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ORIGINAL PAPER

Food at the heart of the Empire: dietary reconstruction for Imperial Rome inhabitants

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Abstract

This paper aims to provide a broad diet reconstruction for people buried in archaeologically defined contexts in Rome (first to third centuries CE), in order to combine archaeological and biological evidence focusing on dietary preferences in Imperial Rome. A sample of 214 human bones recovered from 6 funerary contexts was selected for carbon and nitrogen stable isotope analysis. The baseline for the terrestrial protein component of the diet was set using 17 coeval faunal remains recovered from excavations at Rome supplemented by previously published data for the same geographic and chronological frames. δ^{13}C ranges from − 19.9 to − 14.8‰, whereas δ^{15}N values are between 7.2 and 10.0‰. The values are consistent with an overall diet mainly based on terrestrial resources. All the human samples rely on a higher trophic level than the primary consumer faunal samples. Certainly, C_3 plants played a pivotal role in the dietary habits. However, C_4 plants also seem to have been consumed, albeit they were not as widespread and were not always used for human consumption. The environment played a critical role also for Romans of lower social classes. The topographical location determined the preferential consumption of food that people could obtain from their neighborhood.

Keywords Imperial Rome · Diet · Carbon and nitrogen stable isotopes · Ancient Romans

Introduction

Imperial Rome was one of the largest cities of Europe (Scheidel 2007; Lo Cascio 1994), and feeding its population was a severe concern for political authorities. Demographic surveys witness a peak in both urban and suburban Roman populations during the Imperial Age (first to third centuries CE, herein indicated by the capitalized word "Empire," whereas the uncapitalized word "empire" refers to the geographical boundaries, as suggested by Boatwright et al. (2011)), revealing that about one million people lived in the city or within 50 km. Nearly 17% of the Italian population was

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concentrated in just 5% of Italian territory (Morley 1996; Scheidel 2009), which affected public health, administrative and social organization (Dyson 2010).

Roman authorities began to step in the food supply of the city in the mid-Republican period. The introduction of grain distribution by *C. Sempronius Gracchus* in 123 BCE is considered the first legal provision for supplying the citizens of Rome. According to this rule, each legal resident was entitled to receive a monthly allotment of essential foods at a discounted price or even for free. Because wheat supplied most of the calories citizens consumed, the government focused its interventions in the wheat market, especially for the poor, although meat and oil were also distributed in later years. Eligibility for the food allotment required an ever-watchful eye by the authorities. From the second half of the first century BCE, the names of those entitled to receive the *frumentatio* were recorded in dedicated registers. However, eligibility for the provision could also be acquired by donation or by the purchase of the *frumentaria* card, the tablet on which the eligible citizen's name was engraved.

In the Principate, the *Annona* (the grain supply) was a critical element of the relationship between the Emperor and the citizens, and an influential political leader headed this office. Beyond the imperial estates' production, the empire collected tax grain primarily in Sicily and Africa. Two ancient authors provide the best indication of the amount involved in this trade: *Aurelius Victor*, in his *Liber de Caesaribu*s, reported that under Augustus, Rome annually received ca. 135,000 tons from Egypt, while *Flavius Josephus* in his *De Bello Judaico*, told us that under *Agrippa II*, the North African colonies granted Rome for up to 400,000 tons of grain. The obtained stock was distributed at the *frumentationes*, which fed a large part of the population but not its entirety. The primary conditions for accessing the public supply were Roman citizenship, residence in Rome, being male, and legal age, though there were many exceptions (Johnson 2013). The massive amount of grain imported and the strict regulation for its distribution clearly demonstrate that Rome depended on a grain supply, and if it were cut off, it would face hardship and even famine. Of course, the food requirements of Rome could not be fulfilled only by the central distribution of supplementary grain, and Roman social stratification in the city and suburbs created many related problems.

Archaeological evidence suggests the area outside the city walls, the *Suburbium*, was inhabited both by poor people, who could not afford the city lifestyle, and the upper strata of Roman society (Champlin 1982). Pliny the Younger in his *Epistulae* (*Plin. Ep. 2.17*) celebrated the countryside, where people wanted to spend their lives outside the unhealthy urbanized environment. However, this liminal area between the city and the open countryside also included marginal industries excluded from the city for religious or public safety reasons, such as landfills, quarry pits, brickmaking facilities, and funerary areas (Killgrove and Tykot 2013; Catalano 2015). Movements between the *Urbs* and the *Suburbium* were frequent, and the permanent Rome-ward migration from the countryside helped maintain the population size of Rome (Scheidel 2007). The migration to Rome was already testified by thousands of grave inscriptions and notorious contemporary authors such as *Lucius Annaeus Seneca* in his *Ad Helviam matrem de consolatione (6.2-3)* or *Decimus Iunius Iuvenalis*'s *Satirae (3)*. However, the biomolecular analysis is currently supporting this topic, suggesting that the Rome population size was granted by people with different origins and cultural features (Killgrove and Tykot 2013; Antonio et al. 2019), including their dietary habits.

Roman diet was and continues to represent a fertile area of investigation, and the historical record provides a great deal of evidence of the variety of foodstuffs available to at least some of the Roman people. The broadest discussion of the diet of ancient Romans is provided by primary sources, such as novels and artworks (Purcell 2003; Wilkins and Hill 2006).

Several Latin authors handed information on dietary habits in ancient Rome, starting from the Republican time. One of the earliest treatises dealing with this topic was Cato's *De Agricultura*. To provide the best moral behaviors to his son, he gave dietary prescriptions forming the basis for many of the recipes found in the following literary sources, such as the *Marcus Terentius Varro's De Re Rustica*. However, the ancient Roman agronomist Columella left the most massive amount of information on agricultural techniques and food processing for the Imperial Age in his *De Re Rustica*, which represents the leading literary source for understanding the diet in that period. Pliny the Elder's *Naturalis Historia* also provides us with a historical perspective of the Imperial age diet, as he described both faunal and horticultural landscapes.

Furthermore, *Petronius* and *Apicius* were the primary sources on Roman cuisine with their Satyrico*n* and *De Re Coquinaria*, respectively, where hundreds of recipes were collected, and Martial's Epigrams.

Food was a popular motif also in the decoration of Roman estates, where wealthy Romans enjoyed a fully catered lifestyle, especially in rooms associated with food consumption, such as kitchens and dining rooms (Yardley 1991). However, these luxury items were undoubtedly mainly produced by and for the upper social stratum, representing less than 2% of the population.

According to these primary sources, grain would have been the base of diet for Romans. This is not surprising since carbohydrates from grains would have accounted for about 70% of their daily energy intake (Delgado et al. 2017). Grain was used in various recipes, mainly as bread or *puls*, a grain pottage that could also be mixed with vegetables, meat, and cheese (Garnsey 1999). As previously stated, cereals were widely cultivated in the empire, and consistent importation came from Sicily and Egypt areas. The commercial value of grain was determined by the Edict of Diocletian, which set the maximum price of wheat, barley, and millet. Remarkably, the role of millet is still not completely understood, and it might have been mainly used for livestock fodder rather than for human sustenance (Spurr 1983) even though *Dioscorides*, a Roman physician, pharmacologist and botanist of Greek origin, mentioned the *panicum* in his 5-volume *De Materia Medica*. The pivotal role of cereals in the Empire is also attested by evidence concerning Roman skill in ensuring a continuous supply of those foodstuffs through diverse agricultural practices, artificial farming techniques, and food preservation methods (De Ligt 2006).

Along with the cereal backbone, a wide variety of vegetables, fruits, and legumes were eaten (or drunk, as in the case of wine) by Romans (Garnsey 1999; Prowse 2001).

Certainly, meat represented a critical element of an individual's food consumption: livestock breeding and trade were rampant in the Roman world (Kron 2002; MacKinnon 2004) and the primary sources of meat were goats, sheep, lambs, and pigs (Brothwell and Brothwell 1998; MacKinnon 2004). Varro told us about a price list for the meat (*Res Rust. 2.5.11*), that clearly distinguished purchase for butchery from purchase for sacrifice, even though their consumption was not common amid the populace, as also referred by Pliny the Elder in his Historia Naturalis ("*ex horto plebei macellum, quanto innocentiore*", that could be translated as "the populace market resides in the garden, carrying the simplest food"; *HN 19.52*). Furthermore, the role of fish in the Empire is unclear as this foodstuff was alternatively seen as an expensive or a common food (Purcell 2003) in various ecological contexts. In a simplistic view, preserved and fresh fish consumption was dependent on the social constraints (Marzano 2018). Generally, the consumption of certain types of fresh fish conferred status, as also reported in Juvenal's *Satura* 4, whereas the exploitation of preserved and salty fish was more affordable across low social strata, as Cato reported in his *De Agricultura* (88).

According to Galen, marine fish were more highly valued than freshwater fish (*De Alimentorum Facultatibus*), and their consumption in ancient Rome increased with *garum*, the staple fish sauce.

Information about the Roman diet could also be provided by mounting archaeobotanical evidence found at roughly coeval sites, such as the floral remains from Pompeii and Herculaneum (Rowan 2017). Similarly, recovered faunal remains suggest the types of meat and fish available to Romans (King 1999; Cool 2006; Prowse et al. 2004, 2005).

The evaluation of human bone remains recovered in archaeological contexts could provide an even clearer glimpse into the lives of the people who lived and died in Rome. Indeed, human bones play a critical role in evaluating a community's subsistence strategy through carbon and nitrogen stable isotope analysis of bone collagen (De Niro 1985; Ambrose and Norr 1993; O'Brien 2015).

Carbon and nitrogen isotopic analysis of collagen recruited through a bulk sampling of the bones reflects the latest years of life due to the turnover rate (Tsutaya and Yoneda 2015; Fahy et al. 2017). Carbon and nitrogen signatures derive primarily from consumed foodstuff and could, therefore, act as proxies to identify the diet. The carbon isotope ratio could be roughly used to differentiate between the consumption of plants with different photosynthetic pathways (C_3 vs. C_4) (Tykot 2014) or differentiate between terrestrial-based and marine-based resources in a C_3 plant-based environment (Tykot 2014). Conversely, nitrogen isotope values provide information about the trophic level of an individual with an offset of 3–5‰ being detectable rising through the trophic levels. However, several confounding factors should be borne in mind in that evaluation. Metabolic and physiological processes could bias the straightforward relationship between stable isotopes and diet reconstruction (Bocherens et al. 1994; Cherel et al. 2005; Mekota et al. 2006; Waters-Rist and Katzenberg 2010; Pecquerie et al. 2010; Reitsema 2013; O'Connell 2017; Walter et al. 2020).

Despite the multiple primary information about diet in ancient Rome, the direct evidence for its analysis is not enough to clearly identify the food consumption of the common and poor people of Rome.

Several studies have provided isotopic data to reconstruct people's diet in western communities of the *Suburbium* (Prowse et al. 2004, 2005, 2008, O'Connell et al. 2019) or in peri-urban Christian catacombs (Rutgers et al. 2009; Salesse et al. 2014; Salesse 2015). Similarly, evidence about the diet of commoners living close to the city walls has started to accumulate (Killgrove and Tykot 2013; Killgrove and Montgomery 2016; Killgrove and Tykot 2018), bridging the gap to a more comprehensive analysis of the diet in Imperial Rome.

The available isotopic evidence agrees that grain was a source of staple foods for Romans, to be mixed with vegetables, meat, and cheese (Prowse et al. 2004, 2005, 2008, Killgrove and Tykot 2013; Killgrove and Montgomery 2016; Killgrove and Tykot 2018). Only a few isotopic glimpses for C_4 plant exploitation have been found (Killgrove and Tykot 2013), while domestic animals were the primary faunal resources, as venison consumption was only locally consumed (O'Connell et al. 2019) and fish exploitation could be pointed out for an increased preference among early Christians (Rutgers et al. 2009).

