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Fast or feast: reconstructing diet in later medieval England by stable isotope analysis

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Abstract

In this pilot-study, which was designed to assess the range of isotopic variation in English medieval populations, we present the results of stable isotope analysis of carbon and nitrogen of human and animal bone collagen from three later medieval sites in Northern England.

The isotopic values observed for the rural hospital of St. Giles by Brompton Bridge (N. Yorks.), the Augustinian Friary at Warrington and a mass-grave with casualties from the Battle of Towton (N. Yorks.) are significantly different from those reported for other archaeological populations in Britain, namely by their very enriched $\delta^{15}N$ ratios which are combined with almost entirely terrestrial carbon signals. We discuss possible explanations for the unusual human data and argue on grounds of the available faunal data, that a mixed diet of terrestrial, marine and freshwater resources is most likely. This may indicate the significant impact of the medieval fasting regulations on everyday subsistence. We conclude that stable isotope analysis can complement the available historical information on diet in the Middle Ages.

Keywords: Stable isotope analysis; Carbon; Nitrogen; Bone collagen; Palaeodiet; Aquatic foods; Middle Ages

1. Introduction

Medieval historians have recognised the importance of the study of diet and nutrition and its link with medieval society relatively early on (e.g. [57]). Today's understanding of diet in the Middle Ages is therefore largely based on written sources, although more and more new evidence is contributed by the disciplines of medieval and environmental archaeology (e.g. [19]).

Scientific methods for reconstructing diet and in particular stable isotope analysis of bone collagen have until now only rarely been applied to the medieval period. This is unfortunate, as isotope analysis can complement existing approaches. Where documentary sources are biased towards the upper ranks of society and zooarchaeological and botanical assemblages are usually limited to giving bulk information about a site as a whole, stable isotope analysis can provide a direct measure of human diet on an individual level.

Previous isotope studies on medieval material have either focussed on a single site [9,33,45] or have been designed to explore very specific questions, such as the importance of marine foods [41] or the age of weaning [51]. The present paper takes a more general approach to the study of diet by comparing isotopic data from several sites, of the same time period, yet of different functions, representing a variety of social groups. This allows us not only to obtain direct evidence for diet in

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later medieval England but also to assess the range of isotopic variation in medieval populations.

2. Reconstructing diet by stable isotope analysis

Stable isotope analysis for palaeodietary reconstruction is based on the principle that both animals and humans record the isotopic composition of the food they have eaten in their body tissues. The relative abundance of the stable carbon isotopes ^{13}C and ^{12}C ($\delta^{13}C$), varies characteristically between different ecosystems, e.g. terrestrial and marine [16,55], and plants of different photosynthetic pathways [60]. The nitrogen stable isotope ratio of ^{15}N to ^{14}N ($\delta^{15}N$) increases by usually 3–4‰ with each step up the food-chain [54]. When interpreted in relation to the isotopic signatures of available food sources, the combination of carbon and nitrogen isotope ratios in archaeological bone therefore provides a direct measure of the diet of an individual [2,56].

The preferred substance for analysis is collagen, not only because it is the only considerable nitrogen source in bone, but also because its isotopic integrity can be assessed by relatively easily applicable quality indicators [20,61].

Since dietary protein is routed for body protein synthesis, collagen stable isotope ratios reflect the isotopic signals of the main dietary protein sources rather than of diet as a whole [3,35]. They only separate rather broad categories, mainly plant, herbivore and carnivore protein derived from terrestrial or marine ecosystems, while different protein sources from the same animal, such as meat and dairy products, are isotopically indistinguishable.

Bone is renewed constantly, yet turnover is rather slow and also decreases significantly after the growth period. Collagen stable isotope data therefore represent a long-time average of diet over the last decade or more of an individual's life [28,38].

Despite these limitations, stable isotope analysis of bone collagen is currently the most widely used method for palaeodietary reconstruction by bone chemistry analysis. In recent years, it has been applied throughout the world and to various archaeological periods and research questions (for reviews see [36,56]).

3. English society in the later Middle Ages

The Middle Ages are traditionally defined as the *"period in-between"* the fall of the Roman Empire in the late 5th century AD and the beginning of the Early Modern Period around 1500 AD. In a British context, use of the term is often limited to the period after the Norman Conquest of 1066, and a further subdivision is frequently made between the earlier (11th and 12th cent.) and later medieval periods (13th to early 16th cent.).

Medieval economy and society are often described as "feudal", implying a system in which lords granted access to land and other resources, in exchange for services and rents paid in kind or cash. As the lords were obliged to their tenants for protection and justice, this arrangement was generally seen as a system of mutual benefit [25,37].

The social hierarchy was complex. The land was cultivated by free peasants with holdings of varying sizes, but also by unfree serfs or wage-labourers. The landed aristocracy lived mostly of the proceeds, however, they too owed service, especially military and administrative, to their own lords, ultimately the king [37,52].

