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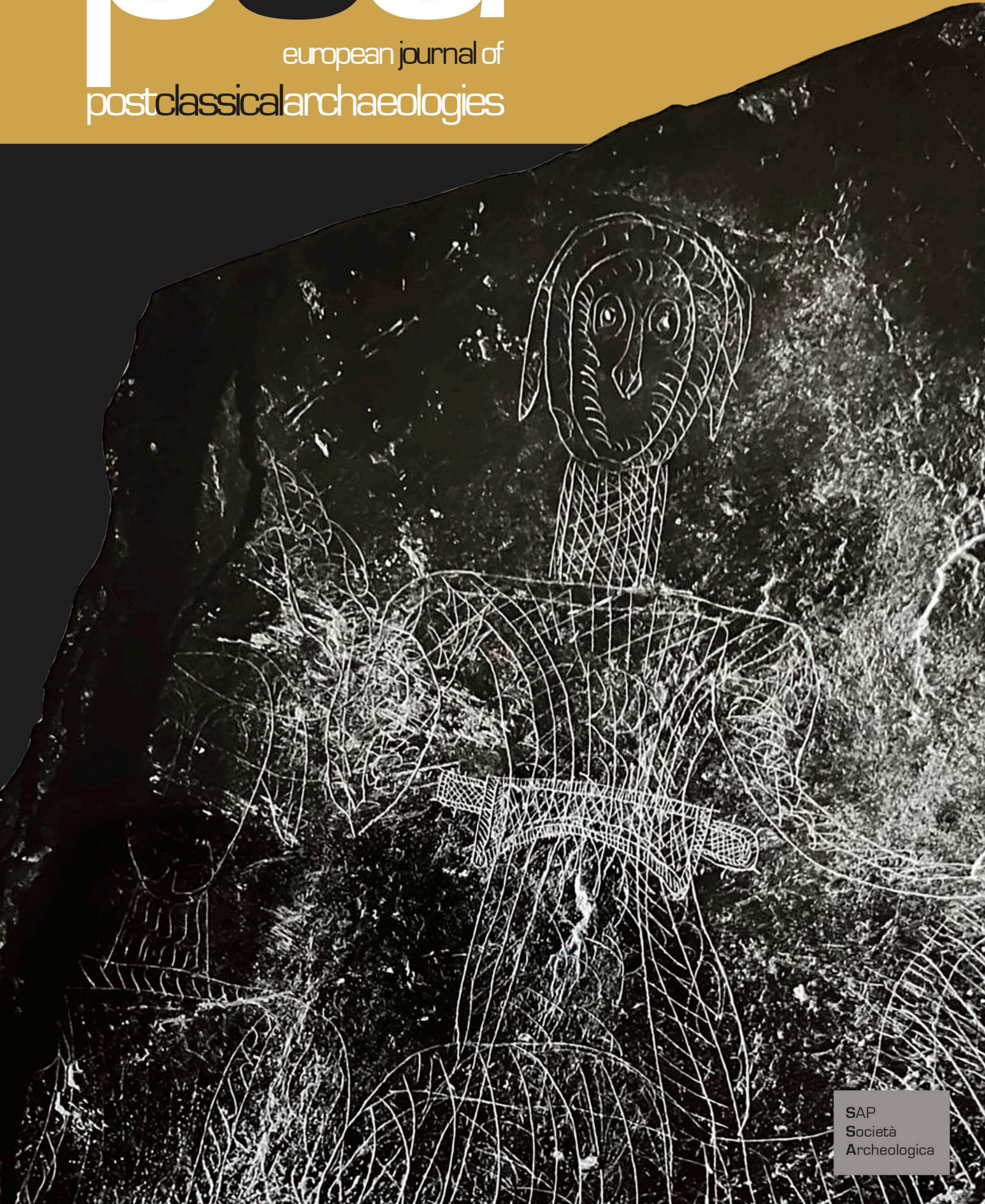

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Ilenia Gentile[1], Dulce Neves[1,2], Viola Cecconi[1,3],
Arianna Giordano[1], Elena Fiorin[1], Emanuela Cristiani[1*]

Diet and health in Roman and Late Antique Italy: integrating isotopic and dental calculus evidence

1. Introduction

In the Roman world, diet was not merely a physiological necessity or a matter of subsistence but also a fundamental lens for understanding the social, cultural, and identity-related dimensions of human life.

A diverse corpus of literary, iconographic, material, and bioarchaeological sources provide valuable insights into ancient foodways, though critical reflection is needed to evaluate the nature of this evidence and the segments of the population it represents (Garnsey 1999; Wilkins, Hill 2006; Montanari 1993; King 1999; Killgrove, Tykot 2013).

In recent years, Roman archaeology has increasingly adopted a critical perspective, aligning itself with the broader field of people-centred archaeology (see, for example, Acconcia 2021; Pitts *et al.* 2015). This approach seeks to reconstruct everyday practices and material conditions, shifting the focus from institutional history to everyday experience. In this context, methods such as material culture studies, particularly object biographies, consumption studies, and the archaeology of identity (Miller 1987; Gosden *et al.* 1999; Pitts 2007), alongside bioarchaeology, household archaeology, and biological sex and childhood studies, have been employed to provide a voice for groups who are often overlooked in written records, such as slaves, women, children, workers, and migrants who are frequently excluded from elite narratives (Laurence 2011; Revell 2009; Hope 2007).

[1] DANTE-Diet and Ancient Technology Laboratory, Department of Odontostomatological and Maxillo-Facial Sciences, Sapienza University of Rome, Rome, Italy.

[2] University of Coimbra, CIAS – Research Centre for Anthropology and Health, Department of Life Sciences, Coimbra, Portugal.

[3] Freelance Anthropologist, Bioarchaeology Service, Museum of Civilisations – Museo delle Civiltà, Rome, Italy.

* Corresponding author: emanuela.cristiani@uniroma1.it.

Alongside these important advances, a key line of research has focused on the bioarchaeological reconstructions of diet, although this field continues to face significant challenges. Some of these challenges are intrinsic to the subject itself: the Roman Empire encompassed a vast array of ecological settings, food traditions, natural resources, and cultural practices. Rather than a single "Roman diet", a multiplicity of local dietary regimes existed, which must be examined through rigorous methodology and careful historical and regional contextualisation.

This review is based on published isotopic and dental calculus data from archaeological sites across the Italian peninsula. The sites were selected because they provide published human bone collagen $\delta^{13}C$ and $\delta^{15}N$ data and/or published dental calculus analyses. They also report sufficient contextual information to allow cross-site comparison, such as the site's location (urban or rural) and whether it is coastal or inland. The rationale for the selection, the search strategy, and the inclusion and exclusion selection criteria are detailed in the 'Materials and methods' section below.