However, the already provided reconstructions miss some of the most significant cemeteries recently discovered in the Rome area, which can provide remarkable data for coping the complex bio-cultural variability of Rome. Indeed, the dietary habits in the whole city should have been heterogeneous, reflecting the multifaceted reality of the capital of one of the most influential Empires in the ancient World. Thus, we would contribute to the spread of investigations into ancient

Rome diets by assessing a significant sample of commoners who were buried (and perhaps lived) in the nearby *Suburbium* is still far from being proficiently accounted for.

Dietary information represents a critical source of knowledge into complex societies such as ancient Rome as it has now been established that customs around food are a key tool for understanding the relationship between humans and their cultural and natural environment in the past (Smith 2006). Therefore, this paper aims to provide a broad diet reconstruction for people buried in Imperial Rome, to combine archaeological and biological evidence from recent excavation results focusing on commoners living in the Imperial Rome.

Materials and methods

Sample

A sample of 214 human bones (Table 1) recovered from 6 funerary contexts (Fig. 1) were selected for carbon and nitrogen stable isotope analysis. The good preservation status of the skeletons according to the lack of soil infiltration in the cancellous bone tissue of the rib bones was the leading inclusion criterion for the recruitment. Information on sex and age at death for each individual were available from previous studies (Catalano 2015), in which the results of osteometric and paleopathological analyses were reported.

The necropolis of Castel Malnome was excavated in the southwestern suburbs (Catalano et al. 2010; Catalano et al. 2013). The sex ratio and juvenile index value, along with osteological suggestions related to musculoskeletal stress markers, push to consider that the funerary area was related to the salt flats unearthed close to the necropolis, where its living community might have worked (Caldarini et al. 2015).

The burial ground of Casal Bertone was set in the eastern suburbs close to the Aurelian walls, in proximity to a large productive area related to an ancient tannery (*fullonica*) (Musco et al. 2008). The funerary context was archaeologically subdivided into three sections: a mausoleum, a necropolis, and an area, named Area Q, contiguous to the production area. The demographic profile of the mausoleum and necropolis communities allows us to consider them as a unique population (De Angelis et al. 2015), and the analysis of skeletal stress markers suggests the population from both areas could have been engaged in work at the *fullonica*. Conversely, the demographic profile of Area Q is significantly dissimilar to the others and is characterized by a peculiar distribution of mortality, in which 48% were in the 0–6 years age range. This has been explained by the hazardous environmental conditions in Area Q, evidenced by the presence of pathological alterations likely caused by infectious diseases (De Angelis et al. 2015).

Table 1 Sample size for each funerary context

Funerary context	Code	Sample size
Castel Malnome	CM	79
Casal Bertone Mausoleum	CBM	26
Casal Bertone Area Q	CBQ	20
Casal Bertone Necropolis	CBN	19
Via Padre Semeria	PS	30
Quarto Cappello del Prete	QCP	40

Quarto Cappello del Prete necropolis was established in the extreme eastern suburbs of Rome, along the Via Prenestina, near the ancient city of Gabii. Monumental structures, such as a circular basin and a nymphaeum, were found at the site, and the graves were located along the edges of a pool and in a hypogeum. More than 70% of the buried people were infants and juveniles; 50% of them were in the 0–6 years age range, and more than half of them seem to have suffered from dysmorphic alterations (De Angelis et al. 2015).

The funerary area of Via Padre Semeria is located on the southern side of Rome, along the Via Cristoforo Colombo (Catalano 2015) and close to the Aurelian walls. Land use was related to farming activities, as evidenced by the discovery of the ruins of a "*villa rustica*" and some hydraulic works (Ramieri 1992), as well as analysis of skeletal stress markers suggesting that females were also involved in agricultural activity (Caldarini et al. 2015).

The baseline for the terrestrial protein component of the diet was set using 17 coeval faunal remains recovered from excavations at Rome (6 from Castel Malnome, 2 from Via Padre Semeria and 9 coming from Colosseum Area), to be used as ecological reference data, supplemented by previously published data for the same geographic and chronological frames. These published data were downloaded from IsoArcH database in several queries performed on or before October 30, 2019 (Salesse et al. 2018; Prowse 2001; O'Connell et al. 2019).

Analytical methods

The extraction of collagen was individually performed at the Centre of Molecular Anthropology for Ancient DNA Studies, Department of Biology, University of Rome Tor Vergata, following Longin's protocol modified by Brown et al. (1988), which was also simultaneously applied to a modern bovine sample as a reference. In order to obtain a satisfactory yield of collagen, the extraction was performed on about 500 mg of bone powder collected by drilling the bones. The ultrafiltration step was also performed for all the samples in order to magnify the collagen concentration through > 30 kDa Amicon® Ultra-4 Centrifugal Filter Units with Ultracel® membranes.

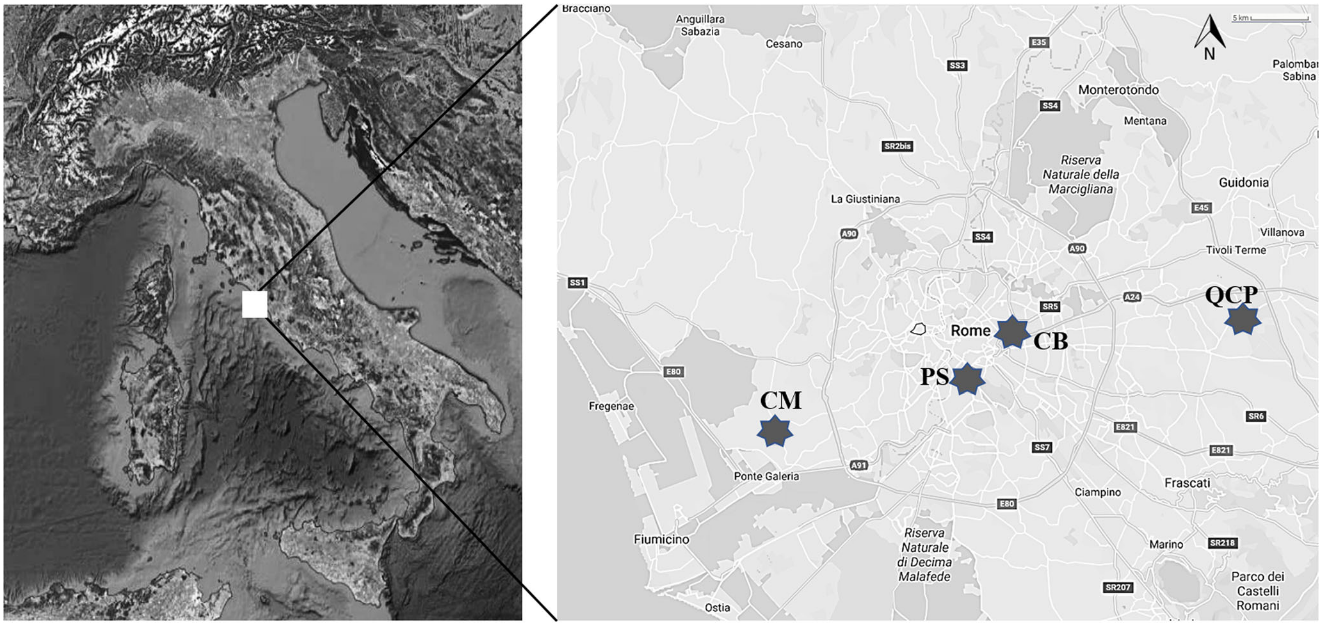

Fig. 1 Topographical locations of the funerary areas. CM, Castel Malnome; PS, Via Padre Semeria; CB, Casal Bertone; QCP, Quarto Cappello del Prete

Each sample of collagen extract weighed 0.8–1.2 mg and was analyzed using an elemental analyzer isotope ratio mass spectrometer at the iCONa (isotope Carbon, Oxygen and Nitrogen analysis) Laboratory of the University of Campania. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios were measured in a single run on a Delta V Advantage isotope ratio mass spectrometer coupled to a Flash 1112 Elemental Analyser via a Conflow III interface (Thermo Scientific Milan, Italy). Results were expressed in δ notation (Coplen 1995) and reported in permille units. The measurements of $\delta^{13}C$ were calibrated to the international standard VPDB with the standard reference materials IAEA-CH3, IAEA-CH6, and stable isotope ratio facility for environmental research at the University of Utah (SIRFER) yeast; $\delta^{15}N$ measurements were calibrated to the international standard AIR with the standard reference materials USGS-34, IAEA-N-2, and SIRFER yeast.

To test reliability and exclude contamination from exogenous carbon and nitrogen sources, the samples were compared against established criteria to ascertain the percentages of carbon and nitrogen, atomic C/N ratios, and collagen yields (Ambrose 1990; Ambrose and Norr 1993; De Niro 1985; Van Klinken 1999). Analytical precision was ± 0.3‰ for $\delta^{15}N$, and ± 0.1‰ for $\delta^{13}C$.

Descriptive statistics and comparison tests were performed by R v.3.6.1 (R Core Team 2017).

The suggestions provided by Fraser et al. (2013) and recently further developed by Fontanals-Coll et al. (2016) were employed to detect the consumer's role for humans compared to the available ecological resources. As described by the authors, this model uses the midpoint and the offsets between consecutive trophic levels to identify the effect of predators on their prey. Thus, the information based on faunal remains was organized according to typology (herbivores, omnivores, marine resources, freshwater organisms), and human data were plotted together in order to detect dietary preferences.

Results

The collagen extraction was performed for the whole sample, but the preservation status of the extracted collagen led us to exclude some individual data: carbon content greater than or equal to 30%, nitrogen content greater than or equal to 10% (Ambrose 1990), and an atomic C/N ratio between 2.9 and 3.6 (De Niro 1985) were the leading determinants for assessing suitable data. CM3 was depleted in elemental compositions, but its C/N ratio and the associated $\delta^{13}C$ and δ^{15} results are consistent with conspecific samples.

The extraction yield was not used as a criterion (Ambrose 1990) because the ultrafiltration technique was used. Only samples with a yield of 0% were ruled out.

Faunal remains yielded enough collagen to be analyzed. Three bones of *Canis sp.* and two deer samples were recruited in Castel Malnome along with a cattle fragment and two herbivore fragments (sheep and cattle) from the Via Padre Semeria archaeological survey. The Colosseum Area domestics (one bird, one chicken, three pigs, two lambs, one hare, and one cattle) return valid values too (Table 2).

The obtained faunal $\delta^{13}C$ values are consistent with a C_3 European ecosystem (Schwarcz and Schoeninger 1991), and the $\delta^{15}N$ signature suggests the proper trophic level for the identified species.

Table 2 Individual results for faunal remains

Labcode	Species	%C	%N	C/N	δ^{13}C‰	δ^{15}N‰
CM1	Dog	35.7	12.7	3.3	− 19.4	10.1
CM2	Dog	31.6	11.3	3.3	− 20.0	9.1
CM3	Dog	17.4	6.1	3.3	− 20.0	10.6
CM4	Deer	49.8	17.1	3.4	− 22.2	5.9
CM5	Deer	38.4	13.9	3.2	− 19.7	5.0
CM6	Cattle	39.8	13.6	3.4	− 21.5	5.3
PS1	Sheep	44	15.7	3.3	− 21.1	6.7
PS2	Cattle	45.5	16.3	3.3	− 20.1	6.7
COL1	Pig	45.5	16.6	3.2	− 20.4	6.8
COL2	Goat	84.6	31.3	3.2	− 20.6	4.2
COL3	Pig	41.6	15.3	3.2	− 20.2	4.6
COL4	Chicken	50	18.5	3.2	− 20.8	5.5
COL5	Bird	31.4	11.2	3.3	− 19.9	8.1
COL6	Sheep	42.4	15	3.3	− 21.8	5.4
COL7	Cattle	48	17.3	3.2	− 20.8	5.5
COL8	Hare	31.1	11.4	3.2	− 21.9	3.8
COL9	Pig	33.2	11.8	3.3	− 20.0	6.3

Out of 214 human samples, only 199 fit the quality criteria. Considering all 199 human individuals, δ^{13}C ranges from − 19.9 to − 14.8‰, whereas δ^{15}N values are between 7.2 and 10.0‰ (Table 3).

