



Food for Rome: A stable isotope investigation of diet in the Imperial period (1st–3rd centuries AD)

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ABSTRACT

During the Empire, the population of Rome was composed mostly of lower-class free citizens and slaves. Viewed from historical records, the Roman diet included primarily olives, wine, and wheat, but poor and enslaved Romans may have eaten whatever they were able to find and afford, leading to significant heterogeneity in the Roman diet. Previous carbon and nitrogen isotope analyses of skeletons from Imperial Italy have begun to reveal variation in diet, but little is known about what people ate in the capital city. This study complements previous work by adding new isotope data from human skeletons found in two Imperial-period (1st–3rd centuries AD) cemeteries in Rome. These data suggest that urban and suburban diets differed, most notably in the consumption of the C₄ grain millet. Comparing these new data with all published palaeodietary data from Imperial Italy demonstrates that significant variation existed in the diet of the common people.

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Introduction

During the Empire (1st–5th centuries AD), the population of the city of Rome was divided into different social strata. Less than 2% of people were counted among the upper strata of society—those who controlled the government, religion, and economy of both Rome and the Empire—while about 98% of the Roman population was composed of the non-elite—the commoners, slaves, and freedpeople whose social, economic, or legal status prevented them from joining the upper ranks (MacMullen, 1974; Alföldy, 1985; Bradley, 1994; Scheidel, 1997).

In spite of the fact that the vast majority of the population of Rome would have been among the lower socioeconomic strata and perhaps one-third of that population was composed of slaves (Noy, 2000; Scheidel, 2004), the diet of the people of Rome has not been thoroughly investigated. For example, primary sources lay out the contents of the ancient Roman diet, but these histories, novels, and art were produced by and for the upper class, meaning the diets they portray were likely not representative of what the average inhabitant of Rome ate (Garnsey, 1999; Prowse, 2001; Alcock, 2006; Cool, 2006). Scholars have started to realize that understanding the Roman diet is complicated by an elite bias as well as by factors such as sex, age, occupation, and social class (Beer, 2010; Garnsey, 1999; Purcell, 2003; Wilkins and Hill, 2006).

There is little textual evidence of the diet of the lower classes of Rome, although Cato the Elder suggests in *de Agricultura* (160 BC) that slaveholders provide each of their farmhands with certain rations: four *modii* (roughly 26 kg) of wheat and half a liter of olive oil each month; olives, salt, or fish pickle as a condiment; and 42 gallons of wine per annum (White, 1976). The most common grain consumed was wheat (Garnsey, 1999), and in Imperial Rome, the grain dole provided 5 *modii* (roughly 33 kg) of wheat per month to each male citizen (Garnsey and Rathbone, 1985; Garnsey, 1988, 1991). This wheat, however, was unmilled, meaning many people were likely not taking advantage of the dole for lack of resources to process the grain (Spurr, 1983; Sippel, 1987; Garnsey, 1991). An alternative to wheat was millet, which grows easily and cheaply in Italy, but which was often viewed as a substandard grain (Evans, 1980; Spurr, 1983, 1986; Nenci, 1999). A wide variety of vegetables, fruits, and nuts were eaten. Particularly popular in rural areas according to historical sources like Pliny, legumes in the form of lentils, chickpeas, broad beans, and garden peas could be eaten on their own or in a mixture with millet or wheat (Faas, 1994; Garnsey, 1999; Evans, 1980; Spurr, 1983). The role of legumes in the diet of lower-class residents of Rome and rural inhabitants of Italy, however, is still being debated (Garnsey, 1991, 1999).

Our knowledge of the kind and amount of meat consumed by the average inhabitant of Rome is sparse, in spite of the importance of the livestock trade to the Roman economy (Kron, 2002; MacKinnon, 2004). Sources of meat included goat/sheep, poultry, and fish, but probably little beef, and consumption of pork and

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other meats increased in the early Empire (White, 1976; Brothwell, 1988; Brothwell and Brothwell, 1998; Garnsey, 1999; MacKinnon, 2004). Patterns of fish consumption in ancient Rome are particularly unclear, as this category of animal was alternately seen as a threat to seafaring and as a common food; sometimes expensive and sometimes easy to procure; a luxury item in the form of *garum* (fish sauce) and a food of the common fisherman, all depending on the time period in history, a person's social status and occupation, and a variety of other contextual factors (Purcell, 1995; Beer, 2010).

Analysis of the stable isotopes of carbon and nitrogen has been used for decades to characterize human diets in the past because it provides a way to generalize the types and amounts of proteins and plant matter an individual consumed (Katzenberg, 2008), making it ideal for answering questions about the ancient Roman diet. Carbon isotope ratios measured in bone collagen ($\delta^{13}\text{C}$ or $\delta^{13}\text{C}_{\text{co}}$) mainly indicate the protein component of the diet (Krueger and Sullivan, 1984). The measurement of carbon isotopes in bone apatite ($\delta^{13}\text{C}_{\text{ap}}$) provides a picture of dietary energy, including carbohydrates and lipids (Katzenberg, 2008). Stable carbon isotope analysis is often used to distinguish a diet based on C_3 plants—temperate grasses such as wheat and barley—from C_4 plants, including millet and sorghum. Plotting $\delta^{13}\text{C}_{\text{co}}$ versus $\delta^{13}\text{C}_{\text{ap}}$ provides an additional dimension to the carbon isotope data by elucidating an individual's dietary energy source (C_3 , C_4 , or mixed) and protein source (C_3 , C_4 , or marine) (Kellner and Schoeninger, 2007).

In environments where a population was utilizing both aquatic resources (freshwater fish or seafood) and C_4 plants, however, it can be difficult to understand the diet based on carbon isotopes alone (Larsen et al., 1992). Stable isotopes of nitrogen better discriminate between aquatic and terrestrial protein (Schoeninger et al., 1983; Katzenberg, 2008). Understanding nitrogen isotopes involves knowledge of an organism's trophic position in the food chain. An increase in trophic level is known to correlate with an increase in $\delta^{15}\text{N}$ value. Body tissues are generally 3–4‰ higher than the $\delta^{15}\text{N}$ of the diet (Schoeninger and DeNiro, 1984), but the relationship between aquatic protein consumption and human $\delta^{15}\text{N}$ value is not completely straightforward (Hedges and Reynard, 2007). Measurement of both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values has also been used to understand breastfeeding and weaning in past populations (Katzenberg et al., 1996; Fuller et al., 2006; Katzenberg, 2008). Breastfeeding infants consume the product of their mothers' body tissues and therefore occupy a higher trophic level than adults and weaned children. Studies have shown that nursing infants, compared to their mothers, have a ^{15}N enrichment of about 2–3‰ and a ^{13}C enrichment of about 1‰ (Fogel et al., 1989; Fuller et al., 2006).

