wiley & Sons, Ltd, pp. 333–360.

Halcrow, S., Warren, R., Kushnick, G., Nowell, A., (2020). Care of Infants in the Past: Bridging evolutionary anthropological and bioarchaeological approaches. *Evol. Hum. Sci*. 2, e47-undefined.

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

Henríquez-Valido, P., Morales, J., Vidal-Matutano, P., Moreno-Benítez, M., Marchante-Ortega, Á., Rodríguez-Rodríguez, A., Huchet, J.-B., (2020). Archaeoentomological indicators of long-term food plant storage at the Prehispanic granary of La Fortaleza (Gran Canaria, Spain). *J. Archaeol. Sci.* 120, 105179.

Hernández Gómez, C.M., Velasco-Vázquez, J., Alberto-Barroso, V., (1999). Consideraciones en torno a los sistemas productivos de las sociedades prehistóricas canarias : los modelos de Tenerife y Gran Canaria. *Vegueta Anu. Fac. Geogr. E Hist*. 4, 33–56.

Hughes, K.L., Whiteman, J.P., Newsome, S.D., (2018). The relationship between dietary protein content, body condition, and *Δ*15N in a mammalian omnivore. *Oecologia* 186, 357–367.

Irl, S.D.H., Harter, D.E.V., Steinbauer, M.J., Gallego Puyol, D., Fernández-Palacios, J.M., Jentsch, A., Beierkuhnlein, C., (2015). Climate vs. topography – spatial patterns of plant species diversity and endemism on a high-elevation island. *J. Ecol.* 103, 1621–1633.

Kancle, L., Montgomery, J., Gröcke, D.R., Caffell, A., (2018). From field to fish: Tracking changes in diet on entry to two medieval friaries in northern England. *J. Archaeol. Sci. Rep*. 22, 264–284.

Katzenberg, M.A., Waters-Rist, A., (2018). Stable Isotope Analysis: A Tool for Studying Past Diet, Demography, and Life History, in: Biological Anthropology of the Human Skeleton. John Wiley & Sons, Oxford.

Kinaston, R.L., Buckley, H.R., Gray, A., (2013). Diet and social status on Taumako, a Polynesian outlier in the Southeastern Solomon Islands. *Am. J. Phys. Anthropol*. 151, 589–603.

Kinaston, R.L., Buckley, H., Valentin, F., Bedford, S., Spriggs, M., Hawkins, S., Herrscher, E., (2014). Lapita Diet in Remote Oceania: New Stable Isotope Evidence from the 3000-Year-Old Teouma Site, Efate Island, Vanuatu. *PLoS ONE* 9, 1–18.

Kirch, P., (2009). Island societies: Archaeological approaches to evolution and transformation, New Directions In Archaeology. Cambridge University Press.

Kirch, P., (1980). Polynesian Prehistory: Cultural adaptation in Island Ecosystems: Oceanic islands serve asarchaeological laboratories for studying the complex dialectic between human populations and their environments. *Am. Sci.* 68, 39–48.

Lécuyer, C., Goedert, J., Klee, J., Clauzel, T., Richardin, P., Fourel, F., Delgado-Darias, T., Alberto-Barroso, V., Velasco-Vázquez, J., Betancort, J.F., Amiot, R., Maréchal, C., Flandrois, J.-P., (2021). Climatic change and diet of the pre-Hispanic population of Gran Canaria (Canary Archipelago, Spain) during the Medieval Warm Period and Little Ice Age. *J. Archaeol. Sci*. 128, 105336.

Lee-Thorp, J.A., (2008). On Isotopes and old bones. *Archaeometry* 50, 925–950.

Lovell, N.C., Nelson, D.E., Schwarcz, H.P., (1986). Carbon isotope ratios in palaeodiet: Lack of age or sex effect. *Archaeometry* 28, 51–55.

Maca-Meyer, N., Arnay-de-la-Rosa, M., Rando, J.C., Flores, C., González, A.M., Cabrera, V.M., (2004). Ancient mtDNA analysis and the origin of the Guanches. *Eur. J. Hum. Genet*. 12, 155–162.

