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Uniform Diet in a Diverse Society. Revealing New Dietary Evidence of the Danish Roman Iron Age Based on Stable Isotope Analysis

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ABSTRACT A systematic dietary investigation during Danish Roman Iron Age (1-375AD) is conducted by analyzing stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in the collagen of human and animal bone. The human sample comprises 77 individuals from 10 burial sites. In addition 31 samples of mammals and fish were analyzed from same geographical area. The investigation characterizes the human diet among different social groupings and analyses dietary differences present between sex, age, and site phase groups. Diachronically, the study investigates the Roman influences that had an effect on social structure and subsistence economy in both the Early and Late Period. Geographically the locations are both inland and coastal. The isotopic data indicate extremely uniform diet both between and within population groups from Early and Late Roman periods and the data are consistent throughout the Roman Iron Age. Protein consumption was dominated by terrestrial animals with no differences among social status, age, sex, or time period, while terrestrial plant protein only seems to have contributed little in the diet. Furthermore, the consumption of marine or aquatic resources does not seem to have been important, even among the individuals living next to the coast. Am J Phys Anthropol 000:000–000, 2010. ©2010 Wiley-Liss, Inc.

Evaluating human dietary patterns is one way of understanding the relationship among food production, subsistence economy, and culture. By using stable isotope analysis of carbon and nitrogen inferences may be made regarding social and economic aspects of prehistoric diet. The interpretation of isotopic compositions of past diet is based on comparing the isotopic compositions of bone collagen as well as available food because the building blocks of bone collagen (amino acids) retain the isotopic composition of the foods that contributed to the formation of that collagen (Ambrose and Norr, 1993). This type of analysis is now well established and widely applied in dietary studies, but isotopic compositions can only be used to distinguish certain food groups rather than individual meal ingredients. Thus stable isotope analysis provides a method for independently testing dietary reconstruction that is generated from interpretation of other sources of evidence.

Isotopic data available for Iron Age populations in Europe so far stem mostly from relatively few isolated case-studies which cover a range of burial and social contexts where variation and distinction between the sexes and among social status and geographical locations are evident (e.g. Murray and Schoeninger, 1988; Richards et al., 1998; Prowse et al., 2004, 2007; Le Huray and Schutkowski, 2005; Bocherens et al., 2006; Müldner and Richards, 2007; Ericsson et al., 2008; Rutgers et al., 2009). Here we present stable isotope data from just a couple of 100 km from the river Elb, the nearest border of the Roman Empire. The focus is on East Denmark, where several changes occurred during the transition from early to late Roman Iron Age. A centralized hierarchical structure emerged from small chiefdoms. New elites were established and contact with the Roman world is evident from the imported grave goods. In addition, a combination of increased human activity and climate change (to a cool, wetter climate) lead to a profound change in the environment and substantial agricultural development (Jensen, 1995: p 195).

The aim of this study was to conduct a systematic synchronic and diachronic investigation of ancient Danish human diet from inhumations covering the Early Roman Iron Age (AD1-150/200) and Late Roman Iron Age (175/200-375AD) using carbon and nitrogen isotope analysis of bone collagen.

DIET DURING THE ROMAN IRON AGE—THE ARCHAEOLOGICAL EVIDENCE

Archaeological evidence from this period in East Denmark plays an integral role in dietary reconstruction. Remains of food and food debris from burial and settlement sites include the faunal bones of mainly cow,

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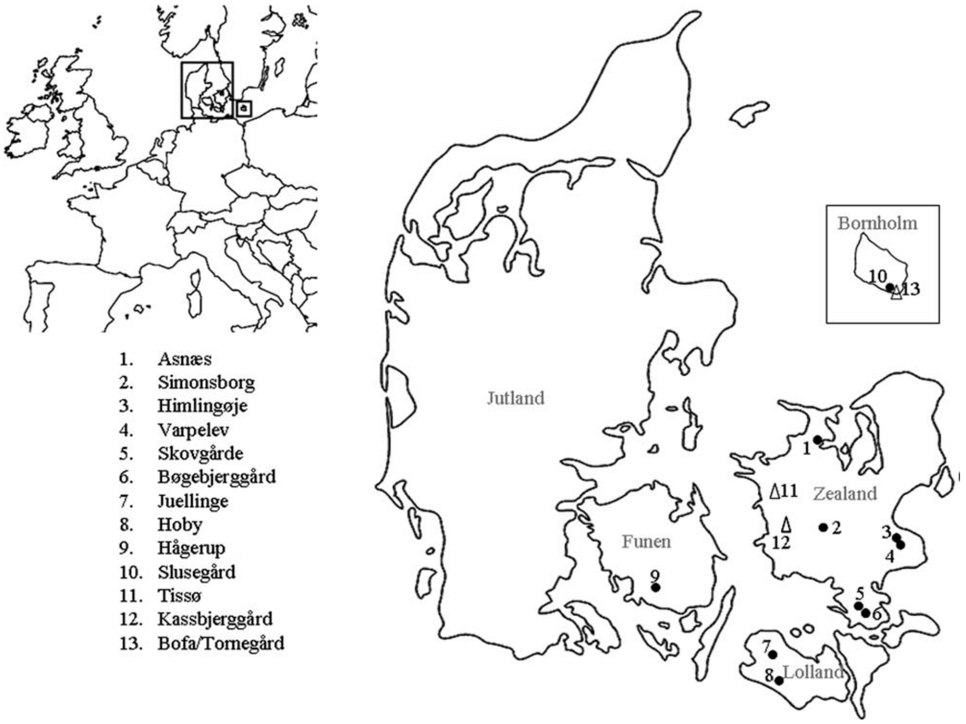

Fig. 1. Map of Denmark showing the sites from which human and animal samples have been obtained.