The overall data distribution and the density plots indicate a certain heterogeneity: δ^{13}C and δ^{15}N values range between 1.9 and 6.0‰ and between 3.2 and 6.6‰, respectively (Fig. 2).

Indeed, the wider range for δ^{13}C than δ^{15}N could be due to the presence of a few enriched outliers such as CM34 and CM52 (− 14.8‰ and − 17.0‰ for δ^{13}C) as well as CBN1 (− 16.5‰ for δ^{13}C) and CBQ13 (− 17.6‰ for δ^{13}C). Likewise, some lower-δ^{15}N outliers in Casal Bertone necropolis (CBN3, CBN4, and CBN18 with 9.3‰, 8.6‰, and 8.4‰ respectively) and the spanned values for QCP samples account for the wide range detected for δ^{15}N.

The values are consistent with an overall diet mainly based on terrestrial resources. All the human samples rely on a higher trophic level than the primary consumer faunal samples, with no clear indication of exclusive marine food source consumption, although appreciable consumption of these cannot be ruled out, especially for some people at Castel Malnome and Casal Bertone, both at the necropolis and the mausoleum, due to the less negative δ^{13}C data.

The sample stratification according to the necropolis could allow us to evaluate putative differences in food source exploitation. The descriptive statistics for δ^{13}C and δ^{15}N for the six funerary areas were calculated (Table 4).

The osteological evaluation of the human remains allowed us to determine the gender of all individuals, which led us to dissect the variability in food consumption between males and females, as summarized in Table 5.

Discussion

Data integration

Two previously analyzed samples from Casal Bertone necropolis and Casal Bertone mausoleum (Killgrove and Tykot 2013, Supplementary Table 1) were appended to the presented data in order to obtain a whole sample of 231 individual, whose basic descriptive statistics are listed in Table 6.

Furthermore, we are aware that the very restricted sample size for the faunal remains (17 animals) might be only minimally useful for representing the animal baseline, resulting in a bias for the dietary reconstruction of this large urban area. Thus, coeval data was collected by IsoArch Database and from the literature (O'Connell et al. 2019) in order to address this issue. The faunal remains of 48 animals from several species (Supplementary Table 2) made up the whole sample to support this data set as local ecological reference data for Imperial Rome.

A few diachronic samples (mid-fifth to early-sixth centuries CE) were included in the data set to provide additional data for marine species and *Leporidae*; their isotopic data were obtained by O'Connell et al. (2019) at the nearby Portus site. The data distribution for the faunal remains is consistent with the expected locations in the food net, and very few samples seem to be outliers. A bovine sample from Portus has a higher δ^{15}N value than expected, and the pigs from Ostia (Portus and Isola Sacra) and Colosseum area seem to suggest different foraging strategies due to their different δ^{15}N values. These could represent imported foodstuffs, consistent with the longstanding commercial connections between Rome and the nearby river and maritime ports of Portus and Ostia, and between Rome and other Mediterranean areas through the first centuries CE (O'Connell et al. 2019; Keay 2013). Furthermore, the local baselines for Castel Malnome, Via Padre Semeria, and Colosseum seem to roughly align with the ecological background determined for Portus and Isola Sacra for primary consumer herbivores. Accordingly, omnivores such as dogs from Rome lie one trophic level up and align with other Canidae from Isola Sacra and a bird from Portus. Unfortunately, no freshwater fish remains could be listed in the dataset, while the diachronic marine fish values are accordingly located at less negative δ^{13}C values (Fig. 3).

The humans' overall high trophic level (compared to the fauna) suggests that the livestock should be considered prey for humans (Fig. 4). This is also confirmed by the strong correlation between δ^{13}C and δ^{15}N (Pearson's r (243) =

Table 3 Individual results for humans. F, female; M, male; Ind, gender not available. * indicates individual died when they were more than 3 years old

Site	Sample	Sex	Age	%C	%N	C/N	δ^{13}C‰	δ^{15}N‰
CM	CM1	M	50–x	39.9	13.9	3.3	− 18.7	11.2
CM	CM2	M	40–46	42.0	15.1	3.2	− 18.7	11.4
CM	CM3	M	40–49	41.6	14.8	3.3	− 19.1	11.4
CM	CM4	M	30–39	40.8	14.6	3.3	− 18.7	12.2
CM	CM5	M	20–29	39.6	15.1	3.1	− 19.0	9.8
CM	CM6	F	20–29	43.7	15.2	3.4	− 19.3	10.6
CM	CM7	F	20–29	40.2	15.2	3.1	− 19.3	9.3
CM	CM8	M	40–49	40.1	15.3	3.1	− 19.5	10.2
CM	CM9	M	40–49	40.1	15.2	3.1	− 19.8	9.2
CM	CM10	M	20–29	38.9	15.1	3.0	− 19.4	9.7
CM	CM11	M	40–49	38.1	12.3	3.6	− 19.1	11.2
CM	CM13	M	50–x	40.1	14.8	3.2	− 19.1	11.0
CM	CM14	M	40–49	40.2	13.7	3.4	− 19.0	10.5
CM	CM15	M	40–49	36.1	12.4	3.4	− 19.4	11.8
CM	CM16	M	20–29	32.2	11	3.4	− 20.4	7.2
CM	CM17	M	20–29	34.4	13.9	2.9	− 18.9	11.3
CM	CM18	M	40–49	39.5	13.7	3.4	− 19.6	11.1
CM	CM19	M	30–39	40.7	14.2	3.3	− 19.0	11.5
CM	CM20	Ind	13–19	42.1	13.6	3.6	− 20.6	8.5
CM	CM21	F	13–19	41.4	13.3	3.6	− 20.8	7.7
CM	CM22	M	40–49	41.3	14.1	3.4	− 18.8	11.1
CM	CM23	F	30–39	41.2	15.1	3.2	− 20.4	8.0
CM	CM24	M	40–49	45.3	15.6	3.4	− 18.8	12.3
CM	CM25	M	30–39	44.5	15.0	3.5	− 19.0	9.7
CM	CM26	M	40–49	44.6	15.6	3.3	− 19.2	11.2
CM	CM27	M	20–29	44.6	15.5	3.4	− 18.7	9.0
CM	CM28	M	40–49	44.0	15.3	3.4	− 19.1	12.5
CM	CM29	M	20–29	45.4	15.4	3.4	− 18.9	12.6
CM	CM30	M	40–49	45.0	15.7	3.3	− 19.5	10.3
CM	CM31	F	40–49	43.4	15.1	3.4	− 19.0	11.5
CM	CM32	M	50–x	41.9	14.7	3.3	− 18.7	11.9
CM	CM33	M	40–49	40.1	14.8	3.2	− 20.4	8.5
CM	CM34	M	20–29	40.3	14.6	3.2	− 14.8	11.0
CM	CM35	Ind	13–19	40.2	14.7	3.2	− 19.4	11.2
CM	CM36	Ind	13–19	41.2	14.3	3.4	− 19.1	11.3
CM	CM37	F	30–39	42.1	13.9	3.5	− 19.2	11.7
CM	CM39	F	20–29	42.3	14.8	3.3	− 19.2	12.0
CM	CM40	M	40–49	44.7	15.7	3.3	− 19.6	11.0
CM	CM41	M	40–49	42.3	15.1	3.3	− 20.4	9.1
CM	CM42	F	20–29	40.6	15.9	3.0	− 19.1	10.5
CM	CM43	M	30–39	42.3	15.8	3.1	− 19.2	10.6
CM	CM47	M	20–29	43.2	14.2	3.5	− 19.0	12.9
CM	CM48	F	40–49	41.1	14.9	3.2	− 19.2	9.7
CM	CM49	M	30–39	41.2	14.8	3.2	− 18.9	10.5
CM	CM50	M	40–49	41.5	14.3	3.4	− 19.1	11.0
CM	CM51	Ind	13–19	41.6	13.9	3.5	− 19.6	11.5
CM	CM52	M	50–x	43.9	15.5	3.3	− 17.0	12.4
CM	CM53	M	30–39	42.4	14.2	3.5	− 19.8	9.2
CM	CM54	F	30–39	40.8	14.8	3.2	− 19.1	11.7
CM	CM55	M	30–39	41.9	15.1	3.2	− 18.2	12.6
CM	CM56	Ind.	> 21	42.1	14.1	3.5	− 19.2	10.3
CM	CM57	M	20–29	42.9	14.2	3.5	− 19.1	9.7
CM	CM58	F	20–29	42.7	13.9	3.6	− 19.3	11.7
CM	CM60	F	50–x	38.8	13.8	3.3	− 19.1	10.9
CM	CM61	M	30–39	39.8	14.2	3.3	− 19.5	11.3
CM	CM62	M	30–39	39.9	14.4	3.2	− 19.3	12.0
CM	CM63	F	30–39	41.1	14.6	3.3	− 19.3	11.3
CM	CM64	F	40–49	42.4	14.8	3.3	− 18.9	11.0
CM	CM65	M	40–49	40.8	15.1	3.2	− 19.8	10.6
CM	CM66	M	30–39	41.8	15.3	3.2	− 20.6	9.3
CM	CM67	M	40–49	42.2	15.0	3.3	− 19.4	11.6
CM	CM68	F	40–49	39.8	15.0	3.1	− 19.1	12.0
CM	CM69	M	40–49	40.0	15.3	3.1	− 20.1	12.2
CM	CM70	Ind	13–19	40.8	15.1	3.2	− 19.5	11.7
CM	CM71	M	30–39	40.6	15.0	3.2	− 18.8	9.8

Table 3 (continued)