In this regard, stable isotope analysis and dental calculus analyses have constituted a genuine methodological breakthrough in the reconstruction of ancient diets. The analysis of stable isotopes, particularly the combined use of $\delta^{13}C$ and $\delta^{15}N$ values, provides direct evidence of dietary composition. This enables the distinction between marine and terrestrial protein sources, detects the contribution of C_3 and C_4 plants, and highlight dietary patterns linked to socioeconomic status, biological sex and geographical origin (Prowse *et al.* 2004; Müldner *et al.* 2005). These data have proven particularly useful in shedding light on the dynamics of social inequality and mobility within Roman populations.

In turn, the analysis of dental calculus has made food categories and practices that were otherwise invisible in the isotopic record accessible. Microremains, including starch granules, phytoliths, plant fibres, proteins and secondary metabolites, have documented the consumption of cereals, fruit, domestic plants, dairy products and spices. They have also provided evidence of technological practices such as grinding, cooking and fermentation (Radini *et al.* 2019; Hardy *et al.* 2009; Henry *et al.* 2011).

Archaeozoological assemblages (e.g. mammal bones, fish remains) and archaeobotanical finds (e.g. charred cereals, fruit pits) provide an independent and essential line of evidence for reconstructing dietary practices, shedding light on agricultural regimes, animal husbandry, fishing strategies, and food processing (King 1999; Albarella 2007; O'Connor 2013). This review does not systematically address these categories of evidence, as such data are not consistently available for all the sites considered. The main objective is instead to evaluate the potential of dental calculus studies, integrating stable isotope and microremain analyses, and to assess their respective strengths, limitations, and possible inconsistencies when applied to the same biological matrix.

However, to date, both isotopic and dental calculus analyses have generally been applied at a local or regional scale, often in isolation and without full integration into broader comparative frameworks. This work therefore aims to assess the methodological potential of dental calculus studies and to situate them within the wider field of archaeological studies of past populations. The aim is to facilitate more systematic and interregional reconstructions of diets and daily practices in the Roman world (Killgrove 2013; Redfern 2017).

This article aims to reassess the available bioarchaeological data within a people-centred archaeological framework. By critically examining diet through an interdisciplinary lens, it seeks to move beyond monolithic reconstructions and towards a more nuanced and pluralistic understanding of food practices in the Roman world. Here, diet is not only a subject of inquiry but a privileged entry point into the archaeology of individuals in all their social, cultural, and historical complexity.

2. Reconstructing diet in antiquity: historical sources, recipes and culinary practices

Reconstructing dietary habits in the Roman world requires the integration of multiple strands of evidence. In what follows, we will consider written sources and medical conceptions, bioarchaeological and isotopic data, skeletal evidence for health and disease, domestic remedies, diachronic changes in diet, and the iconographic and material record. Medical and natural history sources, such as Pliny the Elder (*Naturalis Historia* 19.23, 20.56), reflect a long-standing belief in the therapeutic properties of food. Diet was not only aimed at nourishment but also structured within a framework where taste and qualities were considered indicative of pharmacological efficacy. Medical treatises often list foods avoided in daily consumption but prescribed for therapy. Galen provided detailed dietetic classifications (*De alimentorum facultatibus* 1.5; *De victu attenuante* 2.3), while Dioscorides described culinary and medicinal uses of plants and animal products (*De Materia Medica* 2.25; 3.12), including smoking of cheese with applewood or straw to improve preservation and aroma (Kokoszko *et al.* 2018). Archaeological evidence, including plant microremains recovered from dental calculus, has confirmed many of these descriptions (MacKenzie *et al.* 2023). Specific foodstuffs also illustrate the medicinal and symbolic dimensions of Roman diets. Pine nuts (*Pinus pinea* L.), for instance, are documented in Hellenistic and Roman contexts, supported by archaeobotanical evidence from ritual and funerary sites (Popova, Hristova in press). Textual and bioarchaeological integration highlights the dietary and therapeutic use of plants such as nettle, saffron and barley, some directly attested in dental calculus (Gismondi *et al.* 2018).

These practices were embedded in humoral theory, developed by Hippocrates and systematised by Galen, in which health depended on a balance among four bodily fluids, blood, phlegm, yellow bile, and black bile, each associated with elemental qualities (hot, cold, moist, dry), and illness was treated primarily by means of diet (Miller 1962; Temkin 1953). Bioarchaeological evidence complements these textual insights. Dental pathologies such as caries, abscesses, periodontal disease, and enamel hypoplasia reflect carbohydrate-rich diets and poor oral hygiene (Killgrove *et al.* 2013). Metabolic disorders including rickets (vitamin D deficiency) and scurvy (vitamin C deficiency) are attested such as long bone deformities, porotic hyperostosis, and *cribra orbitalia*, especially among juveniles (Minozzi *et al.* 2013; Geber *et al.* 2021).

Stable isotope studies ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) combined with dental calculus analysis additionally reveal regional dietary variability and nutritional stress (Craig *et al.* 2009; Prowse *et al.* 2014). Roman diets evolved over time, changing from mainly plant-based staples in the early period (Garnsey 1999; Dalby 2003) to more varied late Imperial diets influenced by Christianity and economic changes (Purcell 1985; Giacchero 1974; Heather 2005). However, the focus of this study is the direct evidence from dental calculus, which provides unique insights into both ordinary and therapeutic food practices.

Beyond textual sources, iconographic evidence, such as Pompeian frescoes and mosaics (fig. 1), provides valuable depictions of food practices

Fig. 1. Iconographic evidence of food practices: a) *Insula* 10, *Regio* IX in Pompeii (credits to Parco Archeologico di Pompei); b) Ancient *garum* amphora from Pompeii, depiction of a *urceus* (fish-sauce vase), probably linked to the activity of Aulus Umbricius Scaurus, a well-known Pompeian producer (G(ari) F(los) SCOM(bri) SCAURI EX OFFI(ci)NA SCAURI).

(Clarke 1991; Dunbabin 2003). These images juxtapose elite banquets with exotic foods and refined tableware against more modest meals of bread, legumes, and preserved fish, offering insight into the social meanings of food. Another striking example is *garum*, the fermented fish sauce that epitomised Roman culinary identity. It was ubiquitous across social classes, produced in varying qualities, and valued both as a seasoning and for its therapeutic properties (Curtis 1991; Grainger 2014). Amphorae, production facilities, and inscriptions, such as those of the Pompeian producer Aulus Umbricius Scaurus, highlight its economic significance and symbolic role (CIL IV, 1718). Although rarely depicted directly, its presence is inferred from scenes of fish processing and trade, linking iconography and archaeology. Iconographic and archaeological evidence thus reinforces the idea that food functioned not only as nourishment but also as medicine, social marker, economic commodity, and cultural symbol (fig. 1).

3. Materials and methods

3.1. Search strategy and selection criteria

A systematic search was conducted for published studies reporting stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values from the analysis of human bone collagen and/or dental calculus in Italy from approximately the 1st to 6th centuries CE (fig. 2). A purpose-built database was created to compile dispersed published data, to allow for the reassessment of isotopic raw data (Neves *et al.* 2025). The search was conducted in both English and Italian, and contextual information was recorded, including geographical and cultural attribution, sample identification, and the age and biological sex of skeletal remains, whenever available. The following criteria were met by the included studies: original $\delta^{13}C$ and $\delta^{15}N$ values for human bone collagen were reported; or results related to dental calculus were published; a clear archaeological context was provided (site name, chronology and contextual attribution: urban/rural; coastal/inland); sample sizes were reported, and, where available, demographic information (age range, sex) was included. Studies were excluded if they lacked provenance or chronology, did not report clear isotopic values, or did not describe methods in sufficient detail. As noted in other isotopic reviews of different regions and periods, a systematic assessment of analytical procedures and collagen quality indicators was not possible due to variability in how results were presented and to the lack of consistent of standardised reporting criteria.