sheep/goat, and pig with very few wild animals, poultry and marine/freshwater fish (Higham, 1967; Enghoff, 1999, 2000; Hvass, 2001; Gotfredsen, 2003) botanical remains from settlements (Robinson, 1994; Tornbjerg, 1999), and those found in stomach contents of Danish bog bodies (Hvass, 2001). There are also remains of storage structures, farming utensils such as ploughs, querns, sieves, millstones, knives, hooks, and other items connected with the processing of food (Kaul, 1985; Jensen, 2003). In contrast to the diet of animals, human diet is not chiefly determined by accessible resources, but is the result of a variety of choices. One also needs to be aware that there are many differences in food consumption that the isotopic record cannot detect (Gumerman, 1997: p 120). While the importance of livestock resources in Denmark are well-known among archaeologists (e.g., Hedeager, 1992; Hvass, 2001; Jensen, 2003) it has not been possible until now to characterize their dietary contributions. In terms of plant resources, the archaeobotanical evidence point to barley being the most commonly cultivated crop (Robinson, 1994). Barley is commonly grown for animal fodder, although residue analysis shows it was used for making beer (Jensen, 2003: p 319). However, evidence also shows a variety of utility plants such as legumes, spurrey, and flax were grown near farmsteads (Robinson, 1994: p 34), while various wild seed plants, fruits, nuts, and mushrooms could be gathered in the surrounding landscape.

If resources were differentially allocated among socially distinct groups (as seen in other dietary studies of European Iron Age e.g., Richards et al., 1998; Le Huray and Schutkowski, 2005; Müldner and Richards, 2007), it could be assumed that lower status diet was based on greater plant consumption. Hypothetically higher status should be associated with more and better economic means allowing consumption of foods from higher in the food chain. Animal husbandry and an enhanced consumption of animal-derived foodstuffs could therefore be expected among high status people.

MATERIALS

Human samples

Samples were selected from 10 different cemeteries in East Denmark (Fig. 1, Table 1). Material from Jutland was not included due to very poor preservation conditions. Bone samples were processed from a total of 77 human individuals who came from coastal and inland sites, rich and simple burials dating to both Early and Late Roman periods. The age groups for adults include: young (17–25 years), middle (26–45 years), old adult (46+ years), and adult (18+). The subadult age groups include infants (<2 years), Children (2–10 years), and Juveniles (11–16 years). All human remains used in this study were provided by the National Museum of Denmark and the Laboratory of Biological Anthropology, University of Copenhagen.

Faunal samples

To provide an isotopic framework for the human data, a faunal isotopic baseline of the local temperate environment needed to be established. Because the sites were graves/cemeteries as opposed to settlements, only small amounts of animal remains were found. Only three of the sites had animal remains found in the graves. These include the rich grave sites at Himlingøje, Skovgårde, and Hågerup. Additional faunal assemblages therefore had to be obtained. These were selected from nearby or temporally similar settlements (Kassebjerggård on Zealand and Bofa/Tornegård on Bornholm; see Fig. 1). Thirty-one animals were processed (21 mammals and 10 fish).

Unfortunately, fish samples could not be obtained from the Roman Iron Age, as faunal material is very limited

TABLE 1. Site data of the ten Roman Iron Age cemeteries in East Denmark

Site	*n* (total)	Period	Date	Burial	Male	Female	Unknown	Excavation data
Asnæs	5 (18)	ERIA	1-150/200AD	Simple	3	2		Hauschild and Jørgensen, 1981; Sellevold et al., 1984
Bøgebjerggård Sb132	6 (13)	ERIA	1-150/200AD	Simple		4	2	Kudahl, 2005
Bøgebjerggård (LR)	7 (7)	LRIA	170-375AD	Simple/Rich	6	1		
Simonsborg	22 (50)	ERIA	1-150/200AD	Simple	11	9	2	Liversage, 1980; Sellevold et al., 1984
Slusegård	2 (40)	ERIA	1-170AD	Rich	1		1	Klindt-Jensen, 1978; Sellevold, 1996
Slusegård	7 (35)	LRIA	170-375AD	Rich	3	4		
Skovgårde	12 (19)	LRIA	200-300AD	Rich	1	9	2	Ethelberg, 2000
Himlingøje	4 (13)	LRIA	150-300AD	Rich	2	2		Lund Hansen, 1995; Balslev Jørgensen, 1978; Sellevold et al., 1984; Sellevold, 1995
Juellinge	2 (4)	ERIA	150-200AD	Rich		2		Müller, 1911; Lund Hansen, 1987; Sellevold et al., 1984
Varpelev Sb8	7 (14)	LRIA	150-300AD	Simple	7			Lund Hansen, 1987; Tornbjerg, 1991
Varpelev B Vest	1 (1)	LRIA	200-250AD	Rich	1			
Hoby	1 (1)	ERIA	Ca. 50AD	Rich	1			Friis-Johansen, 1923; Eggers, 1951; Klingenberg, 2006; Sellevold et al., 1984
Hågerup	1 (1)	LRIA	200-250AD	Rich	1			Storgaard, 2003; Lund Hansen, 1987; Sellevold et al., 1984

ERIA = Early Roman Iron Age, LRIA = Late Roman Iron Age.

(Enghoff, 1999, 2000). Instead fish samples from both marine and freshwater ecosystems were collected from a Viking Age site (6th to 11th Century AD) at Tissø on West Zealand (Gotfredsen, 2006), (see Fig. 1). From ecological studies by Ignalius et al. (1981) and Elmgren (1984) it is inferred that the ecological conditions in the Southern Baltic Sea with brackish waters has mainly been the same for the last 3,000 years. Since Denmark has the same ecology as the rest of southern Scandinavia, we assume that the ecology did not change significantly between the Iron Age and Viking Age. The isotopic results should, therefore, not be biased because of the different time periods.

The archaeological sites

Excavations of the cemeteries and single graves have taken place throughout the 19th and 20th Century (Table 1). The majority of the graves have been found during gravel digging or construction work. This combined with excavation techniques, local soil conditions, time, and handling of the remains after exposure resulted in varying states of preservation. Furthermore, material available for stable isotope analysis was restricted by cremations, which were the most popular form of burial treatment during the Early Roman Iron Age.

