Stable isotope analysis of a medieval skeletal sample indicative of systemic disease from Sigtuna Sweden

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Abstract

In Sigtuna, Sweden, several medieval cemeteries have been excavated, from which approximately 800 skeletons have been excavated and analysed. Archaeological finds and anthropological analyses have exposed social differences between the cemeteries. Stable isotope analyses have shown that the inhabitants of the town consumed a mixed diet. Significant differences in dietary patterns between the cemeteries may be related to social stratification.

In the outskirts of a churchyard excavated in 2006, bone changes showing systemic inflammatory disease indicative of leprosy were observed in six individuals. The burial location suggests that the affected belonged to a lower social stratum. Bone samples were taken from these six individuals, 19 other human skeletons and five animals from the same cemetery for analysis of the stable isotope composition of carbon (C), nitrogen (N) and sulphur (S).

The results showed no significant differences in 13C and 15N values between the groups, i.e. the seemingly healthy humans and the humans affected by severe inflammatory disease appear to have had similar diets. Nor was a significant difference observed in 34S data between the six affected individuals and the rest of the sample, implying that no difference in origins could be observed between the two groups studied. However, a comparison between the present study and the previous analysis resulted in significant differences in carbon values.

Based on the results obtained in this investigation it is suggested that if a dietary difference existed between people in the outskirts of a cemetery (for example those suffering from leprosy) and people buried in higher ranked regions, it was not a difference in food source but rather in other parameters. Instead dietary differences and possibly social variations are demonstrated between cemeteries. The results from the present study highlight the hierarchical arrangements of social classes in the early medieval society.

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1. Introduction

Individuals with leprosy have been documented in Sigtuna. In a grave excavated in 1995 associated with the church known as “Church 1” (Kjellström, 2005), an affected individual was identified. The grave was located in the periphery of the churchyard. The placement of the graves is in line with coeval Scandinavian burial regulations (for example the Norwegian law Eidsivatinglagen), which assigned the areas most distant from the church to the poor or outcasts (Gejvall, 1969: Daniell, 1997). A similar location for people with skeletal changes of leprosy, showing their low social position in society, has been documented in medieval Lund, in the south of Sweden (Arcini, 1999).

The present study considers the diet and origins of six individuals also discovered in the outskirts of a medieval churchyard in Sigtuna. Skeletal changes indicate that the group had suffered from systemic disease. Their burial location implies that these individuals also belonged to a low social stratum. Previous studies have shown that dietary differences, most likely related to social hierarchy, already existed between groups during the initial phase of the town’s establishment (Kjellström et al., 2009). Although knowledge of the current church and churchyard is low it was most likely not a formal nursing institution. (A hospital was first established in Sigtuna in A.D. 1287, around the time of the abandonment...
of the excavated churchyard [Kjellström and Wikström, 2008]. The hypothetical notion that these individuals were treated differently or that they came from another region is tested in this paper.

2. The history of Sigtuna

Sigtuna was founded in the 10th century AD on the shore of Lake Mälaren, near the coast of the Baltic Sea in east central Sweden, (Fig. 1). Approximately 800 skeletons from several medieval cemeteries in the town have been dated to analyse. The graves are dated to three burial phases; signifying the establishment of the town (Phase 1 c. 900–1100), its peak of prosperity (Phase 2 c. 1100–1300), and its decline (Phase 3 c. 1300–1530) (Kjellström et al., 2005; Wikström, 2008).

During the Viking Age Lake Mälaren was still a bay of the Baltic Sea, and seagoing vessels could sail up it far into the interior of Sweden. However, around 1200 AD the bay became a lake due to post-glacial rebound and today the lake’s surface averages 0.7 m above sea level.