Liguria	Necropoli Del Sottopasso (*Albintimilium*)
Lombardia	Covo, Loc. Bellinzana (Bergamo)
Veneto	San Donato *necropolis* (Belluno)
Emilia-Romagna	TAV *necropolis* (Bologna); Via Macchioni (Spilamberto)
Marche	Civitanova Marche (Macerata)
Tuscany	Cosa (Grosseto); Via Marche *necropolis* (Pisa)
Latium	Rome: Amba Aradam; ANAS *necropolis*; Boccone del Povero; Casal Bertone; Casale del Dolce; Castel Malnome; Castellaccio Europarco; Catacombs of San Callixtus; Gabii; Isola Sacra; *Lucus Feroniae*; Marcellino e Pietro; Muracciola di Torresina; Osteria della Fontana; Palestrina; Piazzale Ostiense; *Portus;* Quarto Cappello del Prete; Via Padre Semeria
Campania	Naples: Herculaneum and *Pompeii;* Salerno: *Paestum* – Porta Sirena; Velia – Porta Marina
Puglia	Vagnari (Gravina)
Sicily	Catacombs of St. Lucia (Syracuse)

Fig. 2. Map of the analysed sites.

3.2. Statistical analyses

Although the full dataset comprises $\delta^{13}C$ and $\delta^{15}N$ values from non-adult individuals to support future investigations, the review focused exclusively on adult data (N=1152). Limiting the dataset to adults allows for a more accurate reconstruction of long-term diet and minimizes confounding life-history effects, ensuring greater interpretive and comparative consistency. Stable isotope ratios in bone collagen (especially $\delta^{13}C$ and $\delta^{15}N$) reflect the average diet over a long period, typically 5-10 years before death depending on bone turnover rates. In adults, this dietary signal is relatively stable, representing habitual food intake. In contrast, children undergo significant physiological changes (e.g. weaning, growth, and metabolic shifts) that strongly influence isotopic values, mainly nitrogen. Thus, including non-adults can introduce heterogeneity that complicates comparisons across sites or populations (De Angelis *et al.* 2020b). In addition to the data available for human remains (N=1152), published $\delta^{13}C$ and $\delta^{15}N$ values from plant (n=95) and faunal remains (n=259) from archaeological sites in Italy (1st to 8th centuries CE) were also included to establish a baseline (N=354). Fauna $\delta^{13}C$ and $\delta^{15}N$ values were divided into main groups: marine (fish), birds (Class *Aves*), and herbivorous, omnivorous, and carnivorous terrestrial mammals. The isotopic signature of *garum* was also included, given its role in Roman cuisine (Sally 2020).

To analyse the effects of categorical variables and their interactions on stable isotope values ($\delta^{13}C$ and $\delta^{15}N$), data normality was first assessed using the Lilliefors-corrected Kolmogorov–Smirnov test (KS, for populations with more than 50 individuals). Given that the isotopic data were not normally distributed, non-parametric methods were employed, including the Mann-Whitney U test (Wilcoxon rank-sum test) for pairwise comparison. We also applied the Aligned Rank Transform (ART) procedure to perform factorial ANOVA with interaction terms on non-parametric data. ART ANOVA was conducted using the ARTool package in R (version 2025.05.0+496). Type III sums of squares were used to test the main effects and interaction effects of factors such as geographical location (inland vs. coastal), social context (urban vs. rural), and chronological phase (Roman vs. Late Antiquity). Significance was set at $p \leq 0.05$. In addition, data from dental calculus research in Italian Roman/Late Antiquity contexts were compiled to complement the isotopic evidence and provide an additional layer of information regarding the dietary and health aspects of Roman communities. The general sites included and discussed in the present review can be found in tables 1 and 2.

Region	Site	Chronology	Context		*n*	References
Liguria	Necropoli Del Sottopasso (*Albintimilium*)	3rd-5th cent. CE	Coastal	Urban	15	Defant *et al.* 2025
Lombardia	Covo, Loc Bellinzana (Bergamo)	4th-6th cent. CE	Inland	Rural	16	Marinato 2016
Veneto	**San Donato *necropolis* (BL)***	1st-4th cent. CE	Inland	Rural	11 (9)	Fiorin *et al.* 2023
Emilia-Romagna	TAV *necropolis* (Bologna)	1st-4th cent. CE	Inland	Urban	10	Milella *et al.* 2019
	Via Macchioni (Spilamberto)	4th-6th cent. CE	Inland	Rural	11	Marinato 2016
Marche	Civitanova Marche (Macerata)	3rd-4th cent. CE	Coastal	Urban	29	Nitsch, 2012
Tuscany	Cosa (Grosseto)	6th cent. CE	Coastal	Urban	2	Scorrano *et al.* 2014
	Via Marche *necropolis* (Pisa)	3rd-5th cent. CE	Coastal	Urban	32	Riccomi *et al.* 2020
Latium	Amba Aradam (Rome)	5th cent. CE	Inland	Urban	4	Varano *et al.* 2020
	ANAS *necropolis* (Rome)	1st-3rd cent. CE	Coastal	Urban	14	Prowse, Macchiarelli 2004
	Boccone del Povero (Rome)*	1st-2nd cent. CE	Inland	Rural	36 (9)	D'Agostino *et al.* 2023
	Casal Bertone (Rome)	1st-3rd cent. CE	Inland	Urban	58	De Angelis *et al.* 2020; Killgrove, Tykot 2013
	Casale del Dolce (Rome)	1st-4th cent. CE	Inland	Rural	59	Nitsch 2020
	Castel Malnome (Rome)	1st-2nd cent. CE	Coastal	Rural	66	De Angelis *et al.* 2020a
	Castellaccio Europarco (Rome)	1st-3rd cent. CE	Inland	Rural	6	Killgrove, Tykot 2013
	Catacombs of St Callixtus (Rome)	3rd-5th cent. CE	Coastal	Urban	16	Rutgers *et al.* 2009
	Gabii (Rome)	1st-3rd cent. CE	Inland	Urban	23	Acosta *et al.* 2019; Killgrove, Tykot 2018
	Isola Sacra (Rome)	1st-3rd cent. CE	Coastal	Urban	189	Bondioli *et al.* 2016; Crowe *et al.* 2010; Prowse, Macchiarelli 2004
	Lucus Feroniae (Rome)	1st-3rd cent. CE	Inland	Rural	30	Tafuri *et al.* 2018
	Marcellino e Pietro (Rome)	1st-5th cent. CE	Coastal	Urban	17	Nitsch 2012; Salesse 2014
	Muracciola di Torresina (Rome)*	1st-3rd cent. CE	Inland	Rural	32 (6)	Baldoni *et al.* 2020
	Osteria della Fontana (Rome)	1st cent. CE	Inland	Urban	14	Nitsch 2012
	Palestrina (Rome)	3rd-4th cent. CE	Inland	Urban	9	Nitsch 2020
	Piazzale Ostiense (Rome)	4th-5th cent. CE	Inland	Urban	7	Varano *et al.* 2020
	Portus (Rome)	2nd-8th cent. CE	Coastal	Urban	61	De Angelis *et al.* 2025; O'Connell *et al.* 2019
	Quarto Cappello del Prete (Rome)	1st-3rd cent. CE	Inland	Urban	22	De Angelis *et al.* 2020a, 2020b
	Via Padre Semeria (Rome)	1st-3rd cent. CE	Inland	Urban	23	De Angelis *et al.* 2020a
Campania	Herculaneum (Naples)	79 CE	Coastal	Urban	67	Craig *et al.* 2013; Martyn *et al.* 2018
	Paestum – Porta Sirena (Salerno)	2nd-4th cent. CE	Coastal	Urban	18	Ricci *et al.* 2016
	Pompeii (Naples)	79 CE	Coastal	Urban	49	Nitsch 2012; Pate *et al.* 2016
	Porta Marina (Velia)	1st-2nd cent. CE	Coastal	Urban	117	Bondioli *et al.* 2016; Craig *et al.* 2019
Puglia	Vagnari (Gravina)	1st-4th cent. CE	Inland	Rural	54	Semchuc 2016
Sicily	Catacombs of St Lucia (Syracuse)	5th-8th cent. CE	Coastal	Urban	35	Tanasi *et al.* 2023