Makarewicz, C., Sealy, J., (2015). Dietary reconstruction, mobility, and the analysis of ancient skeletal tissues: Expanding the prospects of stable isotope research in archaeology. *J. Archaeol. Sci.* 56, 146–158.

Marino, B.P., McElroy, M.B., (1991). Isotopic compositio of atmopheric CO2 inferred from carbon in C4 plant cellulose. *Nature* 349, 127–131.

Mays, S., Gowland, R.L., Halcrow, S., Murphy, E., (2017). Child Bioarchaeology: Perspectives on the past 10 years. *Child. Past* 10, 38–56. https://doi.org/10.1080/17585716.2017.1301066

Mesa Hernández, E., Hernández-Marrero, J.C., Navarro, J.F., López Lorenzo, J.G., (2010). Archaeological shell middens and shellfish gathering on La Gomera island (Canary Islands, Spain). *Munibe* 31, 286–293.

Millard, A., (2000). A Model for the Effect of Weaning on Nitrogen Isotope Ratios in Humans, in: Goodfriend, G., Collins, M., Fogel, M., Macko, S., Wehmiller, J., (Eds.) *Perspectives in Amino Acid and Protein Geochemistry*. Oxford University Press, Oxford, pp. 51–59.

Montgomery, J., Beaumont, J., Jay, A., Keefe, K., Gledhill, A., Cook, G., Dockrill, S.J., Melton, N.D., (2013). Strategic and sporadic marine consumption at the onset of the Neolithic: increasing temporal resolution in the isotope evidence. *Antiquity* 87, 1060–1072.

Morales, J., Rodríguez, A., Henríquez, P., (2017). Agricultura y recolección vegetal en la arqueología prehispánica de las Islas Canarias (siglos III-XV d.C.) La contribución de los estudios carpológicos, in: Miscelánea en homenaje a Lydia Zapata Peña: (1965-2015). Universidad del País Vasco, pp. 189–218.

Morales Mateos, J., Vidal-Matutano, P., Marrero Salas, E., Henríquez-Valido, P., Lacave Hernández, A., García Ávila, Carlos, Abreu Hernández, I., Arnay-de-la-Rosa, M., (2021). High-mountain plant use and management: macro-botanical data from the pre-Hispanic sites of Chasogo and Cruz de Tea, 13–17th centuries AD, Tenerife (Canary Islands, Spain). *J. Archaeol. Sci. Rep.* 35, 102730.

Müldner, G., Montgomery, J., Cook, G., Ellam, R., Gledhill, A., Lowe, C., (2009). Isotopes and individuals: diet and mobility among the medieval Bishops of Whithorn. *Antiquity* 83, 1119–1133.

Navarro-Mederos, J.F., (1997). Arqueología de las Islas Canarias. *Espac. Tiempo Forma Ser. Prehist. Arqueol.* 10, 447–478.

Reitsema, L.J., (2013). Beyond diet reconstruction: Stable isotope applications to human physiology, health, and nutrition. *Am. J. Hum. Biol*. 25, 445–456.

Rigaud, D., Hassid, J., Meulemans, A., Poupard, A.T., Boulier, A., (2000). A paradoxical increase in resting energy expenditure in malnourished patients near death: the king penguin syndrome. *Am. J. Clin. Nutr*. 72, 355–360.

Rivera, F., Mirazón Lahr, M., (2017). New evidence suggesting a dissociated etiology for cribra orbitalia and porotic hyperostosis. *Am. J. Phys. Anthropol*. 164, 76–96.

Rodríguez Santana, C.G., (1996). La pesca entre los canarios, guanches y auaritas: las ictiofaunas arqueológicas del Archipiélago Canario. Cabildo Insular de Gran Canaria, Las Palmas de Gran Canaria.

Rodríguez, A.R., Santana Cabrera, J., Castellano Alonso, P., del Pino Curbelo, M., Francisco Ortega, I., Gómez de la Rua, D., González Ruiz, M. del C., Henríquez-Valido, P., Machado Yanes, M. del C., Marlasca, R., Mesa Hernández, E., Morales Mateos, J., Moreno García, M., Rando Reyes, J.C., Hernández Calvento, L., (2021). Un lugar entre las dunas. Aprovechamiento oportunista de un espacio costero durante la etapa preeuropea de la isla de Gran Canaria (circa siglos VIII-XI AD). *Trab. Prehist.* 78, 325–343.