Sigtuna was from the beginning a highly stratified society where the first Christian kings both planned the topography of the town and controlled the population living within its limits (Tesch, 1990, 2000, 2001; Zachrisson, 1998; Kjellström et al., 2005). Wide-ranging contact with other European countries is demonstrated in artefacts and designs from northern Germany, Denmark, England, Holland, France, Belgium, Germany, Byzantium and Kiev (Karlsson, 1989; Larsson, 1990; Roslund, 1990, 2001). Although small compared to contemporary international towns, Sigtuna had an urban character, lacking agrarian constructions such as stables or barns (Högrell, 1990; Petterson, 1990). The surrounding countryside provided the citizens with meat. In the cultural layers the zooarchaeological data contained bone remains from domestic animals such as cattle, sheep, goat and pig (Hårding, 1990) as well as game animals, wild fowl and fish (Jonsson, 1989; Hårding, 1990; Vretemark, 1997). In addition to the most basic crops, fossil plant remains show that a diversity of vegetables, fruits and herbs were cultivated (Hansson, 1997). Stable isotopic analyses have verified that the diet contained a combination of both terrestrial and marine protein but was generally predominantly terrestrial in origin (Kjellström et al., 2009). Variations in the intake of vegetable protein, most likely socially motivated, were discernable between groups (Kjellström et al., 2009). Significant differences (P < 0.001) in nitrogen values between women at the burial ground Nunnan (δ15N mean = 10.73‰ s.d. = 1.52) and the (supposedly high status) women at a churchyard called “Church 1” (δ15N mean = 13.06‰, s.d. = 0.68) were observed. One of the samples (Church 1, phase 2) was contemporary with the skeletal assemblage in the Humlegården block presented below.

3. Stable isotope analysis in archaeology

Stable carbon and nitrogen analysis is a well-established method for examining prehistoric diet (Schwarz and Schoeninger, 1991; Katzenberg, 1992; Sealy, 2001; Kellner and Schoeninger, 2007; Linderholm, 2008; Eriksson et al., 2008; Linderholm et al., 2008a and 2008b). The central principle behind this method is that “you are what you eat”, namely that skeletal tissue is formed from components in the diet. The main protein in the skeletal tissue is collagen, and it is made up of amino acids which are synthesised directly from the diet. Analysis of this collagen will consequently reflect an individual’s diet during the 10–to 15 years prior to death (Fischer et al., 2007). Collagen can survive in the skeleton for thousands of years under good preservation conditions (Ovchinnikov et al., 2001; Götherström et al., 2002; Smith et al., 2005). Several experimental studies have shown that it is mainly the protein portion of the diet that is reflected in collagen isotopic data (Ambrose and Norr, 1993; Howland et al., 2003; Jim et al., 2004; Tiesse and Fagre, 1993). The carbon isotope ratio, δ13C, distinguishes protein from different sources; it can distinguish between protein from terrestrial or freshwater environments and protein from marine environments, or C4 plants from C3 plants (Schoeninger and DeNiro, 1984). C4 plants are found in tropical or subtropical environments and are not thought likely to have contributed to the diet in medieval Sigtuna. This means that all terrestrial protein is considered to derive from C3 plants in this study. The nitrogen isotope value, δ15N, on the other hand, will increase for each step in the food chain by approximately 3‰, and one can thus discriminate between trophic levels in the food web (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984). Both the carbon and the nitrogen isotopic values are measured against international standards and are expressed in per mil, ‰, i.e. parts per thousand.

![Fig. 1. Map of Sweden and Sigtuna with the location of some of the excavated churchyards (the Humlegården block – Church 2).](image-url)
4. Sulphur analysis as a tool for provenience determination