Table 1. Summary table of the sites reviewed in the article and included in the isotopic database. n: number of individuals included in the isotopic studies. The number in brackets is the number of individuals included in the dental calculus studies. *Sites with dental calculus analysis.

Region	Site	Chronology	*n*	References
Liguria	Necropoli Del Sottopasso, *Albintimilium*	3rd-5th cent. CE	16	Defant *et al.* 2025
Lombardia	Covo, Bergamo	4th-5th cent. CE	2	Marinato 2016
Veneto	Belluno	1st-4th cent. CE	2	Fiorin *et al.* 2023
Emilia-Romagna	Spilamberto, loc. Macchioni, Modena	4th-5th cent. CE	9	Marinato 2016
Tuscany	Via Marche, Pisa	3rd-5th cent. CE	7	Riccomi *et al.* 2020
Latium	Castel Malnome, Rome	1st-3rd cent. CE	6	De Angelis *et al.* 2020a
	Colosseum area, Rome	1st-3rd cent. CE	9	De Angelis *et al.* 2020a
	Gabii, Rome	1st-3rd cent. CE	6	Acosta *et al.* 2019
	Isola Sacra, Rome	1st-3rd cent. CE	8	Prowse *et al.* 2005
	Lucus Feroniae, Rome	1st-3rd cent. CE	2	Tafuri *et al.* 2018
	Portus, Rome	2nd-6th cent. CE	146	Pate *et al.* 2016
	Selvicciola, Rome	6th-7th cent. CE	3	Tafuri *et al.* 2018
	Via Padre Semeria, Rome	1st-3rd cent. CE	2	De Angelis *et al.* 2020a
Campania	Porta Sirena, Paestum, Salerno	2nd-4th cent. CE	2	Ricci *et al.* 2016
	Pompeii, Naples	79 CE	12	Pate *et al.* 2016
	Velia, Salerno	1st-2nd cent. CE	27	Craig *et al.* 2009
Puglia	Vagnari, Gravina	1st-4th cent. CE	43	Semchuc 2016; Trentacoste *et al.* 2023
	San Felice	1st-3rd cent. CE	54	Trentacoste *et al.*, 2023

Table 2. Summary table of the sites with published isotopic data for fauna and plants, which are included in the isotopic database. n: number of samples included in the isotopic studies.

4. Results

Isotopic data were compiled on 1152 adults and a baseline of 354 plant and faunal samples (see table 3 and fig. 3). Statistical comparisons revealed significant differences in both $\delta^{13}C$ and $\delta^{15}N$ between urban and rural, as well as coastal and inland contexts (Wilcoxon rank-sum tests; $p < 0.001$). In contrast, diachronic differences between the Roman and Late Antiquity periods were less pronounced (see tables 4-7). These results support the interpretation of spatially structured access to animal and marine proteins in Roman Italy.

Regarding the human collagen isotopic values, the Lilliefors-corrected Kolmogorov–Smirnov test showed that $\delta^{13}C$ ($D = 0.11$; $p<0.001$) and $\delta^{15}N$ data ($D = 0.06$; $p<0.001$) were not normally distributed. Therefore, subsequent statistical analyses were performed using non-parametric tests.

Differences were found in both carbon and nitrogen mean values across Italian regions and archaeological sites (table 4). The results showed less variability in carbon than nitrogen values, as evidenced by the standard deviation (SD) val-

Site		δ13C (‰)	δ15N (‰)
Plant		**-23.1 ± 1.7**	**6.0 ± 3.4**
	Triticeae	-22.9 ± 1.5	6.4 ± 3.4
	Poaceae	-28.6	2.8
	Fabaceae	-26.5 ± 1.6	3.5 ± 3.2
	Vitaceae (*Vitis* sp.)	-28.4	8.1
Herbivorous		**-20.8 ± 2.0**	**5.2 ± 2.3**
	Ovis/Capra	-20.6 ± 2.1	5.6 ± 2.3
	Cervidae	-21.0 ± 2.1	4.7 ± 2.3
	Bos	-20.8 ± 2.1	5.2 ± 2.3
	Lepus	-21.7 ± 3.6	2.9 ± 2.6
Omnivorous	*Sus* spp.	**-20.6 ± 2.1**	**5.5 ± 2.3**
Carnivorous		**-19.2 ± 2.1**	**8.8 ± 2.3**
	Canis	-19.2 ± 2.1	8.7 ± 2.3
	Vulpes	-19.1	9.3
Aves		**-19.9 ± 1.5**	**8.6 ± 2.2**
Marine (fish)		**-13.1 ± 2.7**	**10.1 ± 2.7**
Garum*		**-14.5 ± 3.9**	**5.7 ± 2.4**
Human		**-19.1 ± 0.8**	**9.9 ± 1.6**

Table 3. Mean values for $\delta^{13}C$ and $\delta^{15}N$ for plant and animal samples.
*Garum is composed of both fish and plant-based ingredients, thus, it was not considered in the marine group.