The burials from both the Early and Late Roman period indicate a glimpse of major social stratification. The treasures and valuable artifacts found in the rich graves testify to the marking of high social rank (Jensen, 2003). It seems Roman drinking with fine wine glasses and bronze containers and ladles for wine became part of the aristocratic tradition (e.g., Lund Hansen, 1987, 1995; Ethelberg, 2000). Prestige items were used for political control and high ranking exchange systems, and reflect how wealth was distributed and new social groups were established. For the purpose of simplicity, graves containing substantial amounts of jewelry, luxurious golden, bronze or silver objects have been termed “rich graves” and are assumed to represent the elite. The graves containing either few simple grave goods (clay pottery and spindle whorls) or no grave goods at all have been termed “simple graves” and are interpreted as representing the “common” people.

The cemeteries of Asnæs, Bøgebjerggård Sb132 and Simonsborg on Zealand (see Fig. 1), which dated to the Early Roman Iron Age (ERIA), all contained simple inhumation graves. Larger groups of rich inhumation graves from the ERIA are scarce (Sellevold et al., 1984). Both of the sites Juellinge and Hoby on Lolland contained rich graves. Based on the presence of many Roman imported goods, the individual from Hoby is considered to be one of the most important and influential chieftains in Northern Europe who had links to the Roman Empire (Klingenberg, 2006), and Juellinge represents elite female burials (Lund Hansen, 1987). The number of rich graves in East Denmark seems to increase in the Late Roman Iron Age (LRIA). Two of the most important elite cemeteries of this period are found at Himlingøje and the neighboring Varpelev on East Zealand. Both were political centers of East Denmark that were strongly influenced by the Romans and interacted with the rest of Scandinavia (Lund Hansen, 1995). Their cemeteries represent chieftain families and their household. Skovgårde, on South Zealand, is another cemetery for an elite group of the LRIA, where the majority of the graves contain women (Ethelberg, 2000). The contemporary Bøgebjerggård LR contained both an elite female burial and simple male graves (Kudahl, 2005) and also included in this study is the single but very richly furnished grave (of a possible chieftain) at Hågerup on Funen (Storgaard, 2003). Finally there is the cemetery, Slusegård, on Bornholm located right next to the Baltic Sea. This cemetery was for both the elite and the common people and covers both the Early and Late Roman period. The most common form of mortuary treatment at Slusegård was cremation, but inhumations have also been found and some people were buried in boats. Unfortunately, the sandy acidic soil made the preservation of the inhumation individuals extremely poor and most of the skeletal remains have been lost (Klindt-Jensen, 1978; Sellevold, 1996).

TABLE 2. Basic statistics of human and animal data

		n	Mean δ^{13}C	1σ	Min	Max	Mean δ^{15}N	1σ	Min	Max
Humans	Asnæs	5	−20.5	0.2	−20.7	−20.3	11	0.7	10.7	11.4
	Bøgebjerggård Sb132	6	−20.6	0.1	−20.7	−20.3	10.8	0.3	10.4	11.2
	Bøgebjerggård (LR)	8	−20.3	0.3	−20.8	−19.9	11	0.8	10.4	12.6
	Simonsborg	22	−20.6	0.2	−20.9	−20.3	10.7	0.5	10.1	11.7
	Slusegård (excl SL229)	7	−20.2	0.2	−20.6	−20	11.5	0.8	10.6	12.6
	Skovgårde	12	−20.6	0.2	−20.9	−20.4	10.6	0.4	10.1	11.2
	Himlingøje	4	−20.6	0.3	−20.8	−20.3	11.3	0.2	11.1	11.5
	Juellinge	2	−20.7	0.2	−20.8	−20.5	11.9	0.4	11.6	12.2
	Varpelev Sb8	7	−20.5	0.1	−20.7	−20.4	10.7	0.4	10.2	11.3
	Varpelev B Vest	1	−20.1				12.1			
	Hoby	1	−20.1				11.9			
	Hågerup	1	−21.1				10.5			
	All humans (excl SL229)	75	−20.5	0.2	−21.1	−19.9	10.9	0.6	10.1	12.6
Animals	Sheep (*ovis aries*)	7	−21.9	0.1	−22	−21.7	6.9	0.6	6.2	7.3
	Cow (*bos taurus*)	3	−21.6	0.7	−21.9	−21.4	5.7	0.5	5.3	6.2
	Horse (*Equus caballus*)	2	−22.8	0.2	−23	−22.7	6.7	1.6	6.1	7.3
	Pig (*Sus domesticus*)	4	−22.1	0.8	−22.5	−21.3	8.6	0.9	7.4	9.6
	Dog (*Canis*)	1	−20.8				9.4			
	Cod (*Gadus morhua*)	1	−12.1				13.3			
	Garfish (*Belone belone*)	3	−13.8	0.2	−13.9	−13.5	12.1	0.3	11.8	12.4
	Carp (*Cyprinidae*)	2	−22.9	1.4	−23.8	−22	11.3	0.1	11.2	11.4
	Pike (*Esox Lucius*)	2	−24.1	0.9	−24.8	−23.5	12.1	1.4	11	13.1
	Perch (*Perca fluviatilis*)	1	−11.6				10.8			
	Roach (*Rutilus rutilus*)	1	−23.7				11.7			
	Herbivores	12	−22	0.4			6.6	0.8		
	Freshwater fish	6	−23.7	1.1			11.7	0.8		
	Marine Fish	4	−13	1.1			12.1	0.8		

METHODS

The majority of the samples were taken from compact bone (preferentially the femur). From fish, the vertebrae (quadrates) were sampled.

Prior to sampling, the bone surface was cleaned with a round milling cutter. Bone powder was then drilled out using a low speed Proxxon MICROMOT 40E drill (drill diameter: 2 mm). Collagen was extracted using the standard procedures by Brown et al. (1988), modified in Richards and Hedges (1999). This involved a two-step filtration using Ezee mesh filter (R) followed by ultrafiltration [Millipore Amicon Ultra-4 centrifugal filter (30.000 NMWL)] allowing molecules larger than 30 kDa to be retained (Jørkov et al., 2007).