During the last ten years analysis of the stable isotopes of sulphur (\(\delta^{34}S\)), has successfully been applied to several archaeological studies (Richards and Hedges, 1999; Richards et al., 2001, 2003; Leach et al., 2003; Craig et al., 2006; Privat et al., 2002; Linderholm et al., 2008a and 2008b; Forndater et al., 2008; Nehlich and Richards, 2009; Nehlich et al., 2010). Plants derive the majority of their sulphur from the soil and the soil’s \(\delta^{34}S\) signal is derived from the local bedrock. A small part of the sulphur intake will be derived from atmospheric depositions and microbial activities in the soil but to a much lesser extent. Terrestrial sulphur isotopic conditions thus vary depending on geological setting. The \(\delta^{34}S\) values of sedimentary rocks range from \(-40\) to \(+40\)%o. European granitic rocks have \(\delta^{34}S\) values that range from \(-4\) to \(+3\)%o, mafic rock \(\delta^{34}S\) values are close to \(0\)%o, and metamorphic rocks exhibit \(\delta^{34}S\) values between \(-20\) and \(+20\)%o (Krouse, 1980; Faure and Mensing, 2005). By comparison, the \(\delta^{34}S\) value for the oceans are rather uniform, averaging \(21\)%o, and the \(\delta^{34}S\) values vary far more than marine ones. The isotopic fractionation between food and consumer is relatively small (\(-1\)%o to \(+2\)%o), meaning that the \(\delta^{34}S\) value in bone reflects the sulphur isotopic composition of the diet which in turns reflects the geology of the food origin (Peterson et al., 1985; Bol and Pflieger, 2002; Sharp et al., 2003; Richards et al., 2003; Fraser et al., 2006; Buchardt et al., 2007; Nehlich and Richards, 2009). Thus any detected variation in the \(\delta^{34}S\) data could indicate geographical origins of the food and with this information migration patterns may be elucidated.

5. Materials

In the summer of 2006 Sigtuna museum conducted an excavation of the southern parts of the Humlegården block (Kjellström, 2008). The excavation covered 160 m² and included 220 east–west oriented graves with 227 skeletons. The same churchyard has been investigated in 1991 when 99 skeletons were documented (Kjellström, 2005). The name of the church is unknown, but in the earlier investigation it was called Church 2, which is used henceforth in this study. The skeletons exhibited a variety of skeletal changes and in comparison with other cemetery assemblages in Sigtuna, significantly higher frequencies of several pathologies were observed (Kjellström and Wikström, 2008). Six skeletons showed signs of severe systemic disease not observed in the rest of the skeletal collection (Kjellström, 2010). Two of three individuals with preserved facial bones demonstrate signs of rhinomaxillary remodelling. Five of the affected exhibit bilateral periostal new bone formation, severe remodelling of the phalanges of the feet and pencil shaped metatarsals. Additionally one of the individuals had lytic lesions confined to the lumbar spine, which had resulted in an angular kyphosis. In at least two individuals lepromatous leprosy and tuberculosis could be confirmed respectively. Although the remaining four skeletons exhibited severe bone atrophy in their feet (and three of them showed mild bone alterations in their hands) characteristic of leprosy, other diseases could not be ruled out.

6. Methods

6.1. Osteological methods

The skeletal assemblage was sexed and aged according to current standard anthropological techniques (Moorees et al., 1963a and 1963b; Phenice, 1969; Stiloukal and Hanáková, 1978; Stewart, 1979; Novotný, 1982; Brothwell, 1981; Lovejoy et al., 1985; Meindl and Lovejoy, 1985; Pearson, 1977 in Bass, 1987:219; Ubelaker, 1988; Brooks and Suchey, 1990; Buikstra and Ubelaker, 1994; Scheuer and Black, 2000; Brzezek, 2002). The measurements were taken according to definitions set up by Buikstra and Ubelaker (1994). Differential diagnosis of leprosy was carried out following criteria presented by Andersen and Manchester (1992); Andersen et al. (1994); Auferheide and Rodríguez-Martín (1998); Ortner (2003); Resnick and Niwayama (1988).

In addition to the six skeletons with bone changes associated with systemic disease a control group of 19 adult individuals of both sexes (ten women and nine men) were picked out. Except for degenerative changes of the joints and signs of trauma on some of the individuals, the skeletons in the control group displayed no signs of systemic infectious diseases (Fig. 2). In addition, as a reference, bone samples were taken from cattle (Bos taurus), cat (Felis catus), pig (Sus domesticus) and pike (Esox lucius).

6.2. Bone sampling and collagen extraction

The long bones used in this part of the study were first cleaned and bone powder was then obtained by use of a dentist’s drill.