Site	Sample	Sex	Age	%C	%N	C/N	δ^{13}C‰	δ^{15}N‰
CM	CM73	F	20–29	41.0	14.3	3.3	− 18.8	11.4
CM	CM74	F	20–29	43.8	14.8	3.5	− 19.3	11.4
CM	CM75	M	40–49	43.5	14.4	3.5	− 19.8	9.3
CM	CM76	M	30–39	41.0	14.6	3.3	− 18.7	10.9
CM	CM77	M	30–39	41.6	14.1	3.4	− 19.9	10.3
CM	CM78	F	30–39	44.6	15.7	3.3	− 19.2	11.7
CM	CM79	F	30–39	43.9	14.9	3.4	− 19.3	11.8
PS	PS1	M	20–29	43.7	15.5	3.3	− 18.9	11.9
PS	PS4	M	13–19	42.2	14.5	3.4	− 19.7	10.3
PS	PS5	M	30–39	31.6	10.8	3.4	− 18.9	10.4
PS	PS6	F	20–29	39.4	13.9	3.3	− 19.4	10.7
PS	PS7	F	40–49	43.7	15.2	3.4	− 18.3	12.4
PS	PS8	F	13–19	40.9	14.3	3.3	− 19.0	10.5
PS	PS9	M	30–39	40.1	15.1	3.1	− 19.3	11.4
PS	PS10	M	20–29	44.7	16.2	3.2	− 18.9	12.0
PS	PS11	M	30–39	44.4	15.3	3.4	− 19.3	12.1
PS	PS12	F	40–49	38.6	13.9	3.2	− 19.5	10.7
PS	PS13	F	20–29	44.3	14.7	3.5	− 19.4	10.9
PS	PS14	F	20–29	39.7	14.0	3.3	− 19.0	11.3
PS	PS15	F	30–39	43.1	15.5	3.2	− 19.1	10.0
PS	PS16	F	20–29	33.8	11.3	3.5	− 20.0	11.3
PS	PS17	M	40–49	40.9	14.2	3.4	− 19.2	11.3
PS	PS18	Ind	7–12	37.3	13.0	3.3	− 19.3	11.8
PS	PS19	F	20–29	40.9	14.3	3.3	− 19.4	11.7
PS	PS20	F	20–29	26.5	8.7	3.6	− 19.8	10.9
PS	PS21	F	20–29	23.8	7.7	3.6	− 19.6	11.4
PS	PS22	M	40–49	24.9	8.3	3.5	− 19.5	10.0
PS	PS23	M	20–29	39.5	14.2	3.2	− 18.6	11.4
PS	PS24	M	40–49	41.8	15.0	3.3	− 18.6	12.4
PS	PS25	F	13–19	25.5	8.5	3.5	− 18.6	13.2
PS	PS26	M	20–29	41.6	14.6	3.3	− 19.3	10.5
PS	PS27	F	20–29	40.8	14.2	3.4	− 19.0	11.8
PS	PS28	F	20–29	36.0	12.3	3.4	− 19.1	12.1
PS	PS30	M	20–29	49.6	17.7	3.3	− 18.1	13.1
QCP	QCP1	F	30–39	44.4	15	3.5	− 19.5	9.9
QCP	QCP2	M	40–49	44.1	14.8	3.5	− 18.6	11.5
QCP	QCP3	Ind	0–6*	50.8	18.5	3.2	− 19.1	8.8
QCP	QCP5	Ind	7–12	43.3	15.1	3.3	− 19.4	8.5
QCP	QCP6	M	40–49	43.7	15.9	3.2	− 18.7	12.3
QCP	QCP7	Ind	0–6	36.7	12.9	3.3	− 19.7	9.1
QCP	QCP8	M	30–39	41.7	15.2	3.2	− 19.3	9.7
QCP	QCP9	M	30–39	43.2	15.5	3.3	− 18.8	10.2
QCP	QCP10	Ind	0–6	42.5	15.5	3.2	− 19.2	9.0
QCP	QCP11	F	20–29	37.0	13.2	3.3	− 19.5	8.7
QCP	QCP12	F	20–29	38.8	15.2	3.0	− 18.8	9.6
QCP	QCP13	Ind	0–6*	39.7	14.1	3.3	− 19.4	8.8
QCP	QCP14	F	30–39	42.2	15.2	3.2	− 19.1	9.0
QCP	QCP15	Ind	0–6	46.5	16.9	3.2	− 19.2	9.4
QCP	QCP16	Ind	0–6	44.5	16.1	3.2	− 18.5	10.9
QCP	QCP17	M	20–29	43.1	14.8	3.4	− 19.8	8.1
QCP	QCP18	Ind	0–6	40.8	14.6	3.3	− 18.9	10.1
QCP	QCP19	Ind	0–6	43.1	15.0	3.4	− 19.5	11.8
QCP	QCP20	Ind	0–6	40.1	15.1	3.1	− 19.4	12.1
QCP	QCP21	F	30–39	44.4	16.2	3.2	− 20.5	8.4
QCP	QCP22	M	30–39	42.2	14.6	3.4	− 19.4	8.8
QCP	QCP23	Ind	0–6*	31.0	10.9	3.3	− 19.7	8.3
QCP	QCP24	Ind	0–6	35.6	12.5	3.3	− 19.1	13.5
QCP	QCP25	Ind	0–6	36.8	13.0	3.3	− 18.4	14.3
QCP	QCP27	Ind	0–6	40.3	13.9	3.4	− 20.1	9.7
QCP	QCP28	M	20–29	40.7	14.3	3.3	− 19.6	7.7
QCP	QCP29	F	40–49	39.2	13.8	3.3	− 19.8	7.7
QCP	QCP30	Ind	0–6	43.2	15.7	3.2	− 18.7	11.8
QCP	QCP31	Ind	13–19	39.2	14.1	3.2	− 19.5	9.7
QCP	QCP32	M	40–49	44.0	14.9	3.4	− 20.0	9.1
QCP	QCP33	F	30–39	37.0	13.5	3.2	− 19.1	10.3

Table 3 (continued)

Site	Sample	Sex	Age	%C	%N	C/N	δ^{13}C‰	δ^{15}N‰
QCP	QCP34	Ind	0–6*	53.3	19.2	3.2	− 19.0	11.4
QCP	QCP35	M	40–49	34.7	11.9	3.4	− 19.3	10.2
QCP	QCP36	Ind	0–6	38.8	14.9	3.0	− 19.9	11.7
QCP	QCP37	Ind	7–12	41.5	15.1	3.2	− 19.0	10.8
QCP	QCP39	M	13–19	42.2	15.5	3.2	− 18.2	8.8
QCP	QCP40	M	30–39	37.7	13.7	3.2	− 18.9	11.4
CBN	CBN1	M	30–39	36.6	12.8	3.3	− 16.5	12.1
CBN	CBN2	M	50–x	32.7	11.5	3.3	− 18.2	11.1
CBN	CBN3	M	20–29	39.9	13.4	3.5	− 20.0	9.3
CBN	CBN4	F	20–29	38.2	13.4	3.3	− 19.7	8.6
CBN	CBN5	M	40–49	25.4	8.6	3.4	− 18.7	11.3
CBN	CBN6	F	30–39	41.4	13.9	3.5	− 18.9	11.9
CBN	CBN7	M	20–29	30.1	10.2	3.4	− 20.4	11.8
CBN	CBN8	M	13–19	38.7	13.5	3.3	− 19.2	11.5
CBN	CBN9	Ind	13–19	43.9	15.2	3.4	− 18.5	11.3
CBN	CBN10	M	30–39	30.0	9.8	3.6	− 19.0	11.6
CBN	CBN11	Ind	13–19	27.1	8.7	3.6	− 18.6	11.3
CBN	CBN12	Ind	0–6*	32.8	11.2	3.4	− 19.2	11.4
CBN	CBN13	Ind	13–19	37.7	13.1	3.4	− 19.1	10.6
CBN	CBN14	M	40–49	41.7	14.6	3.3	− 18.6	12.0
CBN	CBN15	M	20–29	26.2	8.9	3.4	− 19.0	12.4
CBN	CBN16	M	30–39	44.0	15.2	3.4	− 19.0	11.9
CBN	CBN18	F	30–39	45.0	15.8	3.3	− 19.6	8.4
CBN	CBN19	Ind	13–19	35.9	12.1	3.5	− 18.7	11.4
CBM	CBM1	M	30–39	41.9	15.2	3.2	− 18.3	12.2
CBM	CBM2	F	20–29	46.2	16.5	3.3	− 18.6	11.9
CBM	CBM3	Ind	13–19	41.0	14.4	3.3	− 18.8	11.6
CBM	CBM4	M	30–39	42.1	14.7	3.3	− 18.2	11.8
CBM	CBM5	M	40–49	48.7	15.6	3.6	− 18.7	11.4
CBM	CBM6	F	40–49	43.2	15.3	3.3	− 18.9	11.3
CBM	CBM7	F	> 20	40.5	14.2	3.3	− 18.9	11.6
CBM	CBM8	Ind	7–12	41.3	14.4	3.3	− 18.6	11.1
CBM	CBM9	F	30–39	39.3	13.7	3.3	− 18.6	11.3
CBM	CBM10	Ind	13–19	43.7	15.2	3.4	− 19.1	10.8
CBM	CBM11	Ind	7–12	45.6	15.8	3.4	− 18.9	9.7
CBM	CBM12	Ind	13–19	43.5	15.3	3.3	− 19.0	10.7
CBM	CBM13	Ind	7–12	44.2	15.6	3.3	− 19.1	10.6
CBM	CBM14	M	20–29	41.9	14.7	3.3	− 18.7	11.0
CBM	CBM15	F	20–29	42.3	14.9	3.3	− 19.3	9.6
CBM	CBM16	M	50–x	46.9	16.6	3.3	− 18.9	11.5
CBM	CBM17	F	30–39	46.3	16.2	3.3	− 19.3	10.5
CBM	CBM18	Ind	7–12	43.6	15.6	3.3	− 18.8	11.6
CBM	CBM19	Ind	7–12	41.3	14.5	3.3	− 19.3	11.8
CBM	CBM20	Ind	7–12	40.3	14.2	3.3	− 19.1	8.6
CBM	CBM21	M	13–19	41.6	14.6	3.3	− 19.1	11.0
CBM	CBM22	Ind	7–12	46.1	16.2	3.3	− 19.2	9.8
CBM	CBM23	Ind	7–12	41.9	14.7	3.3	− 20.4	8.1
CBM	CBM24	M	40–49	47.3	17.2	3.2	− 18.4	12.2
CBM	CBM25	Ind	13–19	40.6	14.3	3.3	− 19.7	8.6
CBM	CBM26	Ind	7–12	44.4	15.7	3.3	− 19.2	10.1
CBQ	CBQ1	M	50–X	44.7	14.9	3.5	− 19.0	12.6
CBQ	CBQ2	M	13–19	44.7	16.2	3.2	− 18.9	10.7
CBQ	CBQ3	F	13–19	33.2	11.4	3.4	− 20.2	8.3
CBQ	CBQ4	M	> 20	39.8	13.8	3.4	− 19.3	10.6
CBQ	CBQ5	M	50–X	14.6	4.9	3.5	− 19.3	10.3
CBQ	CBQ6	Ind	7–12	36.4	13.3	3.2	− 18.9	11.3
CBQ	CBQ7	Ind	0–6*	47.1	16.8	3.3	− 18.8	10.7
CBQ	CBQ8	Ind	0–6*	43.0	15.3	3.3	− 19.7	10.7
CBQ	CBQ9	F	20–29	34.4	11	3.6	− 19.5	11.4
CBQ	CBQ10	Ind	0–6*	42.6	15.1	3.3	− 19.0	11.9
CBQ	CBQ11	M	40–49	42.2	15.1	3.3	− 18.8	12.0
CBQ	CBQ12	M	50–X	42.0	14.7	3.3	− 19.2	9.4
CBQ	CBQ13	F	40–49	39.6	13.8	3.3	− 17.6	12.6
CBQ	CBQ14	Ind	0–6*	39.9	14.8	3.1	− 19.2	11.7
CBQ	CBQ15	F	50–X	40.2	14.4	3.3	− 18.6	11.1

Table 3 (continued)

Site	Sample	Sex	Age	%C	%N	C/N	δ^{13}C‰	δ^{15}N‰
CBQ	CBQ16	M	40–49	42.8	15.1	3.3	− 18.7	9.6
CBQ	CBQ17	F	30–39	42.9	15.0	3.3	− 19.2	10.8
CBQ	CBQ18	Ind	0–6*	33.5	11.7	3.3	− 19.8	11.2
CBQ	CBQ19	F	> 20	41.5	14.7	3.3	− 19.1	12.6

0.75, $p < 0.01$), excluding the fish data. An explanation for this correlation follows the interpretation of Murray and Schoeninger (1988), which observed a similar trend in their reconstruction of a terrestrial-based diet. Accordingly, our data seem to support the preference for a terrestrial diet based on C_3 plant resources and their consumers, rather than a massive consumption of C_4 plant and marine fish.

Diet reconstruction

The stable isotope analysis performed on the human remains recovered at the 6 funerary contexts in Imperial Rome (first to third CE) suggests people consumed a roughly heterogeneous diet based on C_3 plant backbone resources. As previously reported, several classical authors wrote about agricultural and horticultural practices in the Roman world, confirming the leading role of such a productive activity. Although literary sources on horticulture focused on the cultivation of olives and grapes for their significance in elite production (Lomas 1993), these authors examined the production of cereal grains too, because they made up the bulk of most people's diets as they were used to make bread and porridge (*puls*) (Brown 2011).