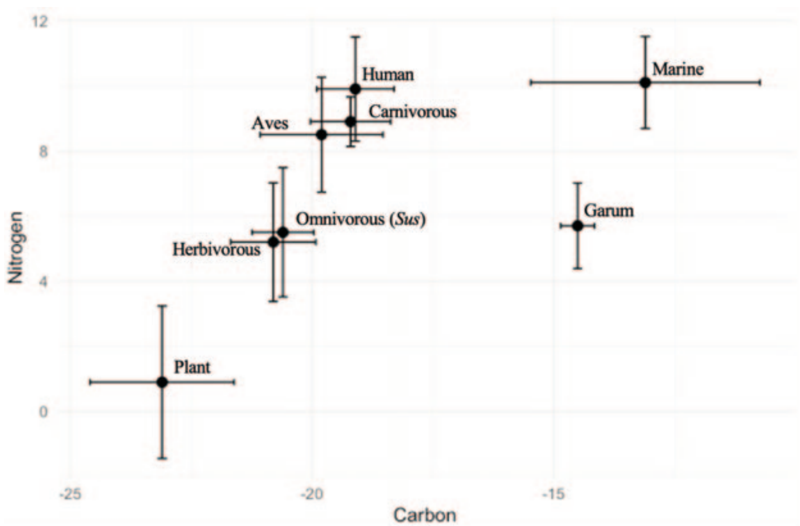

Fig. 3. Mean $\delta^{13}C$ and $\delta^{15}N$ values (‰) with standard for plant and animal samples.

Site		$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Campania		**-19.3 ± 0.5**	**9.3 ± 1.3**
	Pompeii	-18.9 ± 0.8	10.0 ± 0.8
	Herculaneum	-19.2 ± 0.4	10.2 ± 0.8
	Porta Sirena, Paestum	-19.5 ± 0.7	8.1 ± 0.9
	Velia, Porta Marina	-19.4 ± 0.3	8.6 ± 1.3
Emilia-Romagna		**-19.5 ± 0.8**	**8.7 ± 1.1**
	Necropolis TAV	-20.2 ± 0.3	9.3 ± 1.2
	Spilamberto	-18.9 ± 0.5	8.1 ± 0.6
Latium		**-19.1 ± 0.8**	**10.3 ± 1.6**
	Amba Aradam	-20.1 ± 0.8	8.2 ± 0.8
	ANAS Necropolis	-19.4 ± 0.4	9.5 ± 1.8
	Boccone del Povero	-19.1 ± 0.5	10.7 ± 1.3
	Casal Bertone	-18.6 ± 0.7	10.7 ± 1.3
	Casale del Dolce	-20.0 ± 0.5	8.0 ± 1.7
	Castel Malnome	-19.2 ± 0.8	10.8 ± 1.2
	Castellaccio Europarco	-18.6 ± 0.6	9.1 ± 1.4
	Catacomb of St. Callixtus	-19.7 ± 0.5	10.6 ± 0.8
	Gabii	-19.0 ± 0.8	10.6 ± 0.8
	Isola Sacra	-18.7 ± 0.4	11.0 ± 1.1
	Lucus Feroniae	-19.7 ± 0.5	10.0 ± 1.3
	Marcellino e Pietro	-18.9 ± 0.6	10.6 ± 1.9
	Muracciola Torresina	-20.0 ± 0.6	9.0 ± 1.4
	Osteria della Fontana	-19.7 ± 0.3	7.7 ± 1.5
	Palestrina	-19.7 ± 0.5	9.5 ± 1.2
	Piazzale Ostiense	-19.5 ± 0.5	9.3 ± 1.0
	Portus	-19.0 ± 0.5	10.7 ± 1.6
	Quarto Cappello del Prete	-19.3 ± 0.5	9.6 ± 1.7
	Via Padre Semeria	-19.1 ± 0.4	11.4 ± 0.9
Liguria	Necropoli Del Sottopasso	**-18.5 ± 0.9**	**8.9 ± 1.2**
Marche	Civitanova Marche	-19.6 ± 0.6	9.5 ± 1.3
Lombardia	Covo (Bellinzana)	**-16.9 ± 1.4**	**8.5 ± 0.8**
Puglia	Vagnari	**-19.2 ± 0.6**	**9.2 ± 1.3**
Sicily	Catacombs of St. Lucia	**-18.7 ± 0.6**	**10.1 ± 1.5**
Tuscany		**-19.5 ± 0.7**	**9.6 ± 1.0**
	Cosa	-17.8 ± 0.5	10.2 ± 1.2
	Via Marche	-19.6 ± 0.5	9.6 ± 1.1
Veneto	San Donato	**-15.9 ± 0.6**	**8.1 ± 0.5**

Table 4. $\delta^{13}C$ and $\delta^{15}N$ mean values by site and region.

		$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Context			
	Coastal	-19.1 ± 0.8	10.1 ± 1.6
	Inland	-19.2 ± 0.8	9.5 ± 1.6
	Urban	-19.1 ± 0.8	10.1 ± 1.6
	Rural	-19.2 ± 0.8	9.3 ± 1.6
Period			
	Roman	-19.1± 0.7	9.9 ± 1.6
	Late Antiquity	-18.7± 0.6	9.6 ± 1.5

Table 5. $\delta^{13}C$ and $\delta^{15}N$ mean values by type of context and period.

ues. Except for Liguria, Lombardy, Veneto, and Sicily, all the other regions showed carbon values below -19.0‰. However, within regions, sites exhibited considerable heterogeneity in the results: the Latium region (the region with the highest number of archaeological sites analysed for stable isotopes and including Rome) showed the mean nitrogen values but also a wider range of values, as evidenced by the highest standard deviation, thus revealing a greater variability of this isotope.

By comparing the isotopic mean values between rural and urban areas, as well as inland and coastal regions, differences were observed in the nitrogen values. On the other hand, considering the values between periods, distinct carbon and nitrogen signatures are observed (table 5). Nonetheless, the Wilcoxon rank-sum test revealed statistically significant differences only between urban and rural and coastal and inland, for both $\delta^{13}C$ and $\delta^{15}N$ (table 6).

However, more pronounced differences emerged when comparing rural versus urban ($\delta^{13}C$: Df=1; F= 59.67; p<0.00; $\delta^{15}N$: Df=1; F= 9.39; p=0.0022312) and coastal versus inland populations ($\delta^{13}C$: Df=1; F=11.93; p=0.00057; $\delta^{15}N$: Df=1; F=11.88; p=0.00058715) during the transition from Roman period to Late Antiquity (tables 7 and 8). The ART ANOVA showed highly statistically significant interactions between rural/urban and coastal/inland when compared within

	$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)	
	W	*p*	W	*p*
Rural vs. Urban	103976	<0.00	100650	<0.00
Coastal vs. Inland	183491	<0.00	188251	<0.00
Roman vs. Late Antiquity	116252	0.24	105932	0.29

Table 6. Results of the Wilcoxon rank-sum test.

Period	δ13C (‰)		δ15N (‰)	
	Urban	Rural	Urban	Rural
Roman	-19.0 ± 0.7	-19.3 ± 0.7	10.2 ± 1.6	9.4 ± 1.6
Late Antiquity	-19.4 ± 0.8	-17.7 ± 0.9	9.7 ± 1.6	8.3 ± 1.3

Table 7. $\delta^{13}C$ and $\delta^{15}N$ mean values between urban and rural contexts, by period.