![Fig. 2](image_url)  (a) The feet of an adult woman (Case 2); (b) Acroosteolysis of the right fifth metatarsal; (c) A "pencil and cup" deformity of the first metatarsal and proximal phalanx on the right side; (d) A "pencil and cup" deformity of the right first metatarsal and proximal phalange the left side; (e) Acroosteolysis of the left fifth metatarsal.
Collagen was extracted from skeletal elements according to Brown et al. (1988) in a designated bone laboratory at the Archaeological Research Laboratory, Stockholm University. The samples were demineralised in a 0.25M HCl solution for 48 h at room temperature, filtered and washed twice with deionised water through a glass filter. After an addition of 0.01M HCl, the samples were incubated at 58 °C overnight in order to dissolve the organic material. The dissolved organic residue was then filtered and washed with deionised water through an ultrafilter (30,000 MWCO Amicon Ultra-15 Centrifugal filter device (Millipore)), removing particles of less than 30kDa. Particles larger than 30kDa are likely to be undamaged collagen. The residual solvent was then transferred to a 2 ml Eppendorf tube and frozen at −80 °C, after which the sample was freeze-dried and weighed.

For the δ13C and δ15N measurements approximately 0.5 mg of collagen was weighed into tin capsules for combustion in a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa Laboratory # Id no. Sex δ13C (‰) SC δ15N (‰) SN C/N δ34S (‰) % S C/S N/S

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SPSS for windows (version 16.0) and P values <0.05 were considered significant.

7. Results

7.1. Preservation

Post-mortem degradation of bone occurs in at least three ways: chemical deterioration of the organic phase, chemical deterioration of the mineral phase and microbiological attack on the overall composition (Collins et al., 2002; Hedges, 2002). In addition, several parameters are involved in the loss of collagen from bone material, the main ones being time, temperature and pH (Collins et al., 2002; Hedges, 2002). In order to control for diagnostically altered bone we used the parameters put forward by DeNiro (1985), Ambroze (1990), van Klinken (1999), which require that the C/N ratio should fall into the range 2.9–3.6, the collagen should be 15.3–47% carbon and 5.5–17.3% nitrogen by mass, and the collagen yield should be greater than 1%. The sulphur values were verified using the newly established criteria based on C/S and N/S ratios (Fornander et al., 2008; Nehlich and Richards, 2009). Two samples out of the 25 were discarded due to low C/N ratios. None of the samples were disregarded due to the C/S or N/S ratios (Table 1). None of the samples from faunal remains were discarded (Table 2).

Table 1

Results of the stable isotope analysis of human bone samples from the Humlegården block 2008. Individuals affected by systemic disease are marked in grey.

Post-mortem degradation of bone occurs in at least three ways: chemical deterioration of the organic phase, chemical deterioration of the mineral phase and microbiological attack on the overall composition (Collins et al., 2002; Hedges, 2002). In addition, several parameters are involved in the loss of collagen from bone material, the main ones being time, temperature and pH (Collins et al., 2002; Hedges, 2002). In order to control for diagnostically altered bone we used the parameters put forward by DeNiro (1985), Ambroze (1990), van Klinken (1999), which require that the C/N ratio should fall into the range 2.9–3.6, the collagen should be 15.3–47% carbon and 5.5–17.3% nitrogen by mass, and the collagen yield should be greater than 1%. The sulphur values were verified using the newly established criteria based on C/S and N/S ratios (Fornander et al., 2008; Nehlich and Richards, 2009). Two samples out of the 25 were discarded due to low C/N ratios. None of the samples were disregarded due to the C/S or N/S ratios (Table 1). None of the samples from faunal remains were discarded (Table 2).
Table 2

Results of the stable isotope analysis of animal bone samples from the Humlegården block 2008.