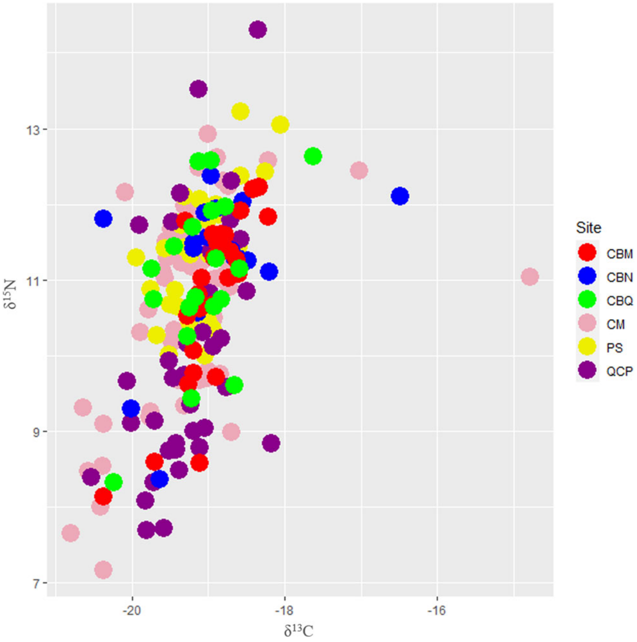

Fig. 2 Plot for δ^{13}C than δ^{15}N values

Our data do not support evidence for exclusive C4 plant exploitation, upholding the notion that animals mainly consumed them in Roman antiquity rather than humans, even though the livestock data reported here does not suggest a foundational role for these plants. Among these, millet represents a generic term for a large group of small-seeded grasses such as both *Setaria italica* and *Panicum miliaceum*. Millet is occasionally mentioned in ancient texts, and well-documented archaeological finds lack in archaeological surveys from Imperial Rome or its commercial hub (O'Connell et al. 2019). Despite millet being not Romans' first choice, it also was not totally discarded by the Romans, though it seems to have been more appreciated far from Rome. The presence of iconographic sources at estates in Pompeii suggests that millet may have been consumed by the wealthy landowners even though they did not totally appreciate it (Jashemski 1992). Indeed, millet was found at several rural Campanian and southern Italy estates (Boscoreale, Herculaneum, and Matrice) (Spurr 1983; Murphy et al. 2013) and its role in cultual practices in northern Italy cannot be ruled out (Rottoli and Castiglioni 2011). Remarkably, millet was often noteworthy in relation to famines and food shortages (Spurr 1983; Garnsey 1999) due to its easy cultivation (Spurr 1983): Columella reports that millet sustained the population of a lot of Italian provinces and the commercial value of millet in the Empire was set in the Edict of Diocletian. Even though millet, which unlike wheat is a non-glutinous grain, can be used for making bread, this seed grass was preferentially used for animal fodder and birdseed rather than direct human consumption (Spurr 1983). Nevertheless, *Panicum* was recommended for several medical uses, and Pliny counseled that "roasted common millet checks looseness of the bowels and removes gripings" to indicate it particularly for regulating the digestive system (Murphy et al. 2013). Although Killgrove and Tykot (2013) found a consistent use of C_4 plants in Castellaccio Europarco for a small sample of buried people, bioarchaeological data about this cereal grain is scarce. Recent archaeobotanical evidence (O'Connell et al. 2019)

Table 4 Descriptive statistics for the 6 necropolises. These statistics are the minimal value (min), the maximal value (max), the range (range, that is, max-min), the median (median), the mean (mean), the standard error on the mean (SE.mean), the confidence interval of the mean (CI.mean) at the $p = 0.95$ level, the variance (var), the standard deviation (std.dev), and the variation coefficient (coef.var) defined as the standard deviation divided by the mean

	Necropolis											
	CBM		CBN		CBQ		CM		PS		QCP	
Sample size	26		18		19		72		27		37	
Average C:N	3.3		3.4		3.3		3.3		3.4		3.3	
	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Min	− 20.4	8.1	− 20.4	8.4	− 20.2	8.3	− 20.8	7.2	− 20.0	10.0	− 20.5	7.7
Max	− 18.2	12.2	− 16.5	12.4	− 17.6	12.6	− 14.8	12.9	− 18.1	13.2	− 18.2	14.3
Range	2.2	4.1	3.9	4.0	2.6	4.3	6.0	5.8	1.9	3.2	2.4	6.6
Median	− 18.9	11.1	− 19.0	11.4	− 19.1	11.1	− 19.2	11.1	− 19.2	11.4	− 19.3	9.7
Mean	− 19.0	10.8	− 18.9	11.1	− 19.1	11.0	− 19.2	10.8	− 19.1	11.4	− 19.3	10.0
SE.mean	0.1	0.2	0.2	0.3	0.1	0.3	0.1	0.2	0.1	0.2	0.1	0.3
CI.mean	0.2	0.5	0.4	0.6	0.3	0.5	0.2	0.3	0.2	0.3	0.2	0.5
Var	0.2	1.3	0.7	1.4	0.3	1.3	0.6	1.5	0.2	0.8	0.3	2.5
Std.dev	0.4	1.1	0.8	1.2	0.5	1.1	0.8	1.2	0.5	0.9	0.5	1.6
Coef.var	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2

shows a consistent amount of cereal grains, mainly free-threshing wheats, emmer, einkorn, and barley, at the Roman harbor of Portus, where no C_4 plants were recovered. This direct evidence, though biased for chance or for trade in the harbor, is consistent with the aforementioned Roman preference for C_3 grains, along with pulses (lentils, peas, and broad beans were recovered) and fruits (a few grapes and elder berries were found in the flotation-sieved contexts at Portus).

The data distribution shows that there is no direct evidence of exclusive marine resource intake too. Although a few individuals, such as CM34, CM52, CBN1, and CBQ13, had less-negative values for $\delta^{13}C$, their moderate $\delta^{15}N$ values do not clearly indicate massive marine fish consumption. Their isotopic signatures could be due to a diet consisting of a combination of marine resources and a mix of C_3/C_4 plant (or primary consumers who eat those plants) related to individual preferences and/or foodstuff availability. Nevertheless, their occasional consumption (along with freshwater resources) cannot be ruled out since up to 20% of the protein consumed could conceivably have come from marine ecosystems without any visible shift in collagen-derived values (Milner et al. 2004; Jim et al. 2006). The seashore vicinity of Castel Malnome hints at the role marine resources could play in the diet, and a local creek could have provided supplemental

Table 5 Basic descriptive statistics for the 6 necropolises stratified according to sex

	CBM		CBN		CBQ		CM		PS		QCP	
	Males (*n* = 7)		Males (*n* = 10)		Males (*n* = 7)		Males (*n* = 47)		Males (*n* = 12)		Males (*n* = 11)	
	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Mean	− 18.6	11.6	− 18.9	11.5	− 19.0	10.7	− 19.1	10.8	− 19.0	11.4	− 19.1	9.8
Median	− 18.7	11.5	− 19.0	11.7	− 19.0	10.6	− 19.1	11.0	− 19.1	11.4	− 19.3	9.7
Variance	0.1	0.3	1.1	0.8	0.1	1.4	0.8	1.5	0.2	0.9	0.3	2.2
	Females (*n* = 6)		Females (*n* = 3)		Females (*n* = 6)		Females (*n* = 19)		Females (*n* = 14)		Females (*n* = 7)	
	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Mean	− 18.9	11.0	− 19.4	9.6	− 19.0	11.1	− 19.3	10.9	− 19.2	11.3	− 19.5	9.1
Median	− 18.9	11.3	− 19.6	8.6	− 19.2	11.3	− 19.2	11.4	− 19.2	11.3	− 19.5	9.0
Variance	0.1	0.7	0.2	4.0	0.8	2.5	0.2	1.7	0.2	0.7	0.4	0.8

Table 6 Basic descriptive statistics for the whole sample

Sample size	Necropolis											
	CBM		CBN		CBQ		CM		PS		QCP	
	38		38		19		72		27		37	
	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Min	− 20.4	7.0	− 20.4	7.2	− 20.2	8.3	− 20.8	7.2	− 20.0	10.0	− 20.5	7.7
Max	− 17.5	12.2	− 16.5	13.2	− 17.6	12.6	− 14.8	12.9	− 18.1	13.2	− 18.2	14.3
Range	2.9	5.2	3.9	6.0	2.6	4.3	6.0	5.8	1.9	3.2	2.4	6.6
Median	− 18.8	10.9	− 18.6	11.1	− 19.1	11.1	− 19.2	11.1	− 19.2	11.4	− 19.3	9.7
Mean	− 18.7	10.5	− 18.6	10.6	− 19.1	11.0	− 19.2	10.8	− 19.1	11.4	− 19.3	10.0
SE.mean	0.1	0.2	0.1	0.2	0.1	0.3	0.1	0.2	0.1	0.2	0.1	0.3
CI.mean	0.2	0.4	0.3	0.5	0.3	0.5	0.2	0.3	0.2	0.3	0.2	0.5
Var	0.3	1.8	0.7	2.0	0.3	1.3	0.6	1.5	0.2	0.8	0.3	2.5
Std.dev	0.6	1.3	0.8	1.4	0.5	1.1	0.8	1.2	0.5	0.9	0.5	1.6
Coef.var	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2

freshwater food sources. Additionally, people buried at Casal Bertone could have accessed these resources through markets due to their proximity to the city walls.

The lack of evidence for exclusive marine fish (or shellfish) consumption should not be confused with occasional consumption of fish through the Romans' staple sauce, *garum*, which could be made with a variety of recipes. Much of the evidence about this ancient fish sauce comes from classical literary sources, which postulate that its popularity derived primarily from social forces influencing individual tastes. The peculiar smell and taste made *garum* a popular food among wealthy people, although the general populace probably also used it (Grainger 2018).

Recent archaeological findings in Portus turned up faunal remains representing a coeval dietary background (O'Connell et al. 2019). Sheep/pig-sized mammals made up the bulk of the findings, with the latter representing the most common species. We are aware that these findings cannot fully represent the local foodstuffs for the communities buried in the analyzed necropolises, but by the same token, the evidence provided by the harbor of Rome should not be undervalued.

We defined the average values in the dietary proxies for herbivores and omnivores from Rome and Portus/Ostia along with their variances, to draw the boxes where the prey could be set. These boxes are then shifted accounting for the predator-prey offsets, which have been estimated as + 1‰ for $\delta^{13}C$ and + 4‰ for $\delta^{15}N$. These dietary markers increase with each trophic level and $\delta^{15}N$ rises approximately + 3/+ 5‰, with deviations depending on species and dietary composition, which suggests using the median value (Robbins et al. 2005; Fraser et al. 2013; Fontanals-Coll et al. 2016).

Unfortunately, no data on freshwater resources could be found in coeval and co-regional samples, so it could be tricky to model freshwater fish exploitation. Indeed, there is a paucity of archaeological evidence for the consumption of freshwater resources in the Empire because the archeozoological record rarely includes lacustrine or riverine faunal remains and, when it does include them, they are in minimal numbers and are difficult to obtain for analysis. Comparative data about this kind of prey have been collected for two diachronic samples from pre-Roman Britain (Jay 2008) and the late-Roman province of Pannonia (Hakenbeck et al. 2017) (Fig. 5). These datasets provide useful isotopic data concerning some freshwater resources, even though we are aware that the ecological background could result in biased values in freshwater fish isotopic signatures (Dufour et al. 1999). However, their isotopic signature cannot be used as specific end-members, but they could be leveraged for supporting the identification of putative freshwater resources consumption as representing the best approximation for such missing local data.

Despite the significant differences between the two samples ($\delta^{13}C$ T-value 3.10, $p < 0.01$; $\delta^{15}N$ T-value 4.27, $p < 0.01$), they consistently have low $\delta^{13}C$ and high $\delta^{15}N$ values, as those expected for these resources.