All sampling and extraction was performed at the Laboratory of Biological Anthropology, Institute of Forensic Medicine, University of Copenhagen. Bulk collagen from each sample was weighed in duplicates of 215–250 μg into tin capsules. The collagen was then combusted using a GV Instruments Isoprime stable isotope mass spectrometer combined with a Eurovector elemental analyzer (continuous flow (CF-EA)) at the AMS Laboratory at the Institute of Physics and Astronomy, University of Aarhus, Denmark. The maximum analytical errors (1σ) for δ^{13}C and δ^{15}N were 0.2 and 0.3‰, respectively.

RESULTS

The isotopic data, collagen quality indicators, and basic information on sampled individuals are summarized in Table Supporting Information S1 and S2. Of the 77 human and 31 animal samples processed for collagen extraction, 5 animal samples produced insufficient amounts of collagen in 1 human (SL531E) had an unacceptable C/N ratio according to the quality criteria set by DeNiro (1985), Schoeninger et al. (1989), Ambrose (1990, 1993), and van Klinken (1999). These samples were not used in the anthropological interpretation. Basic statistics for the human and animal isotope data are summarized in Table 2.

Faunal isotope data

All mammals have δ^{13}C values reflecting a terrestrial (C$_3$) environment, which is consistent with previous studies of European material (Bocherens, 2000; Hedges and van Klinken, 2000; Müldner and Richards, 2007). All animals except for cattle have nitrogen isotopic ratios higher than 6‰. The dog has higher δ^{13}C and δ^{15}N values than the herbivores, but when compared to the pigs and the human values its values reflect more omnivorous diet than carnivorous. Similar nitrogen values (>9.4‰) for dogs have been observed in Roman Iron Age Britain (Müldner and Richards, 2007). The δ^{13}C and δ^{15}N signals for all fish samples are consistent with average marine and freshwater ecosystems, respectively (Schoeninger and DeNiro, 1984; Vander Zanden and Rasmussen, 1999; Von Steindorff and Grupe, 2006).

Human isotope data

Initial data exploration reveals one outlier (SL229; Fig. 2b). This individual is an infant (<2 years) from Slusegård, who has δ^{15}N value of 14.2‰, which is 3.3‰ above the human nitrogen mean and consistent with a trophic shift characteristic of nursing (Herring et al., 1998). Although this δ^{15}N value has little effect on means and measures of dispersion, it will be disregarded in the mean human calculations. The δ^{13}C ratios for the Roman Iron Age population range over 1.2‰, from −21.1‰ to −19.9‰, with a mean of −20.5‰ ± 0.2‰ (1σ). The δ^{15}N values exhibit a range of 2.5‰, from 10.1‰ to 12.6‰, with a mean of 10.9‰ ± 0.6‰.

As can be seen from Figure 2a and Table 2 the human values lie extremely close together and overlap within a

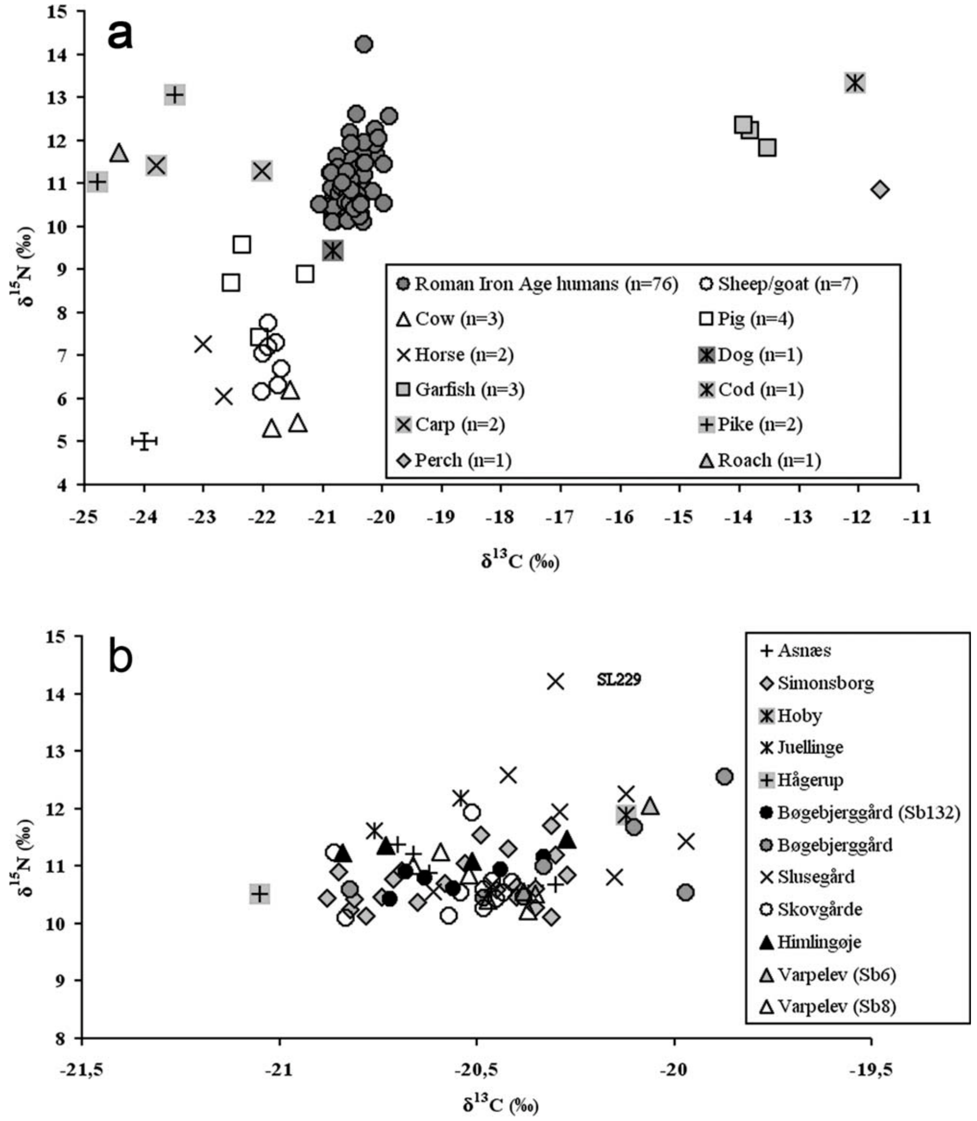

Fig. 2. **a**. δ^{13}C and δ^{15}N values of Roman Iron Age humans, animals, freshwater and marine fish. **b**. Data plot of individual Roman Iron Age humans from East Denmark.

single standard deviation. Although the human carbon values indicate a terrestrial (C_3) diet without a significant measurable contribution of marine foods, the average human nitrogen isotopic data from all of the sites investigated show high δ^{15}N values compared to the herbivore baseline.