Period	δ13C (‰)		δ15N (‰)	
	Coastal	Inland	Coastal	Inland
Roman	-19.1 ± 0.7	-19.3 ± 0.7	10.2 ± 1.6	9.6 ± 1.6
Late Antiquity	-19.3 ± 0.8	-18.6 ± 0.9	9.8 ± 1.6	8.7 ± 1.4

Table 8. $\delta^{13}C$ and $\delta^{15}N$ mean values between coastal and inland contexts, by period.

the Roman and Late Antiquity periods. While carbon isotope values in the Roman period appeared relatively consistent across different contexts, this uniformity diminishes in the Late Antiquity, with rural and inland communities exhibiting higher average $\delta^{13}C$ values. Additionally, these groups showed lower mean $\delta^{15}N$ values, suggesting reduced access to animal or marine-derived protein sources.

Regarding dental calculus analysis, only three sites had published data. While all three sites underwent optical microscopic analysis, focusing on plant remains, such as starches, pollen grains, or phytoliths (table 9), the works of Baldoni *et al.* (2020) and D'Agostino *et al.* (2023) also employed gas chromatography mass spectrometry. This analysis allowed the identification of other dental calculus residues, including fatty acids (plant oils or animal fats), lactose (milk and other animal products), and amygdalin (present in the Rosaceae family) (D'Agostino *et al.* 2023). The work published by Baldoni *et al.* (2020) revealed residues assigned to the Brassicaceae family and *Ephedra* species.

5. Discussion

The synthesis of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes and dental calculus data from Roman and Late Antiquity populations in Italy provides important insights not only into the dietary patterns of ancient communities but also into broader aspects of health, social organization, and regional adaptation. Although these indicators typically reflect dietary intake, when considered in con-

Site		San Donato necropolis (Belluno)	Boccone del Povero (Rome)	Muracciola di Torresina (Rome)
Starch	Fabaceae	114	-	1
	Poaceae (sub.fam. *Panicoideae*)	45	6	16
	Poaceae (*Triticeae* tribe)	Present	70	18
	Poaceae (sub.fam. *Pooideae*)	-	-	39
	Fagaceae	2	-	
	Damaged starch	-	Present	2
Phytolith		>20 Poaceae	-	4 Poaceae
Plant tissue		124	-	-
Wood fragment		Cupressaceae	-	-
Pollen		-	Pinaceae, Cupressaceae, Poaceae (sub. fam. *Chloridoideae*)	
Fungi		*Glomeromycota*	-	-
Charcoal		101	-	-
Reference		Fiorin *et al.* 2023	D'Agostino *et al.* 2023	Baldoni *et al.* 2020

Table 9. Summary of the dental calculus residues currently published.

junction with contextual archaeological and historical evidence, they enable cautious yet meaningful inferences about nutrition and health, socioeconomic disparities, and differential access to food.

The data show a consistent pattern: the mean $\delta^{15}N$ values are higher at urban and coastal sites than at rural and inland sites. This is consistent with greater access to animal and marine proteins in urban and coastal settings (see tables 4-6). At Casal Bertone (urban, $\delta^{13}C$ –18.6‰; $\delta^{15}N$ 10.7‰) and Isola Sacra (urban, –18.7‰; 11.0‰), nitrogen values are significantly higher than in rural contexts such as Casale del Dolce (–20.0‰; 8.0‰) or Castel Malnome (–19.2‰; 10.8‰), indicating more regular access to animal and marine proteins (Killgrove, Tykot 2013; De Angelis *et al.* 2020a). Wilcoxon tests and ANOVA ART reveal significant interactions between urban/rural and coastal/inland variables ($p < 0.001$), suggesting that access to protein was jointly structured by geography and settlement type between the Roman and Late Antique periods. Although isotopic averages suggest a general prevalence of C_3 based diets, the presence of less negative $\delta^{13}C$ values at certain sites (e.g. San Donato) suggests the occasional consumption of C_4 (e.g. millet), potentially as a resilience or adaptation strategy in specific ecological contexts.

Isotopic analyses can reveal a complex and structured dietary landscape shaped by social status, geography, and access to resources. This review shows carbon isotope values ($\delta^{13}C$) across most sites range from –20.5‰ to –18.0‰, indicating a diet rooted in C_3 plants such as wheat, barley, and legumes, staples, consistent with Roman and Late Antique literary sources and archaeological evidence (Frayn 1975; Garnsey 1999). Yet, regional differences suggest localized adaptations and differential resource availability (inland vs. coastal). Sites with slightly less negative $\delta^{13}C$ values (up to -15.9‰) can indicate the inclusion of C_4 plants, such as millets. At San Donato (Veneto), unusually high $\delta^{13}C$ values (–15.9‰; Fiorin *et al.* 2023) point to a non-negligible intake of millet, confirming historical accounts that identify millet as a lower-status or emergency food (Garnsey 1999; Tafuri *et al.* 2009). By contrast, in *Latium* and Campania diets remained consistently based on wheat and barley, with $\delta^{13}C$ values clustering around –19.0‰. The sporadic consumption of millet, often among lower-status individuals or in rural settings, can possibly reflect responses to food insecurity, cultural practices, or military provisioning rather than a widespread dietary reliance (Garnsey 1999; Killgrove, Montgomery 2016). Nonetheless, this result likely reflects geographical factors, as studies on historical diets in Italy have consistently shown of increased C_4 plant consumption in populations located further north, as they are well-adapted to the Alpine climate (Tafuri *et al.* 2009; Iacumin *et al.* 2014; Milella *et al.* 2019; Fiorin *et al.* 2023).

Nitrogen isotope values ($\delta^{15}N$), which range from +7.0‰ to +12.5‰, further illuminate variation in protein consumption. Elevated $\delta^{15}N$ values among individuals from urban centres point to regular access to animal-derived protein, meat, dairy, and marine fish, suggesting greater dietary diversity among higher-status populations. In contrast, the lower $\delta^{15}N$ values observed in rural individuals imply more limited access to animal products and a greater reliance on legumes, such as lentils and chickpeas. Dental calculus at Boccone del Povero (rural *Latium*) revealed starches from pulses and traces of amygdalin (D'Agostino *et al.* 2023), consistent with isotopic values indicating reliance on legumes. By contrast, coastal urban sites such as Portus ($\delta^{15}N$ 10.7‰; O'Connell *et al.* 2019) reflect access to marine proteins. Inland communities tend to show $\delta^{13}C$ and $\delta^{15}N$ values consistent with agriculturally focused diets and reduced access to marine foods. Historical sources, such as Columella and Pliny the Elder describe the diets of rural and lower-class Romans as relying heavily on legumes like lentils and chickpeas, with limited consumption of meat and fish. Modern analyses by Garnsey (1999) and Dalby (2013) support these interpretations, emphasizing the nutritional and economic role of legumes in rural subsistence.