Carbon and nitrogen isotope measurements of individuals from Imperial Rome can thus provide information on diet within the population, which might differ based on sex, age, or status. Palaeodietary isotope analysis is still a new methodology in the Roman world, particularly in Italy. Two previous studies that have been done in the suburbs of Rome illustrate a general diet composed of cereals and some aquatic resources with regional variation. The largest palaeodietary study was done at Isola Sacra (1st–3rd centuries AD), the cemetery associated with the city of Portus Romae, about 25 km southwest of Rome on the Tyrrhenian Sea (Prowse, 2001; Prowse et al., 2004; Prowse et al., 2005; Prowse et al., 2008). Isotope analyses of the Isola Sacra sample showed that people living on the coast consumed aquatic resources and that diet varied with age. The early Christian necropolis of St. Callixtus (3rd–5th centuries AD) near Rome has yielded lower-than-expected $\delta^{13}\text{C}$ values (Rutgers et al., 2009), which the authors interpret as possible evidence for the consumption of freshwater fish from the Tiber River. Additionally, a large study done at the Imperial site of Velia, 400 km south of Rome on the Tyrrhenian

coast, revealed a diet high in grain but low in meat and aquatic protein; males at the site may have been eating more aquatic prestige foods, however (Craig et al., 2009).

Our analysis focuses on two cemeteries from the city of Rome itself and represents the first dietary study of individuals who lived in Rome during the middle Imperial period. In this study, we report the results of stable carbon and nitrogen isotope analyses of bone samples from two Imperial-period sites located just outside the city walls of Rome: the cemeteries of Casal Bertone and Castellaccio Europarco. Burial style and lack of grave goods suggest the individuals buried at these two sites were from the lower strata of Roman society (Toynbee, 1971; Musco et al., 2008; Buccellato et al., 2008), but differences in grave form at Casal Bertone suggest socioeconomic variation within that population. These average inhabitants of the city and suburbs of Rome likely had inconsistent access to high-quality and high-status food, leading to significant variation in the diet. Specifically, with this stable isotope palaeodietary study, we aimed to explore: (a) differences in diet within and between the periurban Casal Bertone sample and the suburban Castellaccio Europarco sample; (b) age- and sex-related variation in diet; and (c) patterns of resource consumption among Imperial-period people living within the Italian peninsula and the *suburbium* of Rome.

Materials and methods

Roman sites and the suburbium

The city of Rome was not a monolithic, spatially distinct area of Italy, as the *suburbium*, a term that literally means below or outside the walls of Rome, stretched up to 50 km from the city walls (Quilici, 1974; Champlin, 1982; Witcher, 2005). It was a liminal area, neither rural nor urban, that included marginal businesses excluded from the city for religious or public safety reasons, such as slaughterhouses, brick-making facilities, quarry pits, landfills, and cemeteries (Witcher, 2005). Archaeological field surveys suggest that population density within the *suburbium* was high, holding about one-third of a million people (Morley, 1996; Witcher, 2005). A peak in both suburban and urban populations during the Imperial period would have put great pressure on the *suburbium* and its lower-class residents to accommodate additional housing, cemeteries, and people, stretching thin finite resources such as money and food (Carafa et al., 2005).

Samples in this study come from skeletons buried in two Roman cemeteries. The periurban cemetery of Casal Bertone (2nd–3rd centuries AD) was located 1.5 km from the walls of Rome along the ancient *via Praenestina* (Fig. 1). Excavations from 2000–2003 were salvage in nature and uncovered an above-ground mausoleum with niches for single and multiple burial, as well as a necropolis with simple inhumations in pits and in *cappuccina*-style graves (Nanni and Maffei, 2004; Musco et al., 2008). In 2007, a large industrial complex was uncovered just meters from the cemetery, representing either a fullery or tannery, along with an associated residential area (a *villa*) (Musco et al., 2008). Out of a total of 138 individuals, we selected for isotope analysis a demographically-stratified sample of 36 individuals whose age and/or sex could be confidently estimated—24 from the necropolis and 12 from the mausoleum. Castellaccio Europarco (1st–3rd centuries AD) is a rather haphazard burial area near a wall that flanked the ancient *via Laurentina*, almost 12 km from Rome (Fig. 1). In 2003, excavators found a *villa*, the burials, and a large storage building (Grandi and Pantano, 2007; Buccellato, 2007; Buccellato et al., 2008). Out of the 48 Imperial-period burials, we analyzed the carbon and nitrogen isotopes in a demographically-stratified sample of 12 individuals whose age and/or sex could be confidently estimated.

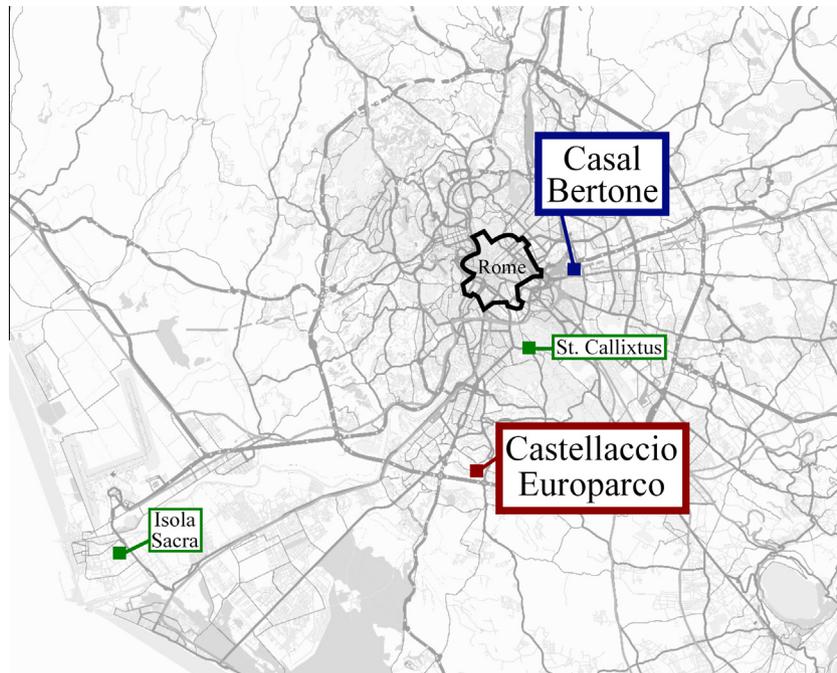


Fig. 1. Imperial Roman and suburban sites.

As the primary goal of this study was to determine the pre-mortem diet of Romans at Casal Bertone and Castellaccio Europarco, femoral mid-shaft sections were taken from adult and older subadult individuals, and rib samples were taken from subadults under 10 years of age. The demographics of the 48 individuals are provided in Table 1. Age-at-death was assessed based on the pubic symphysis (Brooks and Suchey, 1990; Todd, 1921a,b), the auricular surface (Lovejoy et al., 1985), cranial suture closure (Meindl and Lovejoy, 1985), dental development (Moorrees et al., 1963a; Moorrees et al., 1963b; White and Folkens, 2005; Gustafson and Koch, 1974; Anderson et al., 1976), and epiphyseal closure (Baker et al., 2005). Sex of adults was estimated based on pelvic morphology (Phenice, 1969; Buikstra and Ubelaker, 1994) and cranial features (Acsádi and Nemeskéri, 1970).