The clergy was set apart from the aristocracy and commons by their spiritual functions. Nevertheless, the Church was also one of the richest landowners, and the life-style of its bishops and prelates, who frequently held important positions in the political system, resembled that of the aristocracy in many ways. Lower clerics, overseeing individual parishes, drew a varying living from the duties paid by their parishioners [52,59]. The numerous monastic and religious orders, whose life-style was strictly regulated by a common rule, were not firmly bound into the church hierarchy. The wealth of individual Houses could be immense and was largely based on bequests of land, money or privileges made by lay benefactors [14].

Towns emerged as centres of trade and craft mainly from the 9th century onwards, and their growth was actively promoted with economic and legal privileges [25]. By the later Middle Ages, the most successful merchants had come to form a new elite in medieval society and their wealth and life-style rivalled that of the lower aristocracy. Social and occupational diversity was one of the key urban characteristics, however, and the well-off merchants and craftsmen of the middling sort were always outnumbered by petty traders, servants and wage-earners as well as the plain poor [58].

4. Diet in later medieval England: the historical evidence

Historical evidence indicates that later medieval diet was mainly based on cereals, especially wheat, with varying amounts of meat and fish being consumed by different social groups [24].

Meat and fish were the main food expenditure in households of the aristocracy, the upper clergy and also of wealthy town-dwellers. They were often ordered in excessive amounts as items of conspicuous consumption [64]. Meat was served in great variety, mainly beef, followed by pork, mutton and poultry. Venison and

wild birds may have been less frequently consumed but had an important function in the definition of status [1,24].

The church calendar dictated fasting, i.e. the abstinence from meat, for nearly half the days of the year, including every Friday, Saturday and often Wednesday as well as during Lent and Advent. Up until the early 16th century, fish was thus of almost equal importance to meat for the upper classes, and a variety of marine species was available at both coastal and inland locations [63,65]. In contrast, freshwater species were much less common and particularly pond fish appears as highly priced luxury food which only the very wealthy could afford on a regular basis [23,65].

The bulk of lower class diet was again made up of cereals. Boiled pottage on the basis of grain or pulses, supplemented with vegetables, was a ubiquitous dish. Although meat was available to peasants and labourers, it was consumed in much smaller quantities and probably lesser quality cuts than by the elites. Instead, milk, cheese and eggs were the most important protein source for the lower classes, at least until the later 14th century when meat became more affordable. Dairy products were also regularly consumed on fast days, substituting for fish, although salted herring and some marine molluscs were also relatively cheap commodities [22,24].

Differences between town and country were subtle but urban living standards seem to have been generally higher and a greater variety of fresh foods was readily available from the markets [24,62].

The diet of religious communities was originally strictly regulated as to the number of meals and the foods allowed. The rule of St. Benedict, for example, the most influential in medieval England, prohibited the consumption of quadruped flesh, except for the sick. Skilful "interpretation" of the original text, however, enabled the monks to progressively bend these regulations. By the end of the medieval period, the diet of most well-off religious communities therefore closely resembled that of the grand secular households, except for perhaps a closer observance of fast days [10,31].

5. The sites in their historical context

In order to explore the range of isotopic variation in medieval populations, samples for this study were selected from three contemporaneous, yet different use, sites to provide dietary data from a variety of social groups (Fig. 1).

5.1. St. Giles

The rural hospital of St. Giles by Brompton Bridge on the River Swale in North Yorkshire was founded in

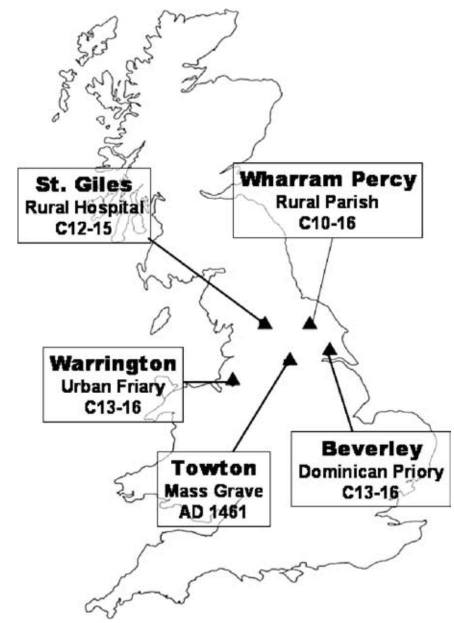

Fig. 1. Map of Britain, showing the locations of the five sites from which isotope data are presented here.

the second half of the 12th century and probably went out of use in the late 15th century [15]. Medieval hospitals were primarily religious institutions, and rather than offering medical treatment, they provided care for the sick, the poor and the elderly who were living together under a common rule [24]. St. Giles was always a fairly humble, low-status establishment, although building work on the site reflects a temporary rise in fortune in the mid-13th century [15]. Nineteen adults from the hospital's cemetery, most likely the inmates, were selected for isotope analysis. These included two (SG 1280, 1423) which were identified as priests by the inclusion of mortuary chalice and paten in the grave, as well as the so-called "patron" (SG 1483), an adult male who had been buried in prominent position inside the chapel ([15]; see [18]).

5.2. Warrington

Archaeological evidence dates the foundation of the Augustinian Friary in Warrington to the mid-13th century. Like most other religious houses in Britain, it was dissolved in 1539 but the site continued to be in use as a burial ground until well into the 17th century [39].