Moreover, dental calculus analysis reinforces the isotopic trends while offering additional resolution into food practices and diversity, particularly for inland and rural populations, as the published studies consist of material from those contexts (Baldoni *et al.* 2020; D'Agostino *et al.* 2023; Fiorin *et al.* 2023). To date, urban and coastal Roman contexts remain absent from the published literature on dental calculus research. The microremains (mainly starches) found through microscopic analysis of dental calculus support the presence of staple foods, such as C_3 and C_4 cereals, legumes, and acorns. Still, it should be noted that these rich mineralized deposits preserve only a fraction of the individual's full diet (Bartholdy, Henry 2022). Occasional identification of millet starch granules aligns with isotopic signals of C_4 plant consumption and helps contextualize millet's limited but strategic role in the Roman diet (Garnsey 1999).

Across the Roman and Late Antiquity periods, broad dietary patterns remained relatively consistent, centred around terrestrial protein, yet subtle shifts over time reveal how diet became increasingly shaped by economic, social, and cultural transformations. Consistent with the overall picture outlined above, isotopic data still highlight the persistent dominance of C_3 plants but variability in $\delta^{15}N$ values marks growing social and geographic differences. Isotopic evidence points to a stable reliance on C_3 plants, with $\delta^{13}C$ values generally falling between -20.5‰ and -18.0‰ throughout the Roman world. This consistency reflects the enduring importance of wheat and barley as dietary staples. Yet, by the 1st and 2nd centuries CE, particularly in urban settings, greater isotopic variability emerges, especially in $\delta^{15}N$ values, as evidenced by the wider standard deviation values, suggesting increasingly diverse diets in urban areas compared to rural ones.

This diversity appears linked to the expanding complexity of Roman urban economies. As cities like Rome, Ostia, Pompeii, and Naples became integrated into imperial trade and provisioning systems, access to imported goods, including marine fish, *garum*, dried fruits, olive oil, and luxury spices, increased (Rickman 1980; Morley 2007). Isotopic signatures in urban and elite individuals begin to reflect these changes, with elevated $\delta^{15}N$ values (+10.0‰ to +12.5‰) suggesting the consumption of animal protein and marine resources. In contrast, rural populations, particularly those in inland or upland regions, remained reliant on subsistence-based diets. Their lower $\delta^{15}N$ values suggest limited access to animal/marine proteins, while their higher and relatively stable $\delta^{13}C$ values can potentially suggest the consumption of C_4 plants, to some extent.

During the transition from Roman period to Late Antiquity, and despite these broader transformations, there is no widespread isotopic signal indicating a shift toward millet or other C_4 plants as staple foods, suggesting some continuity in agricultural provisioning even during periods of political and economic instability. Nevertheless, what becomes increasingly evident over time is the widening dietary gap between urban and rural populations. The expansion of centralized food provisioning systems under the Empire, particularly following Augustus' reforms, concentrated food supplies in cities through grain doles, *horrea* (public storage), and maritime supply chains (Potter 2010; Van Oyen 2020; Kim 2021).

This may have left rural communities more isolated and vulnerable to harvest variability, environmental pressures, and limited access to locally produced goods. Large agricultural estates (*latifundia*) became focused on cash crops such as wine and olive oil, often for urban consumption or export. The labourers who cultivated these goods were frequently excluded from the products they helped create, instead relying on legumes, garden vegetables, and occasional animal products for sustenance, foods that were lower in status and nutritional value (Cornell, Lomas 2005; Garnsey 1999; Rickman 1980). Ancient sources like Columella (*De re rustica* I.6.9, 12) and Pliny the Elder (*Naturalis Historia*, Gaius Furius Chresimus) corroborate that those who worked the land were often excluded from its most profitable yields.

Together, archaeological, isotopic, and historical evidence point to a widening urban-rural and coastal-inland divide during the Imperial period in Italy. Food access, dietary diversity, and nutritional quality increasingly reflected one's position within a system of centralized provisioning and stratified consumption, making diet a powerful marker of both privilege and marginality in the Roman world (Garnsey 1999; Kim 2021).

Despite the challenge, the combined isotopic and dental calculus evidence provides a new lens into the lived experiences of diet-related health and medicinal practices across diverse sociocultural contexts. Isotopic data consistently indicate a population that was primarily reliant on C_3 cereals, such as wheat and barley, with legumes such as lentils and chickpeas forming important protein sources (Flint-Hamilton 1999; Purcell 2003). This broad pattern aligns closely with historical texts emphasizing grain as the basis of Roman subsistence. At the same time, significant variability in $\delta^{15}N$ values highlights differences in protein consumption across regions and social groups. Elevated values, especially in urban and coastal settings, indicate greater access to animal-derived foods, whether terrestrial meat, dairy, or marine resources, while lower $\delta^{15}N$ values in rural and/or inland contexts reflect heavier reliance on pulses and plant-based proteins (e.g. D'Agostino *et al.* 2023; Fiorin *et al.* 2023).

These dietary patterns are more than nutritional observations, as they also carry implications for health and inequality. At Covo (Lombardy), relatively high $\delta^{13}C$ values (-16.9‰) combined with low $\delta^{15}N$ (8.5‰) coincide with skeletal stress markers such as *cribra orbitalia* (Marinato 2016), suggesting nutritional stress. At Portus and Velia, high $\delta^{15}N$ values have been correlated with auricular exostosis (Crowe *et al.* 2010), linking marine food consumption to occupational risk and exposure. However, this hypothesis is not entirely supported across geographic and/or socioeconomic contexts. The direct link between isotopes and palaeopathological signatures is challenging to address, despite the undeniable role of diet in human health and well-being (Marinato 2016). However, this remains difficult to assess, as some isotopic results are not directly linked to individuals with such conditions, but rather within comparative interpretations based on the frequency of such conditions and isotopic values, from a populational perspective.

Beyond diet and occupational habits, these results reflect potential health risks tied to subsistence strategies. Thus, the co-occurrence of auricular exostosis and marine isotope signatures offered a rare opportunity to triangulate diet, occupation, and health in the Roman world, allowing inferences regarding not just what people ate, but also how resources were acquired and at what physical cost.

Moreover, nitrogen isotope analysis ($\delta^{15}N$), which has long been used in palaeodietary studies, is now also understood to reflect some physiological and pathological states, especially when interpreted alongside skeletal paleopathology (Curto *et al.* 2019, 2020). However, the available data used in this work did not permit further interpretation.

Beyond isotopic signals, dental calculus analysis enriches this picture by capturing direct evidence of microremains and biochemical residues that can be related to medicinal practices (Hardy *et al.* 2012; Gismondi *et al.* 2018; Fiorin *et al.* 2024). In the published literature from the Roman period, the identification of phytotherapeutic substances can suggest the medicinal use of plants, as seen in the case of amygdalin in Boccone del Povero (Rome, Latium). This substance is present in the Rosaceae family, which includes almonds (*Prunus* sp.), a resource widely appreciated by the Romans as both food and a natural remedy, due to their diuretic, laxative, and emmenagogue properties (D'Agostino *et al.* 2023). Hence, dental calculus findings can connect dietary composition not only to nutrition, but also to health and medicinal practices, offering a rare glimpse into the lived realities of those far removed from elite narratives.