Collagen extraction and stable isotope measurements

We followed procedures for extracting collagen from bone based on those of Ambrose (1990), which can be summarized as follows (see also Tykot (2004)). Solid bone samples were first placed in 0.1 M NaOH to remove contaminants, followed by demineralization with 2% HCl, a second treatment with 0.1 M NaOH, and finally a 2:1:0.8 defatting mixture of CH₃OH, CHCl₃, and water. The dried and weighed samples were then analyzed with a CHN analyzer connected to a Finnigan MAT stable isotope mass spectrometer for $\delta^{13}\text{C}_{\text{co}}$ and $\delta^{15}\text{N}$. The reliability of the samples was confirmed through measurement of collagen yields and C:N ratios. Specifically, all samples fall into the expected C:N range for well-preserved collagen of 2.9 to 3.6 (DeNiro, 1985), and all

Table 1
Demographics of sample.

Site	Subadult	Male	Female	Total
Casal Bertone	9	16	11	36
Castellaccio Europarco	3	6	3	12
Total	12	22	14	48

samples but one yielded more than 1% collagen, an amount considered likely to contain the original proportions of amino acids (Ambrose, 1990; van Klinken, 1999).

The methods used for extracting carbon from bone apatite are modified from Koch et al. (1997). Bones were first cleaned, and 10 mg of powder was drilled from each sample. The bone sample was dissolved in 2% NaOCl, and non-biogenic carbonates were removed from the sample with 1.0 M buffered acetic acid. Samples were processed by a Finnigan MAT mass spectrometer with a Kiel III individual acid bath carbonate system. The utility of the Koch et al. (1997) method is that it removes non-biogenic carbonates that come from the ground without fractionating the original bone apatite and produces highly consistent results. Further, the apatite samples in this study were weighed after each chemical step to address potential contamination or alteration issues; all weights were consistent, meaning there were no significant ground carbonates present in the samples.

Analytical precision is $\pm 0.1\text{‰}$ for $\delta^{13}\text{C}_{\text{co}}$ and $\delta^{13}\text{C}_{\text{ap}}$, reported with respect to the VPDB standard, and $\pm 0.2\text{‰}$ for $\delta^{15}\text{N}$, reported with respect to AIR.

Results

Isotope ratios of bone collagen and apatite

Human bone

Tables 2–4 present the results of the analysis of bone for carbon and nitrogen isotopes. The C:N ratio and percent collagen yield are listed as an indication of the reliability of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ sample measurements.

Taking all 48 individuals, $\delta^{13}\text{C}_{\text{co}}$ ranges from -19.6‰ to -12.5‰ , with an average of -8.2‰ and standard deviation of 1.1‰ . Within the sample, $\delta^{15}\text{N}$ ranges from 7.0‰ to 13.2‰ , with an average of 10‰ and standard deviation of 1.5‰ . The $\delta^{13}\text{C}_{\text{ap}}$ data from the sample range from -13.8‰ to -8.6‰ , with an average of -11.8‰ and standard deviation of 1.3‰ .

Three individuals stand out immediately as anomalous. ET20 has a $\delta^{13}\text{C}_{\text{co}}$ value more than three standard deviations higher than

Table 2
Castellaccio Europarco $\delta^{13}\text{C}_{\text{co}}$, $\delta^{13}\text{C}_{\text{ap}}$, and $\delta^{15}\text{N}$ results.

Skeleton	Sex	Age	$\delta^{13}\text{C}_{\text{co}}$ (‰ VPDB)	$\delta^{15}\text{N}$ (‰ AIR)	C:N	% Yield	$\delta^{13}\text{C}_{\text{ap}}$ (‰ VPDB)
ET58	F	41–50	–17.9	9.5	3.3	2.2	–10.8
ET18	F	21–30	–18.8	11.0	3.3	2.6	–10.4
ET68 ^a	F	41–50	–18.1	11.5	3.3	0.4	–9.0
ET31	I	0–5	–18.3	11.8	3.2	1.0	–10.9
ET72	M	31–40	–17.8	9.1	3.3	5.7	–10.9
ET69	M	21–30	–19.5	7.8	3.2	2.2	–10.7
ET38	M	41–50	–18.4	8.8	3.2	1.0	–9.8
ET44	M	16–20	–19.1	8.5	3.3	2.3	–9.3
ET20 ^b	M	31–40	–12.5	8.3	3.2	2.0	–8.6
ET36 ^c	I	6–10	–	–	–	–	–10.1
ET67 ^c	I	11–15	–	–	–	–	–12.2
ET27 ^c	M	16–20	–	–	–	–	–10.2
		Mean	–18.5	9.8			–10.5
		St. dev.	0.6	1.5			0.8

All delta values are reported in ‰.

^a Low collagen yield; removed from calculation of means.^b Anomalous values; removed from calculation of means.^c No collagen yield.**Table 3**
Casal Bertone Necropolis $\delta^{13}\text{C}_{\text{co}}$, $\delta^{13}\text{C}_{\text{ap}}$, and $\delta^{15}\text{N}$ results.

Skeleton	Sex	Age	$\delta^{13}\text{C}_{\text{co}}$ (‰ VPDB)	$\delta^{15}\text{N}$ (‰ AIR)	C:N	% Yield	$\delta^{13}\text{C}_{\text{ap}}$ (‰ VPDB)
T20	I	6–10	–19.6	7.2	3.2	6.5	–12.9
T83B	M	16–20	–19.5	8.4	3.1	7.8	–12.6
T82A	F	41–50	–19.1	7.6	3.2	7.4	–12.9
T80	I	11–15	–19.0	9.5	3.2	10.2	–13.1
T21	M	16–20	–19.0	8.0	3.2	3.4	–11.3
T28	F	51–60	–18.6	11.3	3.2	2.7	–11.7
T70	I	6–10	–18.5	10.2	3.2	2.2	–12.2
T7	M	41–50	–18.2	11.0	3.3	2.6	–11.8
T39	PF	16–20	–18.2	11.8	3.1	8.7	–11.7
T13	M	61–70	–18.2	11.1	3.2	4.2	–12.7
T34	M	31–40	–18.1	11.6	3.2	4.7	–11.7
T42	F	31–40	–18.1	9.8	3.2	2.0	–12.5
T36	I	11–15	–18.1	10.8	3.2	3.8	–10.4
T24	M	51–60	–18.1	9.6	3.2	5.8	–12.7
T23	M	21–30	–18.1	11.6	3.2	3.5	–11.4
T50	PF	21–30	–18.0	10.8	3.2	2.6	–12.2
T30	PF	41–50	–17.8	11.0	3.2	4.8	–12.1
T29 ^a	I	0–5	–17.5	13.2	3.2	5.2	–12.2
T71	I	0–5	–17.4	10.2	3.2	3.6	–12.8
T33	M	41–50	–16.8	9.7	3.2	7.6	–
T81 ^b	M	21–30	–	–	–	–	–10.3
T10 ^b	M	31–40	–	–	–	–	–13.8
T76 ^b	M	31–40	–	–	–	–	–12.0
T18 ^b	M	31–40	–	–	–	–	–13.7
		Mean	–18.3	10.1			–12.3
		St. dev.	0.7	1.4			0.8

All delta values are reported in ‰.