Inter site-comparison. The sites were compared to assess the effects of time period, geographical location, burial types, as well as sex and age (Fig. 3a–f; Table 3). When comparing the sites diachronically using a two-sample *t*-test there is a significant difference in the δ^{13}C values ($P = 0.036$), but not in the δ^{15}N values. A coastal-inland comparison (Fig. 3b) reveals significant differences between both δ^{13}C and δ^{15}N values ($P = 0.042$ and 0.005, respectively). When comparing the isotopic values by burial form (rich and simple; Fig. 3c) a significant difference is seen in the δ^{15}N values ($P = 0.032$), with the rich burials having slightly enriched δ^{15}N values over the simple burials. Finally, males are significantly more enriched in both ^{13}C and ^{15}N than female diet (Fig. 3d; $P = 0.031$ and 0.049, respectively).

When the simple grave types are separated according to sex (Fig. 3e–f) the females have more depleted ^{13}C than the male groups ($P = 0.012$), while the δ^{15}N values are slightly higher in males ($P = 0.048$). Three males (individual BØ4, BØ6, and BØ7 from Bøgebjerggård LR) stand out having enriched ^{13}C compared to the entire group of both males and females. These three males were buried around the rich female grave BØMA2000. It has been suggested that they were slaves of her household (Kudahl, 2005). When the rich graves are compared according to sex, there is no significant difference in δ^{13}C values, but the rich males seems to have slightly higher δ^{15}N values ($P = 0.036$). Finally, no statistical significant difference was found between the pooled age groups (Table 3).

It is evident that the intersite comparison of Early and Late Roman periods, coastal and inland sites, rich and simple graves, sex and age categories shows statistically significant differences. To rank the group differences we

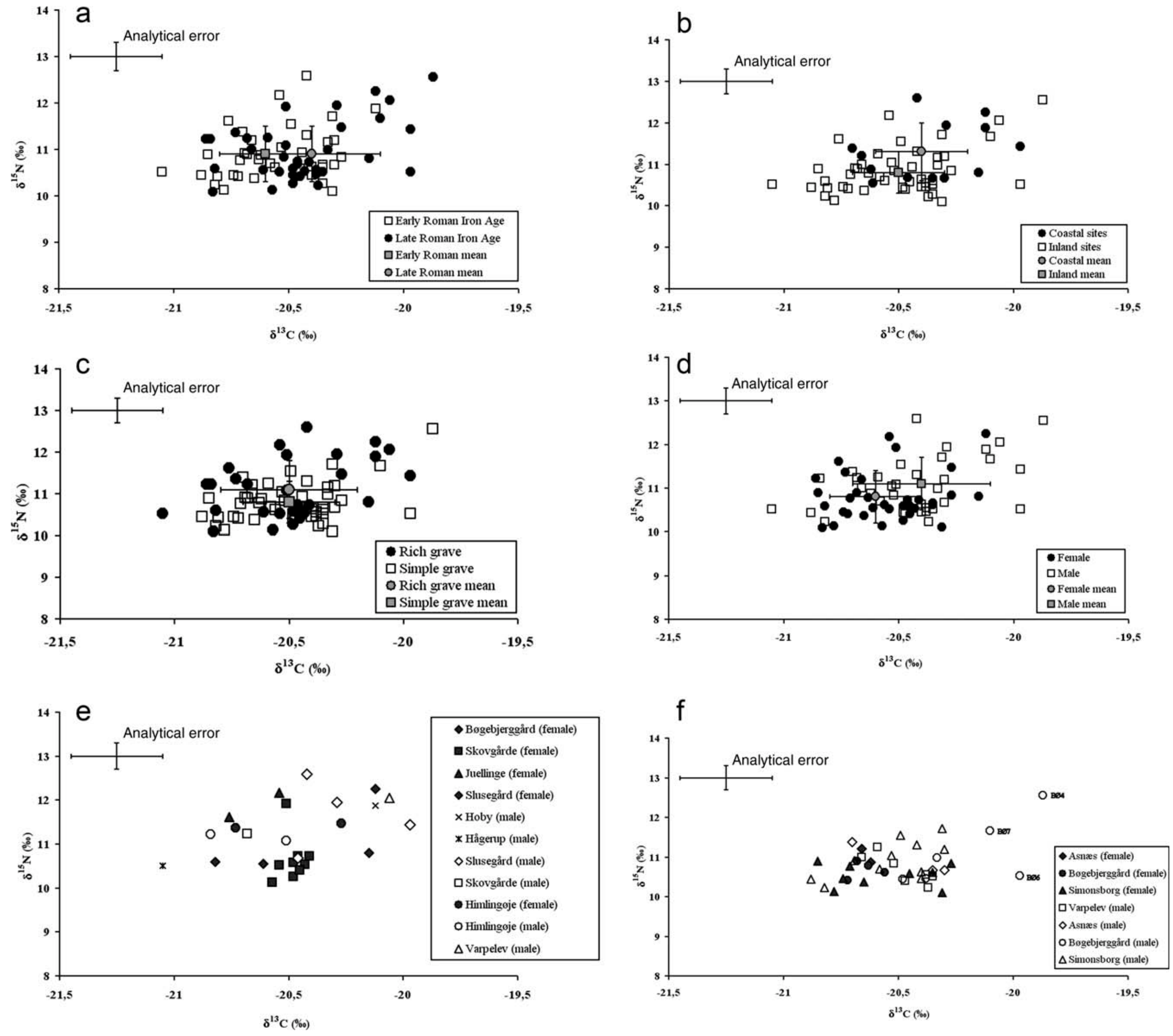

Fig. 3. Intersite comparisons: **a**. Dataplot of Early vs. Late Roman Iron Age burials with mean δ^{13}C and δ^{15}N ratios ± (1σ) indicated; **b**. Coastal vs. Inland sites with mean δ^{13}C and δ^{15}N ratios ± (1σ) indicated; **c**. Rich vs. Simple graves with mean δ^{13}C and δ^{15}N ratios ± (1σ) indicated; **d**. Male vs. female graves with mean δ^{13}C and δ^{15}N ratios ± (1σ) indicated; **e**. Rich male graves vs. rich female graves; **f**. Simple male graves vs. simple female graves.