The isotopic differences found in the transition from Roman period to Late Antiquity in Italy suggest a growing socioeconomic divide between urban and rural, as well as coastal and inland populations, suggest possible differences in health and medical care. However, this is currently an underdeveloped topic, and future studies are needed to move beyond hypothesis and into quantitative models of Roman health inequality.

For the scope of the present work, only adult individuals were considered, excluding potential age-related dietary differences. However, the interpretation of these differences must carefully take into account potential confounding variables. Factors such as sex and socioeconomic status are rarely reported systematically in the primary sources (De Angelis *et al.* 2020b; Tafuri *et al.* 2018), which limits the ability to disentangle intra-community variability from broader geographic or temporal trends. As a result, observed patterns should be understood as reflecting general tendencies rather than precise individual-level differences. While these limitations do not undermine the overall findings of our study, they highlight the need for future research to incorporate more detailed demographic and contextual information to refine interpretations of dietary variation and health outcomes across populations.

6. Challenges, open questions, and future directions

Although stable isotope and dental calculus analyses have considerably improved the reconstruction of diets in Roman and Late Antique Italy, several critical challenges remain, primarily linked to the current state of published dataset rather than the methods themselves. Firstly, isotopic studies vary in terms of collagen quality control and faunal baselines (Cubas *et al.* 2019; López-Costas, Alexander 2019), which limit robust interregional comparisons. Secondly, analyses of dental calculus are still rare and almost exclusively derive from rural or inland contexts (Baldoni *et al.* 2020; D'Agostino *et al.* 2023; Fiorin *et al.* 2023), resulting in the underrepresentation of urban and coastal populations. This imbalance hinders the testing of hypotheses concerning social and geographical contrasts across the peninsula.

Another important limitation is the inadequate reporting of biological and contextual variables. Despite their potential role as confounding factors in dietary reconstructions, sex, age at death and social status are rarely reported systematically reported (De Angelis *et al.* 2020a; Tafuri *et al.* 2018). Their absence makes it difficult to distinguish intra-community variation from broader geographic or chronological patterns. Similarly, information on provenance and mobility, which has become increasingly accessible through strontium and oxygen isotopes (Killgrove, Montgomery 2016; O'Connell *et al.* 2019), is often lacking. This limits our ability to explore the connections between diet, migration and identity.

Future progress will depend on integrating isotope and dental calculus data with archaeobotanical and faunal remains (King 1999; van der Veen 2020), palaeopathology (Curto *et al.* 2019, 2020) and textual sources. A more systematic approach to demographic variables and the socio-economic context of individuals is essential in order to move beyond broad generalisations. Studies explicitly designed to compare differences in diet based on sex and status could reveal previously unexplored dimensions of health and inequality in Roman society (Garnsey 1999; Kim 2021).

7. Conclusion

This review highlights how diet in Roman and Late Antique Italy was structured according to geography and settlement type, with statistically significant differences between urban and coastal vs. rural and inland populations. Isotopic evidence points to widespread reliance on C_3 cereals such as wheat and barley, complemented by animal and marine proteins, which were more readily available in urban and coastal settings, while rural and inland communities relied more heavily on legumes and occasionally on C_4 plants (Garnsey 1999; Killgrove, Tykot 2013; Fiorin *et al.* 2023). Dental calculus analyses, though still limited in number, corroborate these trends and provide additional insights into plant foods and possible medicinal practices (Baldoni *et al.* 2020; D'Agostino *et al.* 2023).

At the same time, the study underscores important limitations. The datasets are uneven, with very few published calculus analyses and a lack of systematic reporting on sex, age, and social status (De Angelis *et al.* 2020b). These gaps prevent a more detailed assessment of how dietary variation intersects with inequality and health.

Future research should prioritize underrepresented contexts, especially urban and coastal sites, and systematically incorporate demographic and socioeconomic variables. Approaches combining isotopic evidence, calculus analysis, and paleopathological data (Crowe *et al.* 2010; Curto *et al.* 2020) will be crucial for clarifying how food access reflected privilege, marginality, and resilience across Roman populations.

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Abstract
This review synthesizes current bioarchaeological research on the Roman and Late Antiquity diet in Italy through the integrated reinterpretation of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes and ancient dental calculus data. Drawing on published data from urban and rural sites across the Italian peninsula (1^{st}-8^{th} centuries CE), the study compiles dispersed evidence and examines dietary variability along the axes of geography, chronology, and social variability in diet and health. Isotopic evidence confirms a broad reliance on C_3 cereals such as wheat and barley, while nitrogen values reveal differential access to animal protein and marine resources, possibly correlating with status or occupation. Dental calculus analysis complements these findings by preserving microremains and biomolecules that reflect the consumption of plant foods, herbs, dairy, as well as phytopharmacological resources. When combined, these approaches provide a more holistic and socially nuanced reconstruction of lifeways in Antiquity, challenging traditional elite-centred narratives and offering insights into health, identity, and inequality. The review also discusses methodological challenges in dietary reconstructions and outlines future directions, emphasizing the need for standardisation, regional comparison, and interdisciplinary integration. Ultimately, this work demonstrates the potential of combining published aggregated data to shed light on the complex interplay between diet, health, and society in past populations.
Keywords: Roman health, diet, dental calculus, isotopes, bioarchaeology.

L'articolo sintetizza le attuali ricerche bioarcheologiche sulla dieta romana e tardoantica in Italia attraverso la reinterpretazione integrata degli isotopi stabili di carbonio ($\delta^{13}C$) e azoto ($\delta^{15}N$) e dei dati relativi al tartaro antico. Attingendo ai dati pubblicati provenienti da siti urbani e rurali in tutta la penisola italiana (I-VIII secolo d.C.), lo studio raccoglie dati prima dispersi ed esamina la variabilità alimentare lungo gli assi della geografia, della cronologia e della variabilità sociale nella dieta e nella salute. Le prove isotopiche confermano un ampio ricorso a cereali C_3 come il grano e l'orzo, mentre i valori dell'azoto rivelano un accesso differenziale alle proteine animali e alle risorse marine, forse in correlazione con lo status o l'occupazione. L'analisi del tartaro integra questi risultati conservando microresti e biomolecole che riflettono il consumo di alimenti vegetali, erbe, latticini e risorse fitofarmacologiche. Se combinati, questi approcci forniscono una ricostruzione più olistica e socialmente sfumata degli stili di vita nell'antichità, sfidando le narrazioni tradizionali incentrate sull'élite e offrendo approfondimenti su salute, identità e disuguaglianza. Questa ricerca discute anche le sfide metodologiche nella ricostruzione delle diete e delinea le direzioni future, sottolineando la necessità di standardizzazione, confronto regionale e integrazione interdisciplinare. In definitiva, questo lavoro dimostra il potenziale della combinazione di dati aggregati pubblicati per far luce sulla complessa interazione tra dieta, salute e società nelle popolazioni antiche.
***Parole chiave**: salute, età romana, dieta, tartaro, isotopi, bioarcheologia.*

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