^a Removed from calculation of means.^b No collagen yield.**Table 4**
Casal Bertone Mausoleum $\delta^{13}\text{C}_{\text{co}}$, $\delta^{13}\text{C}_{\text{ap}}$, and $\delta^{15}\text{N}$ results.

Skeleton	Sex	Age	$\delta^{13}\text{C}_{\text{co}}$ (‰ VPDB)	$\delta^{15}\text{N}$ (‰ AIR)	C:N	% Yield	$\delta^{13}\text{C}_{\text{ap}}$ (‰ VPDB)
F4B	F	51–60	–19.4	7.1	3.1	6.2	–13.3
F11A	F	31–40	–18.7	7.0	3.3	4.0	–
F9B	I	0–5	–18.6	11.0	3.2	10.8	–12.6
F3C	M	41–50	–18.6	10.1	3.2	6.2	–12.9
F12A	M	31–40	–18.1	11.2	3.2	1.0	–12.8
F10D	I	11–15	–18.1	10.7	3.2	8.8	–12.7
F10C	I	6–10	–18.1	8.6	3.2	11.2	–12.3
F6E	F	51–60	–18.1	10.3	3.2	6.8	–13.2
F1A	F	16–20	–18.1	11.3	3.1	9.3	–12.9
F13C	F	41–50	–17.7	11.0	3.2	3.6	–12.8
F7B	M	16–20	–17.7	10.8	3.1	5.0	–12.6
F5A	M	21–30	–17.5	9.3	3.3	2.9	–11.3
		Mean	–18.2	9.9			–12.7
		St. dev.	0.5	1.5			0.5

All delta values are reported in ‰.

the sample average, as well as a $\delta^{13}\text{C}_{\text{ap}}$ value more than two standard deviations higher than the average. T29 has a $\delta^{15}\text{N}$ value more than two standard deviations higher than the sample average. ET68 has a $\delta^{13}\text{C}_{\text{ap}}$ value more than two standard deviations higher than the sample average, but the low collagen yield for this sample makes the value questionable. Therefore, the mean values and standard deviations listed in the last rows of Tables 2 and 3 have been recalculated after excluding ET20, T29, and ET68.

Comparisons with previous faunal results

In order to illustrate the isotopic composition of foods available to a past population, it is customary to plot domestic and wild faunal remains analyzed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. Unfortunately, animal bone was not available for our analysis. However, animal bone from a variety of species drawn from the Isola Sacra necropolis at Portus Romae was analyzed in conjunction with the human samples by Prowse and colleagues (2001, 2004) and was also used to explicate the palaeodietary analysis of the sample of human bone from St. Callixtus in Rome (Rutgers et al., 2009); in both studies, it was assumed the faunal remains were representative of the local domesticates. Few studies have analyzed aquatic resources in conjunction with human bones from Imperial-period cemeteries in Italy, but Prowse (2001) has provided data from *garum* samples, and Craig and colleagues (2009) have studied aquatic resources associated with the site of Velia, 400 km south of Rome on the Tyrrhenian Sea. These faunal data are plotted in Fig. 2 with the human bone results from Casal Bertone and Castellaccio Europarco.

Although Craig and colleagues (2009) also measured carbon and nitrogen isotopes in terrestrial animals from Velia, they found that the values for herbivores were lower than those reported at Portus Romae (Prowse et al., 2004) and that the human isotope values were similarly lower in terms of both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. The best approximation of the domesticated and wild animals available to the people at Casal Bertone and Castellaccio Europarco is therefore reflected in Fig. 2.

The average $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of the humans from Rome is -18.3‰ and 9.9‰ , respectively, whereas the values for the herbivores are -20.6‰ and 5.3‰ , respectively. It would appear that the people buried at Casal Bertone and Castellaccio Europarco were, on average, 2.3‰ higher in $\delta^{13}\text{C}$ and 4.6‰ higher in $\delta^{15}\text{N}$ than the

terrestrial animals from Portus Romae. Both groups from Rome likely ate a diet that was largely based on C_3 plants and herbivores, with some contribution from aquatic protein (either marine or freshwater fish) and/or C_4 plants.

Variation in Imperial Italy and the Roman suburbium

Only a handful of palaeodietary studies have been done in Imperial Italy. Prowse and colleagues analyzed skeletons from the necropolis of Isola Sacra associated with Portus Romae (Prowse, 2001; Prowse et al., 2004, 2005); Rutgers and colleagues published a small dietary analysis from the Christian necropolis of St. Callixtus (Rutgers et al., 2009) (see Fig. 1 for Rome-area sites); and Craig and colleagues conducted a large dietary analysis from the south coastal site of Velia (Craig et al., 2009). Although Prowse (2001) published additional sample data ($n = 14$) from the salvaged cemetery in the Roman suburbs known simply as ANAS, the skeletal material was not well preserved. Since age-related dietary differences have been found within the sample from Portus Romae (Prowse et al., 2004, 2005, 2008) and sex-related differences were found within the sample from Velia (Craig et al., 2009), it is problematic to compare the material from Casal Bertone and Castellaccio Europarco with that from ANAS, where age-at-death and sex of the individuals are unknown.

The mean and 1σ standard deviation for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of adults from the five Imperial sites are presented in Table 5, excluding ET20. Fig. 3 displays all the isotope data gathered from adult human bone from the five archaeological sites; in order to better view the variation within the comparative sites, individual ET20 was excluded from this graph.

Many of these Imperial datasets, however, present difficulties for comparison with the present study materials. As noted above, we should not expect the people from Rome to have similar carbon and nitrogen isotope values as the people from Velia, where both humans and terrestrial animals had significantly lower isotope values than did the comparable samples from Portus Romae, 400 km away. Testing this hypothesis reveals that the adults from Rome ($n = 30$) and the adults from Velia ($n = 116$) are indeed significantly different in terms of both $\delta^{13}\text{C}$ (Mann–Whitney $U = 210.5$, $p \leq 0.001$) and $\delta^{15}\text{N}$ ($U = 866.5$, $p \leq .0001$). Although the faunal isotope values are only part of Craig and colleagues' (2009)