Santana Cabrera, J. A. (2018). Reflexionando sobre la mujer aborigen de Gran Canaria: integrando arqueología y etnohistoria desde una perspectiva de género. *Complutum*, 29(1), 207-224. https://doi.org/10.5209/CMPL.62403

Santana Cabrera, J., Velasco-Vázquez, J., Rodríguez Rodríguez, A., (2015). Entheseal changes and sexual division of labor in a North-African population: The case of the pre-Hispanic period of the Gran Canaria Island (11th–15th c. CE). *J. Comp. Hum. Biol*. 66, 118–138.

Sánchez-Cañadillas, E., Carballo Pérez, J., Padrón, E., Hernández-Marrero, J.C., Melián, G.V., Navarro-Mederos, J.F., Pérez, N.M., Arnay-de-la-Rosa, M., (2021). Dietary changes across time: Studying the indigenous period of La Gomera using δ13C and δ15N stable isotope analysis and radiocarbon dating. *Am. J. Phys. Anthropol*. 1–19.

Schminke, H.-U., Sumita, M., (2010). Geological evolution of the Canary Islands : a young volcanic archipelago adjacent to the old African continent, Göerres-Druckerri. ed.

Schulting, R.J., MacDonald, R., Richards, M.P., (2022). FRUITS of the sea? A cautionary tale regarding Bayesian modelling of palaeodiets using stable isotope data. *Quat. Int.*

Soler Segura, J., Pérez Caamaño, F., Rodríguez Rodríguez, T., (2011). Excavaciones en la Memoria: Estudio historiográfico del Barranco del Agua de Dios y de la Comarca de Tegueste (Tenerife). Gobierno de Canarias, Tegueste.

Springer, R., (2019). El alfabeto líbico-bereber canario: la distribución geográfica de los signos en el Norte de África y Sáhara. *Vegueta Anu. Fac. Geogr. E Hist*. 19, 759–772.

Springer, R., (2001). Origen y Uso de La Escritura Líbico-Bereber En Canarias, 1st ed. Centro de la Cultura Popular Canaria, La Laguna.

Stantis, C., Buckley, H.R., Commendador, A., Dudgeon, J.V., 2021. Expanding on incremental dentin methodology to investigate childhood and infant feeding practices on Taumako (southeast Solomon Islands). J. Archaeol. Sci. 126, 105294.

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. *Nat. Plants* 3, 17076.

Tieszen, L.L., (1991). Natural variations in the carbon isotope values of plants: Implications for archaeology, ecology, and paleoecology. *J. Archaeol. Sci.* 18, 227–248.

Tieszen, L., Matzner, S., Buesman, S.K., (1995). Dietary reconstruction based on stable isotopes (13C,15N) of The Guanche pre-hispanic Tenerife, Canary Islands. *Proc. 1st World Congr. Mummies Stud.* 1, 41–57.

Tsutaya, T., Yoneda, M., (2013). Quantitative Reconstruction of Weaning Ages in Archaeological Human Populations Using Bone Collagen Nitrogen Isotope Ratios and Approximate Bayesian Computation. *PLoS ONE* 8, 1–10.

van Klinken, G.J., (1999). Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements. *J. Archaeol. Sci*. 26, 687–695.

Varalli, A., Desideri, J., David-Elbiali, M., Goude, G., Honegger, M., Besse, M., (2021). Bronze Age innovations and impact on human diet: A multi-isotopic and multi-proxy study of western Switzerland. *PLoS ONE* 16, e0243726.

Velasco-Vázquez, J., (1998). Economía y dieta de las poblaciones prehistóricas de Gran Canaria. Una aproximación bioantropológica. *Complutum* 9, 137–154.

Velasco-Vázquez, J., Alberto-Barroso, V., Delgado-Darias, T., Moreno-Benítez, M., Lécuyer, C., Richardin, P., (2019). Poblamiento, colonización y primera historia de Canarias. El C14 como paradigma. *Anu. Estud. Atlánticos* 66, 1–24.