The estimation of the consumers' boxes indicates that most individuals fall inside the boxes built for herbivore and omnivore consumers (Supplementary Fig. 1) even though 48 individuals fall beyond the threshold for a clear C_3-derived omnivore consumer (Table 7). This evidence pushes us to reconsider the fraction of people whose diet was based on mixed C_3/C_4 plants and/or marine resources. The data stratification for those 48 individuals by site, sex, or age classes does not support any specific trend except for adult/child comparison

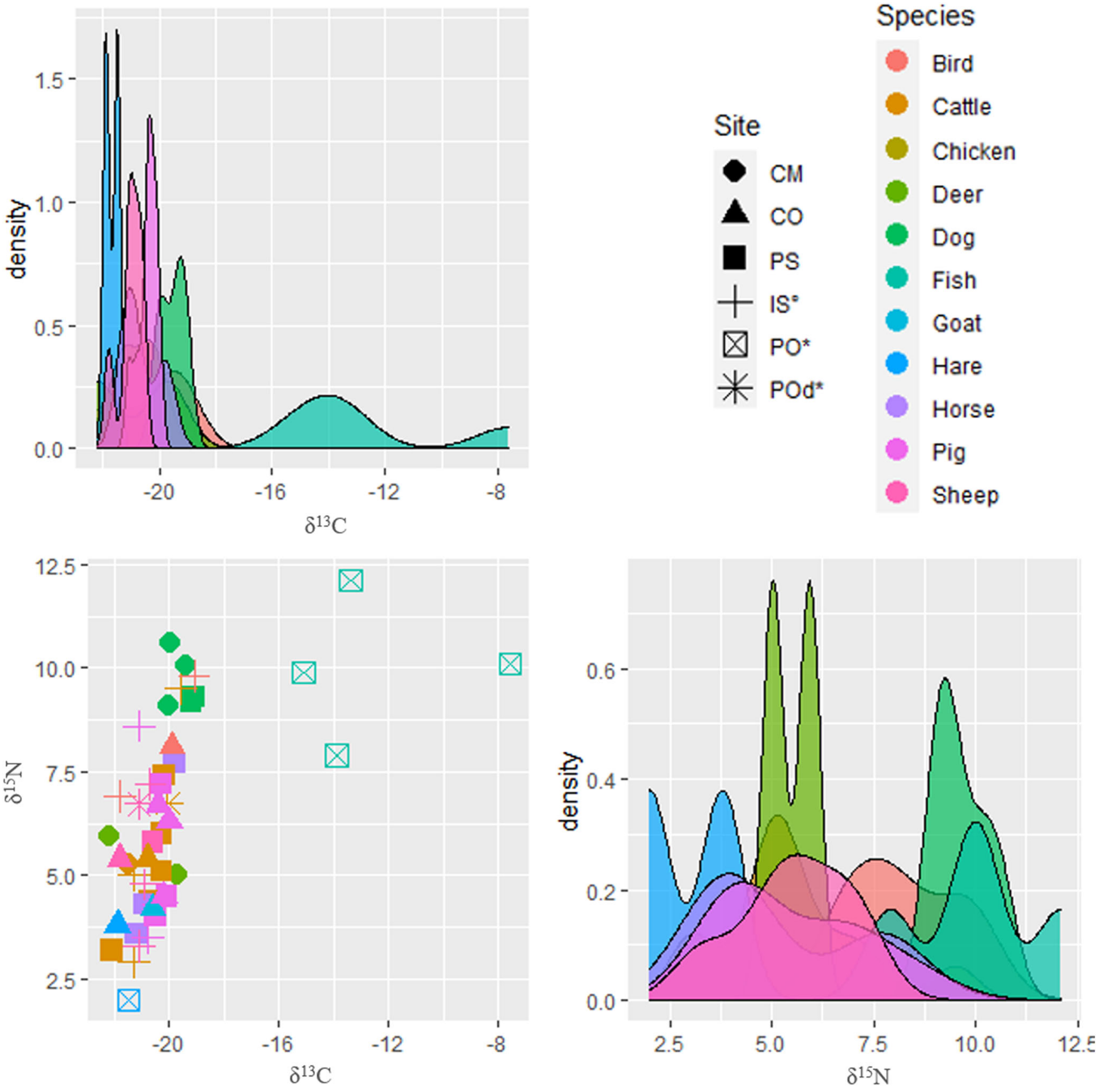

Fig. 3 Bivariate distribution for faunal remains. CM, Castel Malnome; COL, Colosseum; IS, Isola Sacra; PO, Portus; POd, diachronic samples from Portus; PS, Via Padre Semeria. * from Prowse 2001, via IsoArch (Salesse et al. 2018); ° from O'Connell et al. 2019

for δ^{15}N (δ^{13}C: Kruskal-Wallis chi-squared = 8.44, df = 5, *p* value = 0.13 for site; Kruskal-Wallis chi-squared = 0.03, df = 2, *p* value = 0.98 for sex; Kruskal-Wallis chi-squared = 0.11, df = 1, *p* value = 0.73 for age class; δ^{15}N: Kruskal-Wallis chi-squared = 9.62, df = 5, *p* value = 0.09 for site; Kruskal-Wallis chi-squared = 2.55, df = 2, *p* value = 0.28 for sex; Kruskal-Wallis chi-squared = 4.40, df = 1, *p* value = 0.04 for age class) suggesting a subtle stratification between age classes in that sub-sample. People from Casal Bertone (both necropolis and mausoleum) seem to be overrepresented (33 out 48 people). The moderate δ^{15}N values offset between humans and marine fish (mean values 11.5‰ for adults and 11.0‰ for children vs 10.0‰ for marine resources herein considered) might deter to consider this shift due to marine resources exploitation exclusively. This could be supported by the notion that marine fish was considered expensive food in the Empire, suggesting that regular fish consumption may have been restricted to the upper strata of Roman society (Frayn 1993). However, the presence of several people buried in Casal Bertone (Musco et al. 2008) could advise to consider that they were a fairly wealthy

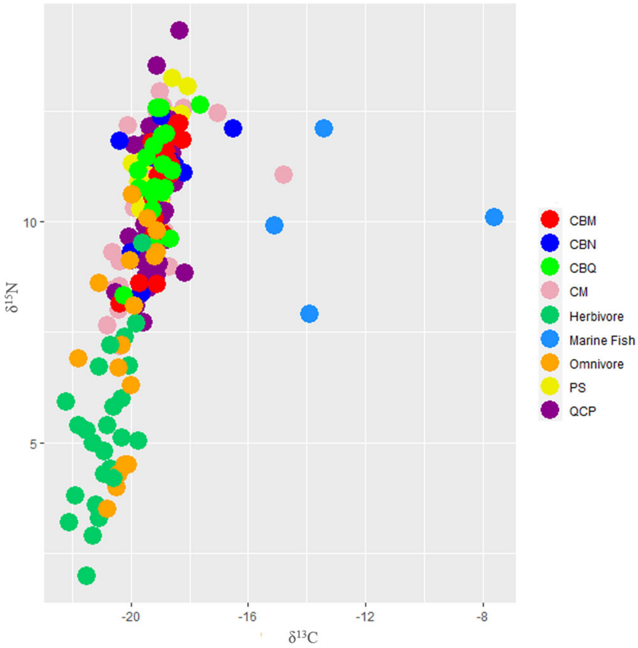

Fig. 4 Plot for $\delta^{13}C$ than $\delta^{15}N$ values for humans and faunal remains

group whose diet was varied and heterogeneous. This evidence is further supported by the topographical location of the cemetery, close to the city center. Hence, people buried in this area (and perhaps living and working at the same location, Catalano 2015) could easily access to market system featuring the city of Rome, where several *horrea* (large warehouses and other storage facilities in Ancient Rome) were located (Vera 2008; Burgers et al. 2015).

Via Padre Semeria necropolis was established in the hydrographic net of Almone river (Tallini et al. 2019), and its data distribution support a more than sporadic consumption of these foodstuffs (Supplementary Fig. 2), which could have represented a supplement food for this farming-based community (De Angelis et al. 2015).

The median value determined for QCP is apart from other cemeteries (Supplementary Fig. 2), suggesting a mostly farming-derived diet. This necropolis is related to a cultic site (Musco et al. 2001; Catalano 2015) where people sharing some biological characteristics related to osteo-dysmorphias seems to be collected, as suggested by osteological analysis (De Angelis et al. 2015). However, as 12 individuals from Quarto Cappello del Prete died before they were 3 years old, we assume that they were not wholly weaned, according to historical and bioarcheological data for ancient Rome (Dupras et al. 2001; Fulminante 2015). We are aware that their isotopic signature could be impacted by the breastfeeding effect (Fogel et al. 1989; Fuller et al. 2006; Beaumont et al. 2015). Accordingly, we removed their isotopic values for the further speculations about diet reconstruction as their $\delta^{15}N$ signatures are different from those obtained from the adults in Quarto Cappello del Prete ($T = 3.23$; $p < 0.01$).

The median values calculated for Castel Malnome and Casal Bertone Area Q are quite similar (Table 4) and suggest a diet high in protein and mainly relied on C_3 plants and C_3-consumer species. This appears noteworthy considering that these necropolises were tied to manufacturing activities (saltworks in Castel Malnome and a tannery in Casal Bertone Area Q), where people should collectively be strong enough for their stressful tasks (De Angelis et al. 2015). The necropolis and the mausoleum of Casal Bertone appear to be shifted respect to Casal Bertone Area Q, suggesting a certain degree of heterogeneity in their diets. This evidence does not fit the archaeological data (Musco et al. 2008; Killgrove and Tykot 2013), which showed a clear difference in the social stratification between necropolis and mausoleum samples: the isotopic results flatten the social mismatch, at least for the dietary landscape.

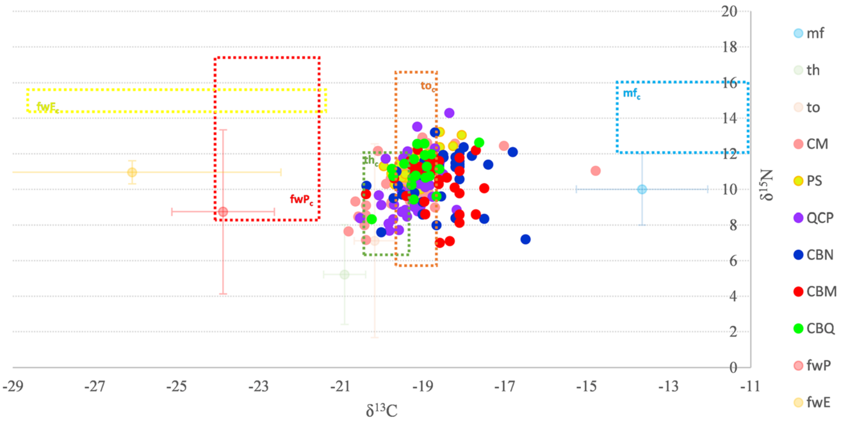

Fig. 5 Linear model for the identification of prey-predator relationship. th, terrestrial herbivore; th_c, box for terrestrial herbivore consumers; to, terrestrial omnivore; to_c, box for terrestrial omnivore consumers; fwE, freshwater fish from England; fwE_c, box for freshwater fish from England consumers; fwP, freshwater fish from Pannonia; fwP_c, box for freshwater fish from Pannonia consumers; mf, marine fish; mf_c, box for marine fish consumers. The dashed lines define consumers' boxes. The cemeteries are identified as referred in Table 1