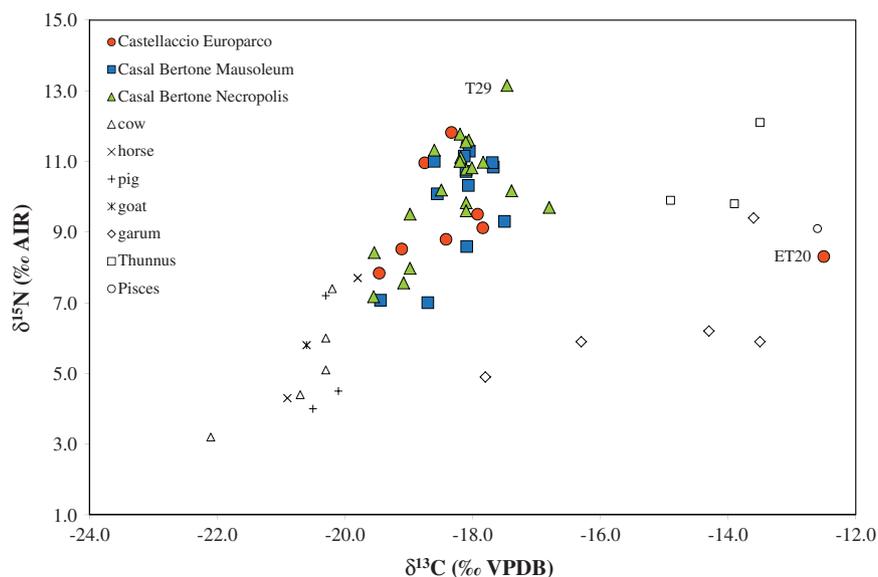


Fig. 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for humans from Rome with fauna from Portus Romae and Velia. Terrestrial faunal data and *garum* samples are from Prowse (2001); aquatic faunal data are from Craig et al. (2009).

Table 5
Mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from adults – Imperial cemeteries.

	$\delta^{13}\text{C}$ ‰ VPDB	$\delta^{15}\text{N}$ ‰ AIR
Casal Bertone	-18.2 ± 0.6	10.0 ± 1.5
Castellaccio Europarco	-18.5 ± 0.6	9.5 ± 1.3
St. Callixtus	-19.7 ± 0.4	10.6 ± 0.5
Isola Sacra	-18.8 ± 0.3	10.8 ± 1.2
Velia	-19.4 ± 0.3	8.7 ± 1.3

explanation for the clear differences between humans at Velia and Portus Romae, the isotopic shift makes it problematic to further compare humans from Imperial Velia with humans from Imperial Rome.

We also expected the individuals from St. Callixtus to differ in dietary composition from those at Casal Bertone and Castellaccio Europarco, as St. Callixtus dates to the late Empire (3rd–5th centuries AD) and likely represents the remains of Christians, a growing sect within Imperial Rome. Rutgers and colleagues (2009) interpreted the comparatively low $\delta^{13}\text{C}$ values as possibly related to freshwater fish consumption as a result of Christian asceticism. Our hypothesis that adult $\delta^{13}\text{C}$ values between the middle Imperial sites of Casal Bertone and Castellaccio Europarco ($n = 30$) and the late Imperial site of St. Callixtus ($n = 16$) would differ was borne out (Mann–Whitney $U = 19$, $p \leq 0.0001$), although $\delta^{15}\text{N}$ values were not significantly different. While there is clear variation between St. Callixtus and Casal Bertone and Castellaccio Europarco, particularly in carbon isotope values, it is unclear if that variation is related to time period, religion, or another variable.

Portus Romae remains the best sample with which to compare the results from Casal Bertone and Castellaccio Europarco, owing to their geographic, temporal, and sociocultural similarities. Nevertheless, Portus Romae was located on the Tyrrhenian Sea rather than inland, suggesting the average $\delta^{15}\text{N}$ value should be higher at Portus Romae than at either Casal Bertone or Castellaccio Europarco. The $\delta^{15}\text{N}$ values from the inland Rome samples ($n = 30$) and the coastal Portus Romae samples ($n = 78$) are indeed significantly different (Mann–Whitney $U = 1532$, $p \leq 0.01$). Significance persists when the inland samples are broken down by site and burial style and compared to Portus Romae using t tests (Casal

Bertone mausoleum $t = 2.89$, $p = 0.004$; Casal Bertone necropolis $t = 3.11$; $p = 0.002$; and Castellaccio Europarco $t = 2.59$; $p = 0.01$). The adults from Portus Romae had a significantly higher average $\delta^{15}\text{N}$ value than the adults from the two inland Roman sites, indicating greater consumption of aquatic resources by the population living near the Tyrrhenian Sea. In addition, the $\delta^{13}\text{C}$ values are significantly different between Portus Romae and the two sites in Rome (Mann–Whitney $U = 577$, $p \leq 0.0001$), with the inland sites having higher average $\delta^{13}\text{C}$ values.

Individuals from Casal Bertone and Castellaccio Europarco differed significantly from all three comparative populations in terms of $\delta^{13}\text{C}$ values and from the coastal sites of Portus Romae and Velia in terms of $\delta^{15}\text{N}$ values. There was a considerable amount of variation present in dietary protein sources in Imperial Italy, but we are only beginning to understand how the diet may have varied along the lines of age, sex, geography, socioeconomic status, and religious background.

Variation within Rome

Within the urban metropolis of Rome, it is likely that variation in diet existed. Poor male citizens were eligible for the wheat dole, which they may have shared with their wives and children, but freedmen and slaves were excluded from receiving this handout. Domestic slaves may have eaten well alongside their masters, while agricultural slaves may have been granted the bare minimum for survival. Fig. 2 revealed variation within the samples from Rome, but in comparing the adults at Casal Bertone ($n = 23$) and Castellaccio Europarco ($n = 7$, which excludes ET20), neither t tests nor Mann–Whitney U tests reveal differences in the mean values for $\delta^{13}\text{C}_{\text{co}}$ or $\delta^{15}\text{N}$. There is a statistical difference, however, in the $\delta^{13}\text{C}_{\text{ap}}$ values from each sample ($t = 7.38$, $p \leq 0.0001$; Mann–Whitney $U = 216$, $p \leq 0.0001$), with the Casal Bertone sample having a lower average $\delta^{13}\text{C}_{\text{ap}}$ value than that of Castellaccio Europarco.

The $\delta^{13}\text{C}_{\text{ap}}$ measurements were further investigated within the Casal Bertone sample, in terms of age-at-death, sex, and burial location. No significant differences in $\delta^{13}\text{C}_{\text{ap}}$ were found between Casal Bertone males and females or between subadults and adults. A statistically significant result was obtained in the $\delta^{13}\text{C}_{\text{ap}}$ values of the individuals from the mausoleum and those from the