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<td>37.9</td>
<td>9.5</td>
<td>15.5</td>
<td>2.9</td>
<td>6.5</td>
<td>0.28</td>
</tr>
</tbody>
</table>

7.2. Isotope data

In all, the carbon and nitrogen values from the individuals with bone changes did not differ significantly from nearby skeletons in the control group from the same cemetery (Table 1, Fig. 3). The diet seems to have been rather homogenous with mainly terrestrial protein seen in the carbon values ($\delta^{13}C$ mean = $-20.47\%_{\text{av}}, \text{s.d.} = 0.57$). The standard deviation of 0.57 is however slightly lower than the postulated standard deviation of 0.3 said to represent a population with a homogenous diet according to Lovell et al. (1986), but low enough to infer a fairly homogenous diet. No significant differences can be detected between the affected and non-affected concerning either carbon ($t (21) = -1.283, P = 0.213$) or nitrogen ($t (21) = -0.084, P = 0.934$) values. When looking at males versus females no significant differences can be seen in either the $\delta^{13}C$ ($t (19) = 0.620, P = 0.543$) or $\delta^{15}N$ ($t (19) = -0.489, P = 0.631$) values. There is however a strong indication of a regular animal protein diet, shown in the high values of nitrogen ($\delta^{15}N$ mean = $13.19\%_{\text{av}}$, s.d. = 1.38) (Table 1, Fig. 3).

The sulphur data for the combined sample ($\delta^{34}S$ mean = $7.11\%_{\text{av}}$, s.d. = 2.41) fits in general with the surrounding bedrock signal (granite has a range from $-4\%_{\text{av}}$ to $-9\%_{\text{av}}$). When divided into individuals affected ($\delta^{34}S$ mean = $8.23\%_{\text{av}}$, s.d. = 3.14) and not affected ($\delta^{34}S$ mean = $6.80\%_{\text{av}}$, s.d. = 2.18) with systemic disease no significant difference is seen between the two groups ($t (21) = -1.186, P = 0.249$) (Fig. 4).

When looking at the males ($\delta^{34}S$ mean = $7.90\%_{\text{av}}$, s.d. = 2.73) versus the females ($\delta^{34}S$ mean = $6.33\%_{\text{av}}$, s.d. = 1.45) no significant difference can be seen either ($t (19) = 1.565, P = 0.134$). (Table 1).

The animals analysed show a range of $\delta^{34}S$ values from 1.44 to 6.74\% (Bos 1.4\% to 6.7\%, Felis 5.6\% to 6.7\%, Essox 6.7\% to 6.7\%, and Sus 6.5\% to 6.5\%). They are used as a baseline, a local point of reference for the interpretations of the sulphur values (Table 2, Fig. 4).

Attempts to reconstruct the diet for the same period in Sigtuna have been performed previously in 2005 (Kjellström, 2005; Kjellström et al., 2009). A comparison between the contemporary assemblage from the previous study (of Church 1) and the present analysis resulted in significant differences in carbon values ($P < 0.001$) but not in nitrogen values (Fig. 5).

8. Discussion

8.1. Human diet during the medieval period in Europe

In comparison with other dietary studies performed on similar dated materials across Europe this set of dietary data conforms well (Privat et al., 2002; Polet and Katzenberg, 2003; Bayliss et al., 2004; Mühldner and Richards, 2007; Fornaciari, 2008). In an early study of an Anglo-Saxon cemetery, Privat et al. (2002) showed that the diet was based on terrestrial food with carbon values ranging from $-20.7\%_{\text{av}}$ to $-19.1\%_{\text{av}}$. The nitrogen values confirmed this, having a range of $8.4\%_{\text{av}}$ to $12.8\%_{\text{av}}$. It is clear though that some of the individuals studied here were supplementing their diet with some freshwater fish. Privat and colleagues also tested their data set to examine if there were any differences in dietary composition between the sexes, but no such difference was observed (Privat
et al., 2002). They detected a stronger input of freshwater fish in the "poor" group relative to the “wealthier” population. When a medieval monastic community from the coast of Belgium was examined, the mean values were $-19.1 \pm 0.46\%$, and $11.1 \pm 0.92\%$ for carbon and nitrogen respectively. The carbon isotopes were indicative of a terrestrial based diet. Once again the nitrogen isotopic values are high and can be explained by an input of freshwater fish or other marine products (Polet and Katzenberg, 2003).