Table 7 Samples beyond C_3 plant consumer threshold values

Site	Sample	Sex	Age_class	$\delta^{13}C$	$\delta^{15}N$
CBM	CBM1	M	Adult	− 18.3	12.2
CBM	CBM4	M	Adult	− 18.2	11.8
CBM	CBM24	M	Adult	− 18.4	12.2
CBM	CBM100	F	Adult	− 18.1	11.2
CBM	CBM101	M	Child	− 18.1	10.7
CBM	CBM102	Ind	Child	− 18.1	8.6
CBM	CBM103	Ind	Child	− 18.1	10.3
CBM	CBM104	Ind	Child	− 18.1	11.3
CBM	CBM105	F	Adult	− 17.7	11.0
CBM	CBM106	M	Adult	− 17.7	10.8
CBM	CBM107	F	Adult	− 17.5	9.3
CBM	CBM2	F	Adult	− 18.6	11.9
CBM	CBM8	Ind	Child	− 18.6	11.1
CBM	CBM9	F	Adult	− 18.6	11.3
CBN	CBN1	M	Adult	− 16.5	12.1
CBN	CBN2	M	Adult	− 18.2	11.1
CBN	CBN100	Ind	Child	− 18.2	11.0
CBN	CBN101	M	Adult	− 18.2	11.8
CBN	CBN102	M	Adult	− 18.2	11.1
CBN	CBN103	M	Adult	− 18.1	11.6
CBN	CBN104	Ind	Child	− 18.1	9.8
CBN	CBN105	Ind	Child	− 18.1	10.8
CBN	CBN106	F	Adult	− 18.1	9.6
CBN	CBN107	M	Adult	− 18.1	11.6
CBN	CBN108	Ind	Child	− 18.0	10.8
CBN	CBN109	Ind	Child	− 17.8	11.0
CBN	CBN110	Ind	Child	− 17.5	13.2
CBN	CBN111	F	Adult	− 17.4	10.2
CBN	CBN112	M	Child	− 16.8	9.7
CBN	CBN5	M	Adult	− 18.7	11.3
CBN	CBN9	Ind	Child	− 18.5	11.3
CBN	CBN11	Ind	Child	− 18.6	11.3
CBN	CBN14	M	Adult	− 18.6	12.0
CBQ	CBQ13	F	Adult	− 17.6	12.6
CBQ	CBQ15	F	Adult	− 18.6	11.1
CBQ	CBQ16	M	Adult	− 18.7	9.6
CM	CM34	M	Adult	− 14.8	11.0
CM	CM52	M	Adult	− 17.0	12.4
CM	CM55	M	Adult	− 18.2	12.6
PS	PS7	F	Adult	− 18.3	12.4
PS	PS30	M	Adult	− 18.1	13.1
PS	PS23	M	Adult	− 18.6	11.4
PS	PS24	M	Adult	− 18.6	12.4
PS	PS25	F	Child	− 18.6	13.2
QCP	QCP25	Ind	Child	− 18.4	14.3
QCP	QCP39	M	Child	− 18.2	8.8
QCP	QCP2	M	Adult	− 18.6	11.5
QCP	QCP16	Ind	Child	− 18.5	10.9

Comparisons

To fully explore the dietary scenario, we have attempted to understand the roles of several factors that could be significant in the onset of the differences among the necropolises.

All the data are normally distributed (Supplementary Table 3) except for Castel Malnome (both $\delta^{13}C$ and $\delta^{15}N$ values) and Casal Bertone mausoleum $\delta^{15}N$ values (Supplementary Figs. 3, 4, and 5).

The data distribution for Castel Malnome suggests the presence of diet-based groups, with some outliers. CM16 (male, 20–29 years old), CM20 (13–19 years, not available sex), CM21 (young female), CM23 (female, 30–39 years old), and CM33 (male, 40–49 years) feature significant low $\delta^{13}C$ and $\delta^{15}N$ values and those samples, along with CM66 (male, 30–39 years old), CM69 (male, 40–49 years old), and CM40 (male, 40–49 years old) seem to be clustered outside the normal distribution for $\delta^{13}C$, suggesting a diet mainly underpinned by plant-derived carbohydrate. Conversely, CM34 (male, 20–29 years old), CM52 (male, 50 or more years old), and CM55 (male, 30–39 years old) could have exploited marine fish and C_4 plants, while CM29 (male, 20–29 years old), and CM47 (male, 20–29 years old) are outliers for $\delta^{15}N$, suggesting a protein-rich diet. The diet heterogeneity for Castel Malnome suggests that people buried in that site could have access to various dietary resources that would enable them to satisfy the nutritional requirements in carbohydrates and proteins for facing their everyday tasks related to the saltworks. The intra-community differences show that some people could have exploited more protein-rich stuff, paving the way to consider the hypothesis for the establishment of socially-heterogeneous strata in that working community, that cannot be detected by the osteological and archaeological records.

The $\delta^{15}N$ values in Casal Bertone mausoleum highlight a sub-stratification too. CBM20 (child, 7–12 years old), CBM23 (child, 7–12 years old), CBM25 (teen, 13–19 years old), F10C (child, from Killgrove 2010), F04B, and F11A (two adult females, from Killgrove 2010) do not fit the normal distribution for low values, whereas CBM1 (male, 30–39 years old), CBM2 (female, 20–29 years old), and CBM24 (male, 40–49 years old) are at the upper limit of the data distribution, falling outside the normal distribution. These differences support previous archaeological analysis prompting the hypothesis that the mausoleum at Casal Bertone could host the tannery leadership and extended family, including slaves and freedmen (Musco et al. 2008; Catalano 2015), which could benefit from different dietary habits.

The sample stratification among all the necropolis was evaluated through the analysis of variance (ANOVA) to detect differences among the groups (Levene's test for the homogeneity of the variances $\delta^{13}C$ test statistic 1.45, $p = 0.21$; $\delta^{15}N$ test statistic 1.48, $p = 0.20$) taking into account site, biological sex (male, female, or unknown due to skeletal immaturity), and age at death, with a dichotomic classification between adults and non-adults due to the variety of age classes reported, which was a result of different scoring methods used among the samples.

The site did not represent a significant determinant for the onset of $\delta^{13}C$ differences among the samples (F: 1.18; p = 0.32), as well as sex and age featured similar $\delta^{13}C$ values (sex F: 1.00, $p = 0.32$; age class F: 0.37, $p = 0.54$). However, the cemeteries are different for what concerns the $\delta^{15}N$ (site F: 8.00, $p < 0.01$), while demographic differences are negligible (sex F: 01.75, $p = 0.19$; age F: 0.01, $p = 0.91$). Thus, we can conclude that the people buried in the analyzed necropolis were characterized by different diets regarding the introduction of proteins, but they were not sex-biased. Furthermore, the children more than 3 years old were fed like adults. This is in line with the previous findings for the greater Rome samples. Only Isola Sacra necropolis showed a sex-based differences in diet, even though people buried in that cemetery were considered a biased sample of Roman commoners, with better than average diets (Prowse et al. 2004, 2005). Despite the limited sample size, other samples from Imperial Rome did not point out differences in diet between males and females (Killgrove and Tykot 2013; Killgrove and Tykot 2018), and this is true also for the inhabitants of Velia, an Imperial port in southern Italy (Craig et al. 2009). The small amount of isotopic data pertaining the weaning practices in ancient Rome and the neighboring eastern suburbs are consistent with the identified weaning age-threshold (Rutgers et al. 2009; Killgrove and Tykot 2013; Killgrove and Tykot 2018), that is slightly beyond the suggestion provided for western communities (Prowse et al. 2004, 2005, 2008).

The Tukey HSD test (Maxwell and Delaney 2003; Dubitzky et al. 2013) was performed to determine which cemetery pairs underpin the differences in $\delta^{15}N$, accounting for multiple comparisons and maintaining experiment-wise alpha at 0.05 (Yuan and Maxwell 2005). The significant differences were found between Quarto Cappello del Prete and all the other cemeteries (Table 8). This result supports the peculiar status of the cultual site of Quarto Cappello del Prete respect to the other cemeteries in Imperial Rome that were instead related to low-social strata and working communities. Remarkably, Quarto Cappello del Prete isotopic values are not consistent with those obtained for the roughly coeval Gabines (Killgrove and Tykot 2018), the people inhabiting the ancient city of Gabii, a formerly independent city tackling a population contraction in Imperial age, just a few kilometers far from Quarto Cappello del Prete. The differences ($\delta^{13}C$ F: 5.08, $p = 0.03$; $\delta^{15}N$ F: 13.81, $p < 0.01$ that shift to $\delta^{13}C$ F:4.05, $p = 0.05$; $\delta^{15}N$ F: 14.63, $p < 0.01$ by excluding one outlier and three putatively breastfed children, according to Killgrove and Tykot 2018) seem to confirm that Quarto Cappello del Prete related to a site where shortlisted individuals rather than a living community were buried (De Angelis et al. 2015).

Table 8 Tukey HSD test results for $\delta^{15}N$ according to site. Asterisks indicate significant results

	$\delta^{15}N$/site	
	Q statistic	Adjusted p value
CM vs PS	3.2042	0.214
CM vs QCP	6.2025	0.001*
CM vs CBN	1.4268	0.900
CM vs CBM	0.0749	0.900
CM vs CBQ	1.0815	0.900
PS vs QCP	7.7721	0.001*
PS vs CBN	1.1406	0.900
PS vs CBM	2.694	0.404
PS vs CBQ	1.4832	0.900
QCP vs CBN	5.9596	0.001*
QCP vs CBM	5.1846	0.004*
QCP vs CBQ	5.7393	0.001*
CBN vs CBM	1.2822	0.900
CBN vs CBQ	0.2951	0.900
CBM vs CBQ	0.981	0.900

Comparisons with available data for Roman area

In an attempt to describe the food preferences of people buried in greater Rome area, we collected the data for other funerary contexts such as Castellaccio Europarco (Killgrove and Tykot 2013) and ANAS (Prowse 2004) via IsoArch, and the data for people buried in nearby Isola Sacra (Prowse 2001; 2004, Crowe et al. 2010) and Portus Tenuta del Duca, (O'Connell et al. 2019) are included for comparison.

The data evaluation suggested there were dissimilarities in both $\delta^{13}C$ and $\delta^{15}N$ distributions' variances ($\delta^{13}C$: F value = 8.45, $p < 0.01$; $\delta^{15}N$: F value = 10.02, $p < 0.01$) (Supplementary Table 4).

The joint evaluation of the differences adjusted for multiple comparison allows us to determine common patterns among necropolises, which could be grouped both on $\delta^{13}C$ and $\delta^{15}N$ axes according to the significant differences (the mean values of these can be seen in Figs. 6 and 7, in the upper-right plots).

We can identify two segregated groups on the $\delta^{13}C$ axis. One group (group A) comprises Via Padre Semeria, Casal Bertone Area Q, Castel Malnome, Quarto Cappello del Prete, and ANAS, which are different from a second cluster (group B) including Isola Sacra, Casal Bertone Necropolis, and Castellaccio Europarco. Tenuta del Duca (Portus) in the middle, sharing features from both group A and group B. This is only partially surprising if we consider the location of this latter site at the Rome harbor, where people from other areas and who could have eaten different diets might have been buried. The groups defined on the $\delta^{13}C$ axis suggest that the individuals within them had slightly overall different dietary