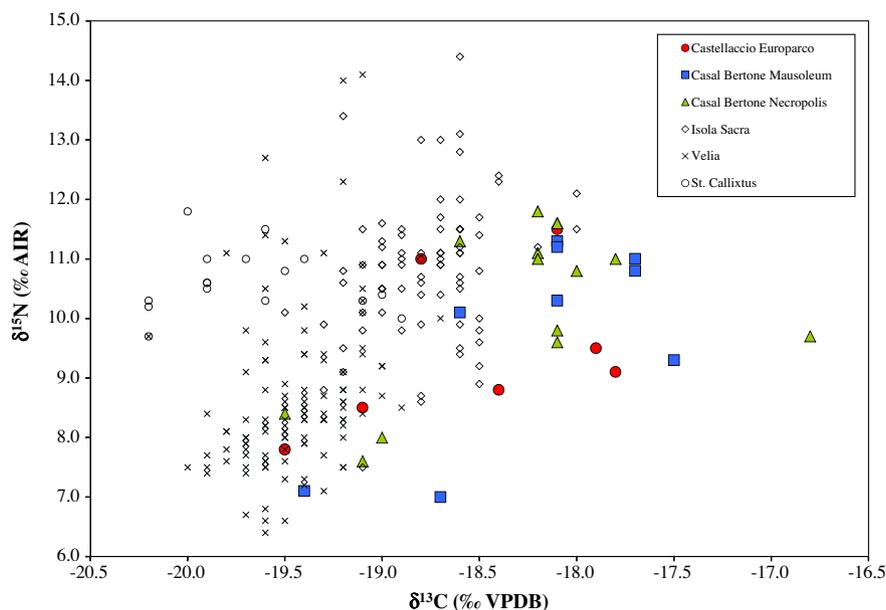


Fig. 3. Adult $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data from comparative sites.

necropolis, however (Mann–Whitney $U = 92$, $p = 0.04$). The Casal Bertone mausoleum sample has the lowest average $\delta^{13}\text{C}_{\text{ap}}$ values, compared to the necropolis and to Castellaccio Europarco. The sample from Castellaccio Europarco was too small to be further subdivided into age, sex, or burial groups.

Plotting the $\delta^{13}\text{C}_{\text{ap}}$ values against the $\delta^{13}\text{C}_{\text{co}}$ values is useful for visualizing the contributions to the Roman diet of marine protein as well as C_3 and C_4 protein and energy. Fig. 4 provides a scatter plot of carbon isotope values from collagen and apatite, displayed with reference to the regression lines formulated by Kellner and Schoeninger (2007).

While ET20 falls along the marine protein line in Fig. 4, his $\delta^{15}\text{N}$ value of 8.3‰ is much lower than would be expected for someone consuming significant amounts of marine protein. Keenleyside and colleagues (2009) have suggested that non-elevated $\delta^{15}\text{N}$ values coupled with high $\delta^{13}\text{C}$ values could reflect consumption of *garum* or low trophic-level fish. The $\delta^{13}\text{C}_{\text{co}}$ and $\delta^{13}\text{C}_{\text{ap}}$ values for ET20, however, suggest that more than 50% of this individual's dietary protein must have come from C_4 resources or low trophic-level fish. The marine resources available in Rome, other than *garum*, do not have particularly low $\delta^{15}\text{N}$ values (Prowse et al., 2004), and it is very unlikely that over half of this man's dietary protein came from *garum*. Further, many of the other individuals from Castellaccio Europarco also have at least partly elevated $\delta^{13}\text{C}_{\text{co}}$, noticeably elevated $\delta^{13}\text{C}_{\text{ap}}$, and modest $\delta^{15}\text{N}$, leading us to conclude that, although consumption of *garum* or lower trophic-level fish is a possibility for ET20, it is most likely this individual was consuming a significant amount of C_4 protein with the addition of some C_3 and marine protein. ET20 may have been dependent on millet for protein and carbohydrates and/or he may have been consuming the meat or other products of an animal foddered on millet.

The scatter along the $\delta^{13}\text{C}_{\text{ap}}$ axis further suggests that the people of Castellaccio Europarco were drawing more of their dietary energy from C_4 resources than were the adults from Casal Bertone. The statistically significant differences in $\delta^{13}\text{C}_{\text{ap}}$ values between Casal Bertone and Castellaccio Europarco as well as between the Casal Bertone necropolis and mausoleum are therefore most likely related to differential consumption of millet.

Variation by age and sex

Some researchers have found differences in diet related to age and sex among cemetery populations in the Roman Empire

(Prowse et al., 2004, 2005; Dupras et al., 2001), but others have found no differences (Craig et al., 2009; Keenleyside et al., 2006; Keenleyside et al., 2009). The number of individuals in our study is comparatively small, so interpretation of differences seen in Fig. 5 must be viewed with caution.

In examining variation in subadults, we expected that children who were still nursing or who had been recently weaned would present isotope values higher than those of the average adult female, of around 1‰ in $\delta^{13}\text{C}$ and $2\text{--}3\text{‰}$ in $\delta^{15}\text{N}$. Three subadults from the sample ($n = 10$) displayed high $\delta^{15}\text{N}$ values. ET31, around 3 years old at death, had a $\delta^{15}\text{N}$ value of 11.8‰ , which is 1.1‰ higher than the adult female average from Castellaccio Europarco. F9B, between 1 and 2 years old at death, had a $\delta^{15}\text{N}$ value of 11.0‰ , which is 1.7‰ higher than the adult female average from the Casal Bertone mausoleum. T29, between 2 and 3 years old at death, had a $\delta^{15}\text{N}$ value of 13.2‰ , which is 2.8‰ higher than the adult female average from the Casal Bertone necropolis, as well as a $\delta^{13}\text{C}$ value 0.8‰ higher than the adult female average.

Fig. 5 shows that both sex categories and both age groups from Casal Bertone are equally widely dispersed on both axes, but the female and male groups from Castellaccio Europarco form distinct clusters on the $\delta^{15}\text{N}$ axis that do not overlap. Nevertheless, a two-tailed t test of the Castellaccio Europarco sex-segregated means of $\delta^{15}\text{N}$ is not statistically significant ($t = 3.45$; $p = 0.08$).

One male from Castellaccio Europarco was eating a very different diet than anyone else in the sample from Rome. Figs. 4 and 5 reveal the aberrant diet of individual ET20, who died in his 30s. His very high $\delta^{13}\text{C}_{\text{co}}$ value of -12.5‰ puts him quite close to the $\delta^{13}\text{C}$ range of modern millet of -12.0 to -10.7‰ (McGovern et al., 2004). Although his $\delta^{13}\text{C}_{\text{ap}}$ measurement is the highest found in this study, it is not significantly higher than others from Castellaccio Europarco. This individual's $\delta^{13}\text{C}_{\text{co}}$ and $\delta^{13}\text{C}_{\text{ap}}$ values therefore suggest he may have consumed large quantities of millet, and his $\delta^{15}\text{N}$ value supports the interpretation that he may have been eating them with beans or other legumes, a practice well-attested among the rural people of Imperial Italy (Spurr, 1983).