8.2. Sulphur isotope values from Sigtuna and other parts of Sweden

Since the number of investigations using $\delta^{34}S$ on archaeological material is low, there are not that many data sets to compare these data to. The sulphur values obtained here show a rather dispersed set of $\delta^{34}S$ values ranging from 2.6 to 11.7$\%_{\text{SMOW}}$, with a mean $= 7.1\%_{\text{SMOW}}$, s.d. $= 2.4$. The $\delta^{34}S$ values are higher compared to two sets of previously published $\delta^{34}S$ values from other places in Sweden; from Birka (in close proximity to Sigtuna) mean $= 5.2\%_{\text{SMOW}}$, s.d. $= 2.5$ (Linderholm et al., 2008a) and from Björnö in the north of Sweden mean $= 5.4\%_{\text{SMOW}}$, s.d. $= 3.4$ (Linderholm et al., 2008b). The interpretation of the human $\delta^{34}S$ values is that they mostly fit with the surrounding geological signal stemming from the granite bedrock (21 individuals fall between $-4$ and 9$\%$). However there are some outliers that may well be from other places. There are for example two individuals with $\delta^{34}S$ values above 11$\%$ (11.6 and 11.7$\%$). They both fall well above the granite signal for the surrounding area and could possibly be from a different region altogether. Based on these results we cannot say that all humans buried at the cemetery were local. It is interesting to note that the individuals with the highest sulphur value represent both groups, this is also true for the individuals with the lowest sulphur values. This supports the interpretation that there is no geographical difference between the two groups investigated here.

None of the 23 remaining human samples or any of the animal samples were disregarded due to low C/S and N/S ratios (Fernandier et al., 2008; Nehlich and Richards, 2009). Accordingly to Nehlich and Richards (2009). Three of the samples showed a lower C/S ratio (207, 287 and 290) and four samples showed a lower N/S ratio (70, 96, 96, and 98) than would be expected. All of these values are however in the range suggested by Fernandier et al. (2008). For these values the indications for collagen preservation are within the documented ranges and are thought to be reliable (Table 1).

Animal $\delta^{34}S$ values are traditionally used as a "local" reference. In this study we have the cat (5.6$\%_{\text{SMOW}}$) and the pig (6.5$\%_{\text{SMOW}}$) as a terrestrial reference, and a marine reference from the fish. Aquatic animals have a different sulphur source and the $\delta^{34}S$ value for the fish can thus be different because of this (6.7$\%_{\text{SMOW}}$). The very limited amounts of animals analysed in this case study severely weakens the construction of a local baseline/signal, however they are suggestive of a local signature. The pig analysed in this investigation could very possibly be a domestic one and if so, might have been fed on human food waste. This would to some extent explain the $\delta^{34}S$ values and the higher $\delta^{15}N$ value. The pigs would most likely have been fed some fish scraps if fish were consumed at the site. Furthermore, it is possible that the pigs fed on plants affected by sea-spray aerosols as a result of, for example, a higher exposure to wind (cf. Angerbjörn and Pehrsén, 1987). Only very small traces of a sea spray effect might be observed in our samples; it might explain the pig and some of the range of our $\delta^{34}S$ values. Since we cannot detect it in any profound way it is unlikely to have a large effect on or data. The only “non-local” value among the animals tested seems to be the cattle sample (1.4$\%_{\text{SMOW}}$). Excluding the cattle sample would give the animals a $\delta^{34}S$ mean $= 6.3\%_{\text{SMOW}}$, s.d. $= 0.6$. This “local” signal fits very well with the mean value obtained for the human individuals tested ($\delta^{34}S$ mean $= 7.1\%_{\text{SMOW}}$). Given that the isotopic fractionation between food and consumer is relatively small ($-1\%_{\text{SMOW}}$ to $+2\%_{\text{SMOW}}$) and the surrounding bedrock signal (granite with a range from $-4$ to 9$\%_{\text{SMOW}}$) the sulphur signals obtained in this study appear to indicate a local origin.