Velasco-Vázquez, J., Arnay-de-la-Rosa, M., González Reimers, E., Hernández Torres, O., (1997). Paleodietary analysis of the prehistoric population of El Hierro (Canary Islands). Biol. *Trace Elem. Res*. 60, 235–241.

Vidal-Matutano, P., Alberto-Barroso, V., Marrero, E., García, J.C., Pou, S., Arnay-de-la-Rosa, M., (2019). Vitrified wood charcoal and burnt bones from the pre-Hispanic site of Chasogo (Tenerife, Canary Islands, Spain). *J. Archaeol. Sci. Rep*. 28, 102005.

Walter, B.S., DeWitte, S.N., Dupras, T.L., Beaumont, J., (2020). Asessment of nutritional stress in famine burials using stable isotope analysis. *Am. J. Phys. Anthropol*. 1–13.

Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., Cohen, M.N., Eisenberg, L.E., Hutchinson, D.L., Jankauskas, R., Cesnys, G., Gintautas Česnys, Katzenberg, M.A., Lukacs, J.R., McGrath, J.W., Roth, E.A., Ubelaker, D.H., Wilkinson, R.G., (1992). The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples [and Comments and Reply*]. Curr. Anthropol*. 33, 343–370.

Data availability statement: The authors confirm that the data supporting the findings of this study its original and first featured in this study unless stated otherwise, in which case the original source is cited. All original data of this study are available within the article and its supplementary materials.

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Figures:

Figure 1: Map of the Canary Islands and Its geographical location.

Figure 2: Map of the archaeological sampled sites from Tenerife and Gran Canaria.

Figure 3: Incremental Dentine profiles from samples TENC-01, TENC-02, TENC-03 and TENC-04. Blue dots represent δ^{15}N dentine values corresponding to age increments, red dots represent δ^{13}C dentine values corresponding to age increments. Blue and red lines correspond to δ^{15}N and δ^{13}C bulk collagen values.

Figure 4: Incremental Dentine profiles from samples TENC-05, TENC-06, GRAN-01 and GRAN-02. Blue dots represent δ^{15}N dentine values corresponding to age increments, red dots represent δ^{13}C dentine values corresponding to age increments. Blue and red lines correspond to δ^{15}N and δ^{13}C bulk collagen values.

Figure 5: plotted δ^{13}C values of each sample corresponding with age increments. The horizontal line represents an estimated boundary between marine (above) and terrestrial foods (below).

Figure 6: plotted δ^{15}N values of each sample corresponding with age increments.

Figure 7: Scatterplot showing trophic positions of each individual based on mean and standard deviation of their incremental dentine values (minus breastfeeding) compared with boxes representing mean and standard deviations of each food source from the Canary Islands.

Figure 8: FRUITS estimations of Marine Contribution on diets from incremental dentine means (minus breastfeeding period). Orange: less than 20% marine contribution. Blue: more than 20% marine contribution. Upper row: model without Priors. Lower row: Prior = Hervibore contribution > Marine Contribution.

Tables:

Table 1: Descriptive data from this study with radiocarbon dates from recent archaeological works.

Table 2: Mean isotope δ^{15}N and δ^{13}C dentine values (minus breastfeeding) with mean food source isotope values from the Canary Islands obtained from recent archaeological works.

Table 3: Student-t test between isotope values from this sample, mixed-diet are individuals with incremental dentine profiles that have been deemed as having a certain amount of marine foods in their diet, while “terrestrial” represents incremental dentine profiles of individuals deemed as not having marine foods in their diet.

Supplementary Tables:

Supplementary Table 1: Collected data from this study, δ^{15}N and δ^{13}C values per increment are shown, as well as quality criteria and archaeological sites.

Supplementary Table 2: Baseline of isotopic data from potentially consumed foods from the prehispanic period of the Canary Islands. Data includes Suess effect corrections and conversion from muscle/body tissue to bone collagen following established procedures.

Supplementary Table 3: FRUITS results on average contributions from each food group towards each sample individual (mean, std and confidence intervals). Incremental dentine collagen mean values as well as bulk bone collagen values have been modelled.

Information without Priors and with Prior = Herbivore/Omnivore > Marine Contribution.