Discussion

Dietary heterogeneity in Rome and the suburbium

The extant primary source material on the ancient Roman diet was written by upper-class Roman authors: agricultural methods

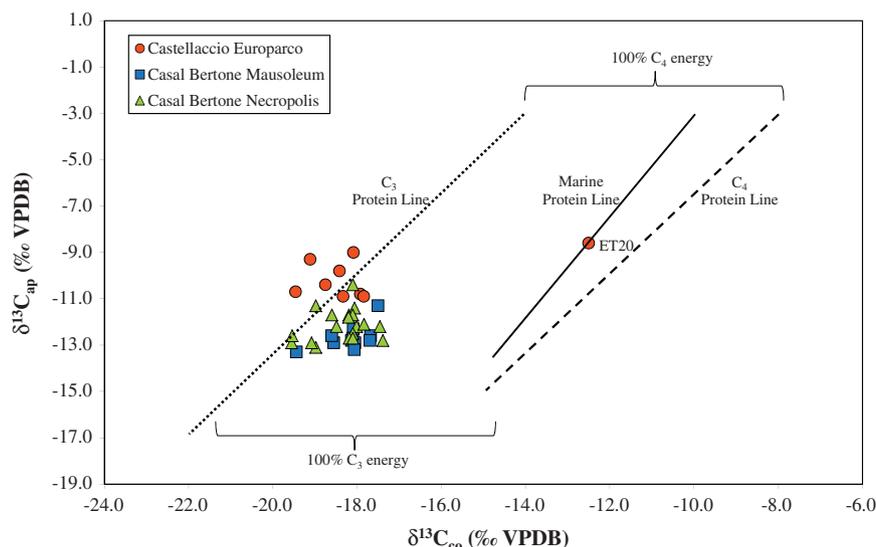


Fig. 4. $\delta^{13}\text{C}_{\text{co}}$ versus $\delta^{13}\text{C}_{\text{ap}}$.

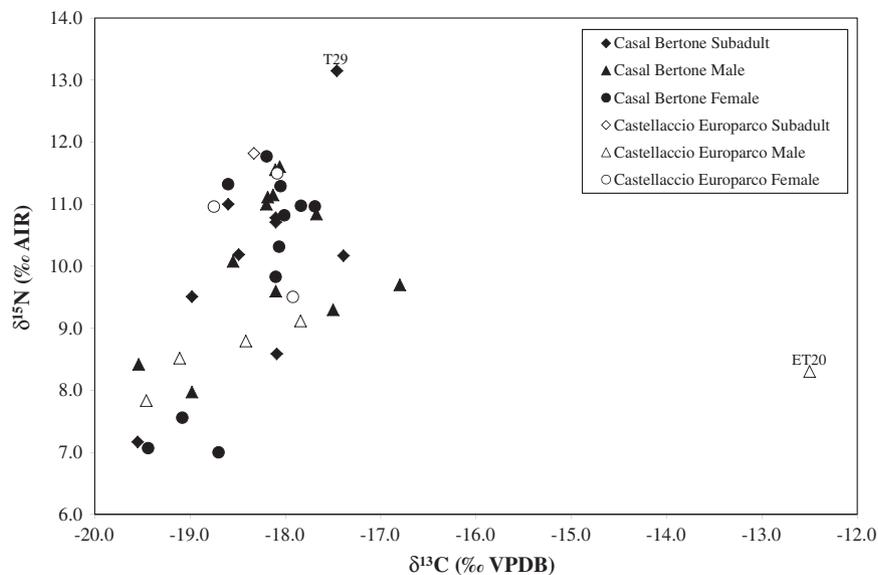


Fig. 5. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ by age and sex.

were detailed primarily by Cato (*de re Agricultura*, 2nd century BC), Varro (*de re Rustica*, 1st century BC), and Columella (*de re Rustica*, 1st century AD). By the fourth century AD, a cookbook of recipes had been compiled, *de re Coquinaria*, often attributed to Apicius but likely a collection by a variety of people. These recipes have been used to understand what cooking was like in this area of the world before the introduction of tomatoes and the invention of pasta. The cookbook includes numerous recipes involving meat (from birds, mammals, and fish), legumes, and fruit and vegetables. Many recipes, however, were quite exotic and probably do not characterize the diet of the lower-class individuals investigated in this study. Similarly, feasts and banqueting depicted in such works as Petronius' *Satyricon* and visual representations of food from mosaics and frescoes in upper-class houses at Pompeii are probably not representative of the diet of the average inhabitant of Rome. In general, scholars discuss the basic Roman diet as a "Mediterranean triad" composed of cereals, wine, and olives (Garnsey, 1999).

Variation in the diet of the lower classes of Rome can be examined using the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data from Portus Romae, St. Callixtus, Casal Bertone, and Castellaccio Europarco. Adults from coastal Portus Romae present the highest average $\delta^{15}\text{N}$ values but $\delta^{13}\text{C}$ values lower than the middle Imperial samples from Rome. As Portus Romae was located on the Tyrrhenian coast, it is not unexpected to find that its people were consuming nitrogen-enriched aquatic protein. The individuals buried in the necropolis at St. Callixtus also have higher average $\delta^{15}\text{N}$ values than the samples from Casal Bertone and Castellaccio Europarco. As the St. Callixtus necropolis was located about 3 km from the Tiber River, people living in the area could have had access to aquatic resources. Rutgers and colleagues (2009) interpret the comparatively low $\delta^{13}\text{C}$ values from individuals in the St. Callixtus necropolis as evidence of consumption of freshwater fish. If these individuals were Christians in largely pagan Rome, their diets may have been atypical due to asceticism.

The average adult $\delta^{15}\text{N}$ values of samples from Casal Bertone and Castellaccio Europarco are lower than those from Portus Romae and St. Callixtus, suggesting a diet composed of mostly terrestrial protein. It does not appear that legumes constituted the bulk of the protein component of the diet at any of the sites in the Roman suburbs. The average $\delta^{13}\text{C}$ values from Casal Bertone and Castellaccio Europarco, on the other hand, are slightly higher

than those at Portus Romae and quite a bit higher than those of St. Callixtus. A higher $\delta^{13}\text{C}$ signature coupled with a $\delta^{15}\text{N}$ average on par with surrounding contemporaneous sites indicates the consumption of more C_4 foods by the people at Casal Bertone and Castellaccio Europarco.

Comparative analysis of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of skeletal populations from the Roman *suburbium* indicates that terrestrial meat and C_3 plants such as wheat made up a large portion of the average diet. Beyond this, however, there is significant variation between sites, as some groups consumed fresh- and/or salt-water protein resources and some consumed C_4 plants.

Additional isotope research is needed on dietary practices in Rome and the Italian peninsula throughout the Imperial period in order to better understand the diversity of foodways and exploitation of local resources.

Breastfeeding and weaning Roman children

In his 2nd century AD work *Gynaecology*, Soranus recommends children be breastfed for at least six months before the introduction of weaning foods such as cow or goat milk, wine mixed with water, honey, and cereals (porridge), with complete weaning by age 2. It is unknown, however, to what extent women followed these recommendations. Upper-class Roman women did not breastfeed their infants for very long if at all, and they routinely contracted out the nutritional needs of their offspring to female slaves and lower-class women who acted as wet-nurses for 6–18 months (Garnsey, 1989; Fildes, 1986; Lefkowitz and Fant, 2005).

Direct evidence of breastfeeding and weaning in Imperial Rome therefore comes from stable isotopic analyses of diet. Prowse and colleagues (2001, 2008) found a significant difference in both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in infants under 2 years of age buried at the Isola Sacra cemetery of Portus Romae and suggested that weaning occurred some time between 3 months and 2 years of age. At St. Callixtus, one subadult was found whose $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were higher than the adult female sample, suggesting this two-year-old was still being breastfed at time of death (Rutgers et al., 2009).