The sulphur values show no difference between individuals affected by systemic disease and non affected individuals, nor does there seem to be any difference between the different sexes. This would indicate that there is no division between the affected and non-affected individuals.

8.3. Disease, religion and diet during the medieval period

In a study from 2004 Bayliss et al. investigated a medieval cemetery in Norwich. It is a cemetery where healthy individuals are buried next to individuals affected by leprosy, thus resembling the cemetery investigated in this study (Bayliss et al., 2004). Even though the focus of the paper was on the radiocarbon dates in conjunction with dietary offsets, similarities may be discerned between the isotopic data obtained in this study and the ones from the Humlegården block. At Norwich the carbon values ranged from $-20.9\%_{\text{SMOW}}$ to $17.0\%_{\text{SMOW}}$ and the nitrogen values from 9.8$\%_{\text{SMOW}}$ to 13.5$\%_{\text{SMOW}}$. There seems to be no difference between the individuals showing signs of leprosy and those who do not. The sample from the Humlegården block has a much higher $\delta^{15}N$ signal than all the data presented in prior studies, and the amount of freshwater fish or other $15N$-rich food digested seems fairly high. However, isotopic values in accordance with those from Humlegården were obtained in an investigation performed by Müldner and Richards in 2007 on a medieval English population (Müldner and Richards, 2007). In this material the religious impact on the diet is strongly demonstrated and can be compared to our data set. Their study is based on stable isotope analysis on populations from three different medieval sites in Northern England: a friary, a mass grave, and a rural hospital. All of these new sites differ from prior investigations performed on archaeological populations in one aspect; they all demonstrate enriched $\delta^{15}N$ values in combination with terrestrial carbon signals. The explanation given by Müldner and Richards for this phenomenon is that what is being measured is actually the impact of medieval fasting regulations. The results also point to the fact that there was little difference in diet between different social groups. There is a slight difference within the populations; the priests and patrons have higher nitrogen values than the rest. Basically what we can see in this study is an increase in freshwater fish consumption in these medieval populations regardless of social standing. The stable isotope values from the three sites range from $-20.6\%_{\text{SMOW}}$ to $-18.1\%_{\text{SMOW}}$ for carbon and from 10.5$\%_{\text{SMOW}}$ to 14.9$\%_{\text{SMOW}}$ for nitrogen (Müldner and Richards, 2007). These values are very similar to the values obtained in the current study and the explanation for the high nitrogen values in combination with extreme terrestrial carbon values may be the same. Hence, what we are seeing in our data set is most likely evidence for medieval fasting practices.

So, in order to explain the high $\delta^{15}N$ ratios seen in this study in combination with totally terrestrial carbon signals one has to look at some possible explanations. These could be a diet based on freshwater resources, migrating birds, sucking animals or on pork from animals that had themselves consumed large quantities of animal products (Privat et al., 2002; Rubenstein and Hobson, 2004; Jay and Richards, 2006). The latter scenario seems rather unlikely based on data from the single pig analysed and thus cannot account for the high $\delta^{15}N$ ratios obtained. Discoveries of bone debris from migratory birds and juvenile livestock have been made in Sigtuna but the explanation of a high input of freshwater fish in the diet seems far more plausible. It has been shown in prior studies that a large part of the diet in medieval populations was based on
freshwater fish (Privat et al., 2002; Polet and Katzenberg, 2003; Mülndner and Richards, 2007). In a recent paper by Grupe et al. (2009) stable isotope analysis was performed in order to evaluate the brackish water aquatic food web. Here they clearly show that freshwater fish can be depleted in their δ13C values. They also observed raised δ15N values for carnivorous, top-consuming fish species (i.e. cod), which could explain the high δ15N values obtained in this study. This is also corroborated with the fact that religious beliefs dictated that fish should be eaten during the fast on certain days (up to one third of the year) (Montanari, 1999).