performed a tree analysis based on the SYSTAT TREE model (Wilkinson, 2004). It indicated that the most important difference in δ^{13}C values from within the sample is primarily whether the population is Early or Late, then coastal or inland, and finally rich or simple graves. The most important factor for δ^{15}N is whether the population is coastal or inland. However, the prediction rates (0.248 for δ^{13}C and 0.100 for δ^{15}N) indicate that the sample is limited and also somewhat skewed in relation to the single subgroups (e.g., almost all rich graves contained females), and that the overall variance is very small.

DISCUSSION

During the Danish Roman Iron Age there was an increase in population and with this a change in cultural development, which gave rise to new agro-pastoral strategies. At the beginning of the Early Roman Iron Age, forests were cleared, which allowed grassland and meadows to expand (Jensen, 1995; Hvass, 2001). The need for food increased proportionally with the increase in human population. The houses became bigger (Jensen, 2003) and the land became extensively used to produce winter forage. Stables expanded as the need for controlled breeding became vital (Hedeager, 1992: p 217; Jensen, 2003: p 270). By the third and fourth centuries AD (Late Roman Iron Age), however, many open pasturelands and fields were reforested. The ancient field systems were abandoned and replaced by an infield/outfield system, which has been interpreted as indicating an intensification of production (Hedeager, 1992: p 219, 246). Based on these changes in land use, social structure and an increase in population density, it has until now been assumed that a variation would also be reflected in the dietary habits (Jensen, 2003).

TABLE 3. Statistics for inter site and age group comparisons

Group	n	Mean δ^{13}C	1σ	Min	Max	Two sample t-test	df	Kruskal-Wallis	Mean δ^{15}N	1σ	Min	Max	Two sample t-test	df	Kruskal-Wallis
ERIA	36	−20.6	0.2	−20.9	−20.3	0.036	73	0.078	10.9	0.6	10.1	12.6	0.657	73	0.797
LRIA	39	−20.4	0.3	−21.1	−19.9				10.9	0.6	10.1	12.6			
Inland	62	−20.5	0.2	−21.1	19.9	0.042	73	0.058	10.8	0.5	10.1	12.6	0.005	73	0.01
Coastal	13	−20.4	0.2	−20.7	−20				11.3	0.7	10.6	12.6			
Simple	46	−20.5	0.2	−20.9	−19.9	0.971	73	0.832	10.8	0.5	10.1	12.6	0.032	73	0.074
Rich	29	−20.5	0.3	−21.1	−20				11.1	0.7	10.1	12.6			
Female	34	−20.6	0.2	−20.9	−20.1	0.031	69	0.021	10.8	0.5	10.1	12.3	0.049	69	0.065
Male	37	−20.4	0.3	−21.1	−19.9				11.1	0.6	10.2	12.6			
Rich male	10	−20.4	0.3	−21.1	−20	0.507	13	0.396	11.5	0.7	10.5	12.6	0.036	18	0.046
Rich female	19	−20.5	0.2	−20.9	−20.1				10.9	0.6	10.1	12.3			
Simple male	27	−20.4	0.2	−20.9	−19.9	0.012	35	0.021	10.9	0.5	10.2	12.6	0.048	40	0.152
Simple female	15	−20.6	0.2	−20.9	−20.3				10.6	0.3	10.1	11.2			
Children (2–10 years)	3	−20.5	0.4	−20.8	−20.4	0.188	73	0.741	10.5	0.4	10.3	10.9	0.218	73	0.129
Juvenile (11–16)	3	−20.7	0.4	−20.8	−20.4				10.6	0.6	10.3	10.9			
Young adult (17–25)	11	−20.5	0.7	−20.8	−20.1				10.7	0.6	10.1	12.3			
Middle adult (26–45)	44	−20.5	1.9	−21.1	−19.9				11	0.6	10.2	12.6			
Old adult (46+)	10	−20.5	0.4	−20.7	−20.3				10.8	0.6	10.4	11.4			
Adult	5	−20.5	0.5	−20.9	−20.4				11	0.4	10.1	11.2			

It was a simple agrarian technology that was used during the whole period. The tool most utilized was the *ard*, a simple plough, which was not well suited to turn the top soil or remove weeds. The soil therefore, could not fully benefit from the manure that was spread. Although there is more energy in crops than in animal products [crops consist mostly of carbohydrates and have relatively little protein (10–25%) and meat consists mainly of protein (85–90%; Ambrose et al., 2003: p 219)], it would have required extremely hard labor all year round to produce enough crops to cover basic human nutritional needs. Animal husbandry is also labor intensive, but the animals would have been more or less self-sufficient. They could be left out to graze most of the year, but during the winter months, they were kept in stables and required fodder.