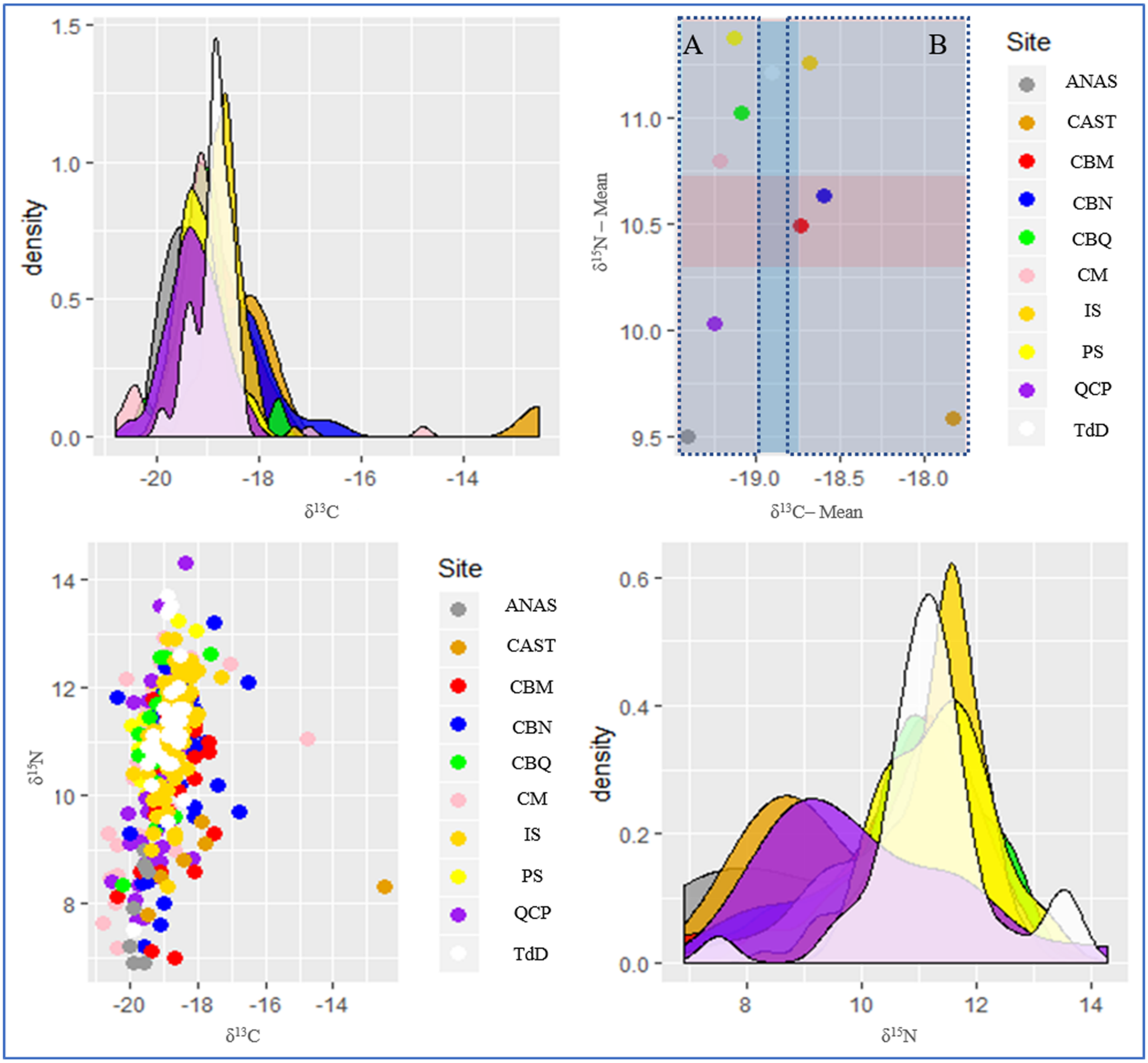

Fig. 6 Data distribution, density plots, and identification of A and B groups by post hoc test

habits. Group A sites share a diet massively founded on C_3 plants, that are consistent with the supposed diet reconstructions for Via Padre Semeria, Castel Malnome, and Casal Bertone Area Q and Quarto Cappello del Prete. Freshwater fauna could have represented a more than sporadic protein supplement for some of these communities that could have grasped these resources because of streaming creeks proximity (Castel Malnome and Via Padre Semeria were close to the Magliana and Galeria creeks, and in the Almone hydrogeological net, respectively). Casal Bertone Area Q was also set in a humid environment as it was established close to the ancient tannery, a factory which needed a massive amount of water, that was putatively provided by several streamlets involved in the Aniene aquifers, also by a subsidiary branch of the Aqua Virgo aqueduct (Musco et al. 2008). Indeed, the easy access to water was one of the leading aspects of considering the establishment of such a productive plant, so it is not surprising that people living in proximity could have exploited freshwater resources. Group B represents people with a more heterogeneous diet, where C_4 plant and marine resources consumption cannot be ruled out, even though their exclusive exploitation should be denied, as previously determined for Isola Sacra and Castellaccio (Prowse et al. 2004, 2005; Killgrove and Tykot 2013). The mausoleum and the necropolis of Casal Bertone fall in this cluster, suggesting a more heterogeneous dietary supply than the other Roman areas.

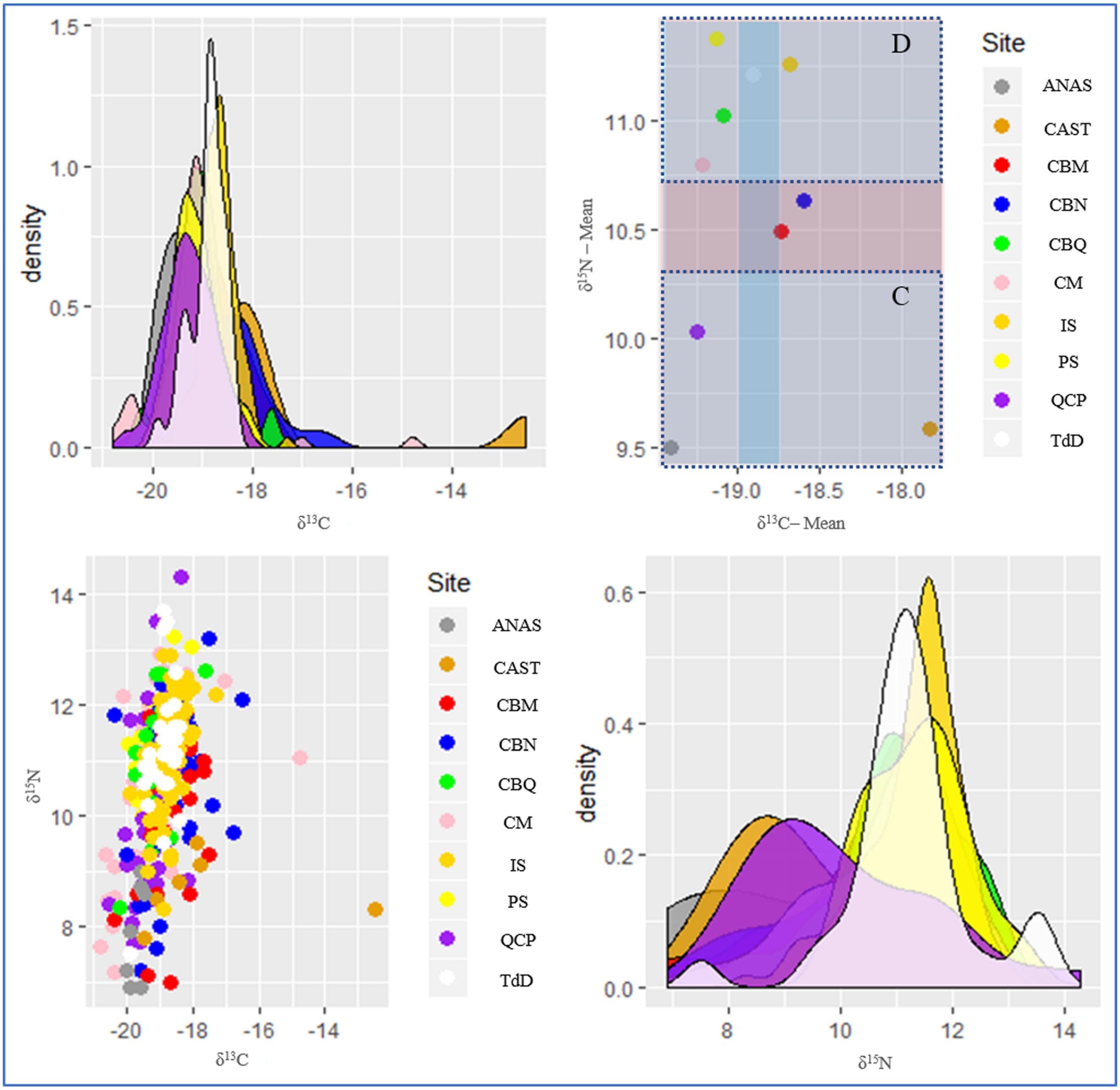

Fig. 7 Data distribution, density plots, and identification of C and D groups by post hoc test

Furthermore, $\delta^{15}N$ values could be useful for determining two additional clusters. The first (group C) groups together ANAS, Castellaccio Europarco, and Quarto Cappello del Prete, while the second (group D) comprises Via Padre Semeria, Castel Malnome, Casal Bertone Area Q, and the samples from Portus and Isola Sacra.

The clusters on the $\delta^{15}N$ axis should display meaningful differences in animal-derived protidic intake. Group C seems to feature lower animal protein intake than group D, where terrestrial fauna and lacustrine and riverine organisms likely provided needed dietary protein.

Again, Casal Bertone samples from the necropolis and mausoleum seem to feature intermediate characteristics. The archaeological differences between them (Musco et al. 2008) are not sustained by anthropological and isotopic evidence. Indeed, De Angelis et al. (2015) already recommended considering these contiguous areas pertaining to a single population related to the *fullonica* that should be decoupled from area Q, where the demographic profile (and dietary habits) suggests a separate community. Even though no certain archaeological data supports this hypothesis, it would be unusual for the funerary buildings of Area Q to be close to a productive area such as the tannery. In our opinion, we should envisage the partial diachronic establishment of the tannery and the funerary buildings comprising Area Q.

The topographical location in the *Suburbium* (eastern suburbs, eastern suburbs close to city walls, southwestern suburbs, southwestern area close to Aurelian walls, Portus and Ostia) seems to indicate some differences (δ^{13}C Kruskal-Wallis chi square = 76.27, $p < 0.01$; δ^{15}N Kruskal-Wallis chi square = 34.92, $p < 0.01$) even though it is hard to identify a cline as well as some other common patterns. Nevertheless, the heterogeneous landscape highlighted in the Ostia and Portus samples is significantly different from eastern (Quarto Cappello del Prete and, close to the city walls, the whole sample of Casal Bertone) and southwestern (Castel Malnome, Castellaccio Europarco, ANAS, and, close to the city walls, Via Padre Semeria) necropolises (Supplementary Tables 5 and 6).

Conclusions

The paper outlines the dietary landscape of Rome in the Imperial period. The evidence presented here provides a unique glimpse into the lives of the people who lived and died in Rome, whose bio-cultural profiles have been previously described through detailed osteological, anthropological, and archaeological evaluations.

The necropolises located outside the city walls are often related to individual low social classes, and people were tied to productive sites or rustic *villae.*

The dietary landscape we provide is heterogeneous and reflects the multifaceted reality of the capital of one of the most influential empires in Antiquity.

The complexity of Roman society remains hard to disentangle even from a dietary point of view, but some elements can be illuminated. One of these is the pivotal role of C_3 plants, which is confirmed as the staple foodstuff of the lower class. However, C_4 plants also seem to have been consumed, albeit they were not widespread. The environment played a critical role for Roman commoners. Even though administrative grain supplements partially sustained them, the topographical location of the settlements (and perhaps of the necropolises where people were buried) determined the preferential consumption of food that people could easily obtain from their neighborhood. People could gain the protidic intake needed to sustain active lifestyles by farming and/or livestock breeding as well as by gathering (fishing and/or hunting). Nevertheless, the complexity of Roman society and trade that passed through Rome during the Imperial period accounted for the broader range of foodstuffs that people could access, making a portrait of the nutritional habits of Romans challenging. However, the meticulous selection of burial grounds in this paper could lead to a less biased reconstruction. Indeed, exotic foods were only partially accessible to commoners, who mainly relied on local food resources, even though markets were accessible, especially to people living close to the city center. The proposed approach represents a powerful tool able to shed light on a crucial aspect of the biological characteristics of this ancient human population but pushing beyond the biological feature. Dietary patterns should be understood as one of the most long-lasting markers of the cultural identity of a population, and the information provided herein represents a step forward in the understanding of the social organization of this ancient society, to be complemented by genomic and isotopic data related to migration, both in synchronic and diachronic perspectives (Killgrove and Montgomery 2016; Antonio et al. 2019; De Angelis et al. in prep). Accordingly, the steady deepening of a combined archaeological and anthropological evaluation will allow us to stratify the Roman sample concerning the bio-cultural factors that impacted the lives of a significant sample of the Roman population.

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Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

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