Based on the medieval religious doctrines concerning a “spiritual geography”, the burial locations of the individuals possibly affected by leprosy suggest a socially stratified society. Severe pathological changes are seen in skeletons in the outskirts of the cemeteries and not in the parts located near the churches. Furthermore, previous studies of skeletal medieval samples from the same site have shown differences in dietary patterns, most likely based on social stratification. Surprisingly, a clear social dichotomy is not observed in the diet of the affected. Individuals with bone changes indicative of systemic diseases such as leprosy had the same diet as the (at least seemingly) unaffected community at the same cemetery. On the other hand, the individuals buried in the same area as the six possible cases of leprosy could have been sick for a long time from diseases that do not affect the skeleton. Hence, comparisons between skeletons with and without skeletal changes are not necessarily the same as comparisons between unhealthy and healthy individuals. However, leprosy affected individuals, according to historical sources, be seen as a group of their own, with a more severe social stigma than others. It is possible that the sample is spatially biased, and that a different result would have been obtained had individuals buried within the church building (clearly signaling higher status) been included. With the results in mind, it is therefore suggested that if there existed a dietary difference between infected and seemingly healthy people it was not a difference in food source but rather in other parameters, i.e. the same type of food was consumed but in varying quality and freshness.

Both the archaeological and the rare historical records indicate that different social groups in society used the churchyard at the Humlegården block and the one belonging to Church 1 (Kjellström et al., 2005; Wikström, 2008). Comparing the sample from Humlegården (Church 2) as a whole with a sample from a contemporary group of people buried in another churchyard (Church 1), some differences in carbon values were discernable. This shows that dietary differences indeed existed in Sigtuna. The results suggest that the people in the Humlegården block consumed fewer vegetables but the same amount of freshwater fish as a contemporary group of people from another cemetery. As in the previous study (Kjellström et al., 2009), the difference could have socio-cultural or socio-economic explanations. Although a supposed social hierarchy is implied by the discovery of the group with signs of systemic diseases (including both leprosy and tuberculosis) in the outskirts of the churchyard, the differences cannot be verified through the dietary analysis. Instead, it seems like the borders of the churchyards not only delimit the distribution of the graves but also symbolize social restrictions and differences in consumption. This is in accordance with the generally high prevalence of pathological changes at the Humlegården block compared to other cemeteries (Kjellström and Wikström, 2008). Furthermore, even though the six most afflicted individuals did not differ in diet from the rest of the sample, it is not clear that they shared food of the same quality and freshness.

9. Conclusions

Knowledge of the diet during the medieval period is mainly based on written sources. As an increasingly substantial archaeological material is unearthed and analysed, it is becoming possible to examine the diet in a more direct way. From the few comparable isotopic studies performed on medieval populations (Privat et al., 2002; Polet and Katzenberg, 2003; Bayliss et al., 2004; Mülndner and Richards, 2007; Fornaciari, 2008), the results indicate a diet based on terrestrial sources with a rather large input of freshwater fish. It has also been possible to investigate potential differences in diet between social groups and, as in this study, between healthy individuals and those affected by systemic disease.

When analysing the sulphur isotope composition, no differences could be ascertained in either affected versus non-affected groups or females versus males. This would indicate that the people buried at Humlegården originated from the same region or at least that no clear distinctions can be made between the origins of the two groups. Comparing the animal reference δ34S measurements with the human δ34S values, the origin of the people buried here seems to be predominantly local but with a few exceptions. This all fits with Sigtuna’s status as a town and trading centre with people from around the Baltic Sea.

The burial locations of the affected suggest a socially stratified society and social stratification has been indicated in previous studies. No dietary differences were observed between affected and non-affected individuals or between females and males. Differences were only found when comparing the total sample with a contemporary cemetery. Given that socially defined diets existed these may have been expressed as differences in food quality rather than food source. The results from the present study highlight the hierarchical arrangements of social classes in the early medieval society.

Acknowledgements

We would like to thank Sigtuna museum for access to the Sigtuna skeletons. We would also like to thank the anonymous reviewer for the comments.

Grant sponsorship: Berit Wallenberg foundation.

References