The range of δ^{13}C values is very narrow and similar for humans and herbivores. The spacing in δ^{13}C between humans and herbivores is only 1.3‰, which is consistent with one trophic level (Schwarcz and Schoeninger, 1991; Bocherens and Ducker, 2003). An environmental distinction can therefore not be seen in the δ^{13}C values across the species and temporal ranges investigated here, which suggest a purely terrestrial C_3 based diet. There can be isotopic variations between herbivores species due to different forage and agricultural systems. Still it can be assumed that the variety of food sources to choose from is not as broad as it is for humans. Nevertheless, the diets of the humans seem to have been extremely consistent within and between the groups analyzed. Diet in which both plants and animals played a significant role would lie between +6 and +9‰. This theory assumes a trophic level difference of 3‰, although it could be up to 5‰ (Bogaard et al., 2007; Hedges and Reynard, 2007). If cereals and other plant protein sources had constituted of just half of the protein source eaten by the Roman Iron Age populations δ^{15}N values would be lower (Dürrwächter et al., 2006; Hedges and Reynard, 2007). It has been proposed that δ^{15}N values can be used to distinguish between dominant plant versus animal consumption (Choi et al., 2003; Dürrwächter et al., 2006). The data from a modern experiment on manured versus nonmanured cereals suggest that a diet largely based on the manured cereals could result in humans having fairly high δ^{15}N values (i.e., resembling those resulting from a largely animal-based diet, or a mixed plant and animal-based diet; Bogaard et al., 2007). However, in this study the observed δ^{15}N isotope values in the herbivores do not exceed those typical for herbivores (Bocherens, 2000) and therefore cannot account for additional ^{15}N-enrichment seen in the Danish Roman Iron Age human samples. A manuring effect on the δ^{15}N of cereals consumed during the Roman Iron Age could therefore be absent in the herbivore isotope data presented here.

The isotopic compositions of the few animals included do not allow us to accurately distinguish the contribution of specific animal protein in the human diet. Herbivore diets are not necessarily consistent in terms of protein consumption. Some plants are higher in protein than others. The herbivores used as the environmental baseline for the human data are cattle and sheep from various sites. The mean δ^{15}N ratio in sheep (6.9‰ ± 0.6‰; n = 7) is elevated by 1.3‰ compared to that of cattle (5.7‰ ± 0.5‰; n = 3). This small difference may reflect their subsistence on different forage, perhaps due to pasture rotations and over-wintering practices involving stored forage (Hedges and Reynard, 2007).

The average human δ^{15}N value (10.9‰ ± 0.6‰) is slightly higher than the expected level of enrichment. The mean human nitrogen value is enriched in ^{15}N by 4.4‰ over the mean herbivore δ^{15}N. The combination of high δ^{15}N ratios (i.e., more than 4‰) and an entirely terrestrial signal has previously been explained as reflecting the consumption of omnivore protein (i.e., pigs feeding on human debris), consumption of young animals (i.e. still suckling) or the use of freshwater resources (e.g., Müldner and Richards, 2005; Jay and Richards, 2006). If the cattle in this sample represent the average cattle baseline for the humans, they do not seem to have contributed significantly in the human diet. It is still possible that meat and dairy products from the cattle were consumed. Although milk has a similar isotopic composition as the bulk protein, diets that have the same isotopic composition are not necessarily the same in terms of their foods or macronutrients consumed. Cat-

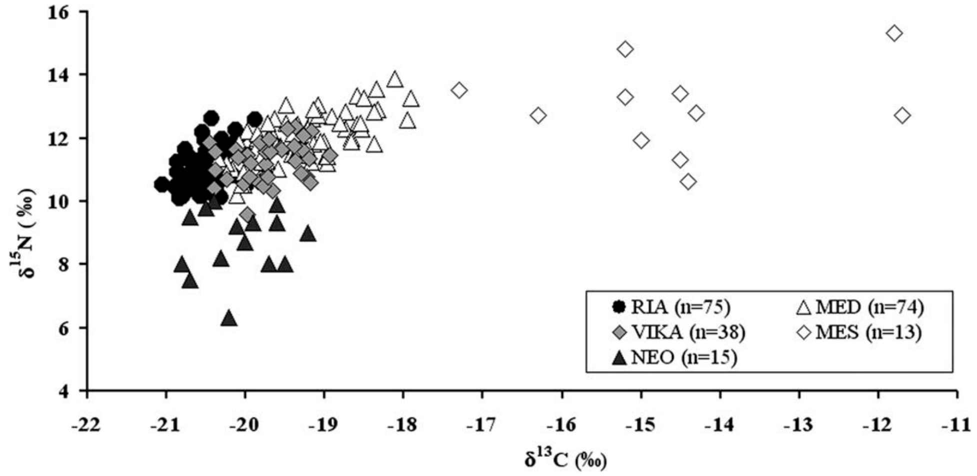

Fig. 4. Diachronic comparison between humans from Mesolithic to Medieval period in East Denmark. Footnote: RIA = Roman Iron Age humans, VIKA = Viking Age humans from Galgedil (after Kanstrup, 2008), MED = Medieval humans from Ahlgade, Holbæk (after Jørkov, 2007), MES = Mesolithic humans (after Fischer et al., 2007), NEO = Neolithic humans (after Fischer et al., 2007).

tle seem to have become a symbol of power, prestige and wealth among the Roman Iron Age populations (Jensen, 2003: p 406), but in order for them to be a status symbol their breeding had to be controlled, which is why we see the expansion in stables (Jensen, 2003). They could have been used as draught animals, provided hides and important dairy products for human consumption. Even though omnivorous pigs are a likely candidate for raising human nitrogen values, it is questionable if they could account for all of the observed enrichments. Consequently, there may be input from other sources. According to the zooarchaeological evidence, sheep are highly represented in this period, and young sheep predominate (Higham, 1967; Hatting, 1999; Gotfredsen, 2003). It is possible that the consumption of young animals e.g., lamb and the culling of young animals, particularly for dairy practice, contributed to the high $\delta^{15}N$ values. If procreation is taken into account, sheep and pigs are very likely to have provided the majority of the animal protein detected. They breed more often than cattle and are therefore economically more profitable. Pigs can produce up to 15 piglets per litter two to three times per year, sheep up to three lambs per litter per year, while cattle only breed one calf per year (Christiansen, 2004; Stolberg, 2007). It seems unlikely that meat from the young cattle (i.e., less than 2 years) was eaten by the lower class in society. Instead meat of young cattle may have been served for the elite who could afford to slaughter the valuable animal.