Three subadults under the age of four were examined in this study: T29, ET31, and F9B. They all display $\delta^{15}\text{N}$ values 1–3‰ higher than those of the adult females. Only T29, however, displays

both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values expected from a child that was still obtaining the majority of his or her nutritional needs from breast milk. Bone turnover rate in subadults is not precisely known (Herring et al., 1998), but given historical documents and bioarchaeological findings at other sites, it is likely that ET31 and F9B may have been in the process of being weaned.

Stable isotopic evidence of breastfeeding in the city of Rome is sparse at the moment. Based on the few data points from St. Callixtus, Casal Bertone, and Castellaccio Europarco, children in the age range of 2–3 were still being nursed but were probably weaned shortly thereafter. This contrasts with Portus Romae, where Prowse and colleagues (2008) found an earlier age of weaning; however, the Portus Romae study was large, involving dozens of subadult samples. More stable isotope studies specifically aimed at understanding breastfeeding and weaning in the city of Rome could provide additional insights into childhood health, gender relations, and differences in social status.

Millet consumption and social stratification

The historical record of Imperial Rome is ambivalent about human consumption of millet, so it is currently unclear to what extent Romans ate this grain. Millet is often mentioned in reference to famines and food shortages (Evans, 1980; Spurr, 1983; Garnsey, 1988), a grain for the poor because it was easy to grow, with the climate of Italy being able to yield up to three plantings per year of both *Setaria italica* and *Panicum miliaceum* (Spurr, 1986). Pliny the Elder, for example, writes in his *Historia Naturalis* (1st century AD) that bean-meal was often mixed with millet by the common people in rural Italy, and Columella in his *de re Rustica* comments that millet sustained the population of many of Italy's provinces. Millet had commercial value in the Roman economy as evidenced by the Edict of Diocletian (301 AD), which set a similar maximum price for all three major cereals; however, millet might have been used for animal fodder, to leaven bread, and as birdseed for hens and pigeons rather than being directly eaten (Spurr, 1983). Both modern and ancient perceptions of millet as a substandard grain may contribute to the assumption that it was not often consumed by humans (Nenci, 1999), but stable isotope analysis can be used to critically evaluate this assumption. The only major study of millet consumption in Italy from a bioarchaeological perspective, however, was undertaken on four Bronze Age (16th–12th centuries BC) samples, two each from northern and southern Italy (Tafari et al., 2009). That study demonstrated that northern Italians in the Bronze Age consumed significantly more C_4 resources than southern Italians but that both geographic groups also ate C_3 plants. New evidence of C_4 resource use has been found in Roman Britain as well (Pollard et al., 2011). Thus far, consumption of C_4 plants has only been demonstrated in isolated individuals in the Roman Empire, suggesting we are only beginning to understand how millet figured into the diet and the economy.

The two study sites of Casal Bertone and Castellaccio Europarco are from different contexts: whereas the Casal Bertone cemetery was periurban, located just outside the city walls of Rome, the Castellaccio Europarco cemetery was likely associated with a large agricultural area. These facts combined with known topographical and ecological variations in the Alban Hills area of Italy mean that we should expect differences in food resources consumed by individuals buried at these two sites. Fig. 4 clearly shows that the $\delta^{13}\text{C}_{\text{ap}}$ measurements differ between the periurban and suburban samples, with the individuals buried at Casal Bertone getting more of their energy from C_3 foods than were the people buried at Castellaccio Europarco, whose $\delta^{13}\text{C}_{\text{ap}}$ values suggest they were obtaining more energy from C_4 foods. The people from suburban Castellaccio Europarco therefore were likely consuming millet to

a much greater extent than were the people buried at periurban Casal Bertone.

Further, the $\delta^{13}\text{C}_{\text{ap}}$ values of the Casal Bertone mausoleum and necropolis samples show an interesting difference, with individuals from the mausoleum having significantly lower $\delta^{13}\text{C}_{\text{ap}}$ values than those in the necropolis. A mausoleum was more expensive than was burial in a simple pit or a *cappuccina*-style grave; whereas the *cappuccina* graves at Casal Bertone were created using repurposed roof tiles, the mausoleum was a freestanding architectural work, complete with carved niches, inscriptions, painted plaster walls, and a black-and-white mosaic floor (Musco et al., 2008). Nevertheless, only 10% of the mausoleum burials had associated artifacts, including coins, nails, jewelry, and pottery. Comparable mausolea exist from the Roman suburbs and in the cemetery of Isola Sacra at Portus Romae (Toynbee, 1971); inscriptions indicate that these mausolea were generally owned either by one family or by a guild (*collegium*). Although the deceased buried in an above-ground mausoleum may appear to be wealthier than those buried in the simple necropolis, the low cost of buying into a *collegium* and the fact that families often buried their slaves within their mausolea mean that social status in Rome cannot be deduced simply from burial treatment. It is possible that the mausoleum at Casal Bertone was associated with the large industrial complex on site; this fullery or tannery may have produced a workers' guild (Musco et al., 2008).

Results of this dietary study suggest that individuals interred in the Casal Bertone mausoleum were eating less millet than were their necropolis counterparts, and that both Casal Bertone groups collectively were eating less millet than those buried in the suburbs. As millet was considered a substandard grain in the Roman Empire, one associated with the poor and famine, the people at Casal Bertone, particularly those buried in the mausoleum, may have been of higher socioeconomic status than those buried at Castellaccio Europarco. The data series are small but suggest that variation within the energy portion of the diet related to consumption of millet may be a way to differentiate among groups of people buried in Rome-area cemeteries with respect to socioeconomic status.

Conclusions

Results of the dietary analysis from periurban Casal Bertone and suburban Castellaccio Europarco indicate the two groups of people were utilizing different food resources. Whereas individuals living closer to the city of Rome were consuming some aquatic resources, those in the *suburbium* made greater use of millet, leading us to conclude that differential use of millet may have been influenced by socioeconomic standing. Within the sample from each site, there is no significant evidence of sex-related variation. Evidence of one breastfeeding child was found from Casal Bertone, demonstrating a lengthier period of nursing than the minimum advocated by ancient physicians.

Comparisons between the diets of individuals at Casal Bertone and Castellaccio Europarco with Imperial-period sites from the Italian peninsula show that there was no singular Roman diet. To a base of cereals, olives, and wine were added terrestrial meat, legumes, fish, and millet in different proportions and from different sources. Although copious amounts of food were imported from various areas of the Empire—grain from north Africa, olive oil from Greece, wine from France—the diet of the average lower-class Roman was likely contingent on foodstuffs available in the immediate area.

This palaeodietary analysis of two sites in the Roman *suburbium* demonstrates the variation that existed in the diet of the common people. More stable isotope research is needed on samples from Rome and Imperial Italy, in addition to zooarchaeological and

palaeobotanical studies, in order to more fully understand the variety of natural resources available for both human and animal consumption in this important historical time period.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.jaa.2012.08.002>.

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