There is no clear evidence to suggest that marine sources were part of the diet. Very meagre quantities of fish bone were recovered from the Roman Iron Age anywhere in Denmark compared to the later historical periods (e.g., Viking Age and Middle Age; Enghoff, 1999). Humans with terrestrial C3 $\delta^{13}C$ values, but $\delta^{15}N$ values greater than 12‰, reflect significant freshwater fish consumption (Bonsall et al., 1997). Even though the freshwater fish constituting the baseline in this study are indeed a limited sample, they do not seem to be a very good match for the enriched human nitrogen data (Hedges and Reynard, 2007). Seasonal consumption or occasional feasts of both marine and freshwater fish, of course, cannot be excluded. Other factors that may affect the $\delta^{15}N$ values such as aridity and the pathology of animals and humans, are not considered here because there is no evidence in the environmental, botanical or archaeological record to suggest that there was aridity in Denmark during the Roman Iron Age and both animal and human remains with evidence of pathological alteration were excluded from this study.

The Roman Iron Age in a diachronic framework

The extremely limited dietary variation among Roman Iron Age humans becomes more apparent when set in a diachronic framework (Fig. 4, Table 4). The available isotopic data for pre-historic and historic humans from Denmark is limited to the Mesolithic and Neolithic period (Tauber, 1981; Richards et al., 2003; Fischer et al., 2007), the Viking Age site Galgedil on Funen (Kanstrup, 2008) and a Medieval population at Holbæk on Zealand (Jørkov, 2007). Nevertheless, when comparing the Roman Iron Age data with the medieval data from Holbæk, which represents a single cemetery (Ahlgade), it is clear that the medieval individuals are more diverse in their isotopic values. As can be seen from Figure 4, the individual plots of the medieval samples from Holbæk are significantly enriched in ^{13}C and ^{15}N compared to the Roman Iron Age populations. In addition, $\delta^{13}C$ and $\delta^{15}N$ values are strongly correlated in the Viking and medieval populations, a trend which is usually observed in populations consuming a mixed terrestrial based diet with a significant but varying amount of marine protein (e.g., Richards and Hedges, 1999; Müldner and Richards, 2005, 2007). By the Viking Age agricultural techniques had developed (the mouldboard plough was introduced, (Hedeager, 1992: p 202), new foods were introduced, such as poultry (Aaris-Sørensen, 1998: p 204), and techniques for deep sea fishing were developed (Enghoff, 1999: p 53). The diversity in the diet seen among the Vikings and especially the medieval humans is also to be expected considering the archaeological and historical records indicating that these populations were comprised of individuals from different occupational background (i.e., pastoralists, craftsmen, fishermen etc.; Asmussen, 1997; Christensen, 2005; Kanstrup, 2008).

TABLE 4. Basic statistics for diachronic comparison

Date	Site	*n*	Mean δ^{13}C	1σ	Mean δ^{15}N	1σ	Data after
MES	Argus Bank, Ertebølle, Melby, Norsminde, Rødhals, Bøgebakken	13	−14.3	0.9	13.3	1.7	Fischer et al., 2007
NEO	Bodal Mose, Vængegård, Østrup Mose, Alderso, Hesselbjerg, Trudstrupgård, Ulkestrup	15	−20.1	0.4	8.7	0.3	Fischer et al., 2007
RIA	Asnæs, Simonsborg, Himlingøje Varpelev, Skovgårde, Bøgebjerggård Juellinge, Hoby, Hågerup, Slusegård	75	−20.5	0.2	10.9	0.6	Jørkov, 2007
VIKA	Galgegil	38	−19.7	0.4	11.2	0.6	Kanstrup, 2008
MED	Ahlgade (Holbæk)	74	−19.3	0.6	12	0.8	Jørkov, 2007

MES = Mesolithic Period, NEO = Neolithic period, RIA = Roman Iron Age, VIKA = Viking Age, MED = Medieval period.

Although there must have been a similar occupational specialization in the Roman Iron Age society, it is not clearly reflected in the dietary signal.

When comparisons are made to Mesolithic and Neolithic human data (Fischer et al., 2007) differences in subsistence patterns become clear. Mesolithic humans subsisted on a much more marine-based diet, and Neolithic diet was based on terrestrial/agricultural (mixed animal-plant protein) resources. Roman Iron Age diet was based on high amounts of animal-protein while Viking Age and Medieval diet was dominated by a greater variety of foods, in which marine foods plays a much greater role.

In complex societies, a more mixed dietary signal and a greater variation among different population groups would be expected. The data in this study indicate a significant isotopic difference among groups. However, the overall isotopic composition of the diet is very uniform throughout the Danish Roman Iron Age. If the Roman Iron Age humans had consumed a larger proportion of plant-derived protein, the nitrogen values would have been closer to those observed in the Neolithic humans. Despite the small variation seen between and within population groups the overall subsistence pattern for the Roman Iron Age indicates a diet based on a high amount of animal protein. The Viking and medieval humans, on the other hand, clearly show greater variability in subsistence patterns, which is consistent with both archaeological and historical data.

CONCLUSION

The results of this study indicate that the majority of the diet during the Danish Roman Iron Age consisted of animal-derived protein, regardless of social status, age, sex or even geographical location by the coast. This trend is seen in both Early and Late Roman periods despite the change in the agro-pastoral system indicated by the archaeological records. The significance of animal protein, as opposed to a mixed plant-animal protein-based diet, is surprising and suggests that we may have to re-evaluate the importance of crop cultivation in that period. However, the isotopic evidence of animal protein coming from sheep/goats and pigs is in agreement with the zooarchaeological findings. Furthermore, the data show that marine resources did not play any significant role in the diet regardless of social position or location by the sea.

The developing hierarchical structure of the society which characterizes east Denmark during the Late Roman period has been statistically demonstrated with this isotopic dietary reconstruction. Nevertheless, the prediction rates indicated that the overall variance is very small. The rich may have had more kinds of animal protein from which to choose, and may have been consuming the more valued meat and drinking the homemade beer and fruit wine as indicated by the luxurious Roman imported table ware. The distribution of specific cuts of meat or the way in which it was prepared for various social groups would not be detectable using this method.

This study is a starting point for future more comprehensive analysis. It is obvious that a larger human sample from each cemetery would have been beneficial in order to give a better picture of the dietary habits in the East Danish regions. Nonetheless, the data presented here compel us to rethink the dietary habits of the Danish Roman Iron Age.

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