The Austin Friars were part of the Mendicant Movement that spread over Western Europe from the early 13th century onwards. Initially obligated to absolute poverty, they settled in towns to preach, but were relatively soon absorbed into the ecclesiastical establishment [14]. Burial in Friaries became increasingly popular with the better-off laity, who would often make considerable bequests for the privilege [30,46].

In the case of the Warrington House, several well-to-do families from in and around the town are known to have chosen the Friary for burial of their dead [7].

Excavations inside the Friary church revealed at least 110 burials of men, women and children from various phases, representing the friars as well as lay benefactors to the House [12,39]. Of these, it was possible to choose 20 adults for isotope analysis, which were selected to contain individuals from all chronological phases and excavation areas. The sample also includes a priest (WR 5710), who was again identified by the inclusion of a lead chalice with his burial.

5.3. Towton

The mass-grave from the village of Towton (N. Yorks.) was discovered in 1996. Contextual evidence convincingly suggests that the individuals were casualties of the Battle of Towton in AD 1461, which is generally regarded as the most violent encounter between the Houses of York and Lancaster in the Wars of the Roses.

Thirty-eight individuals, all adult males, were recovered, most of them showing multiple weapon-related trauma. Some of the lesions were well-healed and suggested that these men were professional soldiers [26]. For this study, 11 individuals were sampled from the disarticulated remains.

5.4. Associated faunal remains

In order to best understand the human isotope data of interest, it is essential to analyse a range of contemporaneous faunal samples from the same region, ideally the same location. Due to the nature of the three sites it was only possible to obtain animal bone from St. Giles. Additional faunal data is therefore included here, from the medieval rural village of Wharram Percy (North Yorks.), for which human isotope values have been published previously [51], as well as fish bone data from 14th and 15th century deposits in the Dominican Priory at Beverley in Eastern Yorkshire [27].

6. Methods

All bone samples were prepared following protocols based on Brown et al. [13] and Collins and Galley [17]. Specifically, samples of 0.1–0.2 g of bone were cleaned by air-abrasion and demineralised in 0.5 M HCl at 4 °C for several days. They were then rinsed to neutral pH with de-ionised H_2O, placed in sealed tubes and gelatinised in a pH 3 HCl solution at 70 °C for 48 h. After removing reflux-insoluble residues with a 5–8 μm Ezee® mesh (Elkay Laboratory Products), the remaining solution was concentrated in Ultrafree®-4 Centrifugal Filter Units fitted with Biomax-30 membranes (Millipore). The supernatant, purified "collagen" (> 30 kDa), was freeze-dried for 48 h. Isotopic measurements were performed in duplicates by Iso-Analytical (Cheshire) and in the Department of Archaeological Sciences, University of Bradford. The analytical error (1σ) for $\delta^{13}C$ and $\delta^{15}N$ was $\pm 0.2‰$ or less.

7. Results and discussion

The results of the isotopic measurements and basic descriptions of the samples are summarised in Tables 1 and 2. The human $\delta^{13}C$ ratios from St. Giles, Warrington and Towton, range between $-20.6‰$ and $-18.1‰$ with a mean of $-19.4 \pm 0.6‰$ (1σ). The associated $\delta^{15}N$ values range between 10.5‰ and 14.9‰ with a mean of 12.2 $\pm 0.9‰$.

This human isotope data are extremely unusual compared to other published stable isotope studies for Holocene Britain. There is no indication for the consumption of any significant amounts of plant protein, and the $\delta^{15}N$ ratios are mostly far too enriched to be explained by the consumption of terrestrial herbivore protein alone. Nevertheless, the $\delta^{13}C$ values suggest a terrestrial, C_3-based diet with no or only minor marine input. Moreover, the nitrogen values are significantly different not only from those reported for adult individuals from the medieval rural settlement of Wharram Percy [51] but also from all other early historical English sites for which published isotope data are available: the Romano-British burial ground at Poundbury in Dorset [50] and the early Anglo-Saxon cemetery at Berinsfield, Oxfordshire [47] (Fig. 2). The isotope data from the three sites are nevertheless comparable with stable isotope ratios observed during ^{14}C-dating of medieval human remains [5,40] and isotope data recently reported from a later medieval monastic community in Western Flanders, Belgium [45].

Somewhat surprisingly, a comparison between the three sites, St. Giles, Warrington and Towton, revealed little isotopic variation between the social groups. The mean $\delta^{13}C$ and $\delta^{15}N$ ratios of all three populations overlap within the 1σ range (Fig. 2). The overall range of isotopic values (2.5‰ for carbon, 3.4‰ for nitrogen) suggests some variation within the populations and "special burials" like those of the three priests and the St. Giles "patron" all plot within the upper range of the observed $\delta^{15}N$ values. No convincing case for social variation in diet can nevertheless be made by comparing isotopic with archaeological and anthropological data. Results (*not shown*) for differences between males and females and burials in and outside of the church are inconclusive, although they may merit further investigation [42,43].

Table 1
Human samples: isotopic results and basic anthropological information

Sample no.[a]	$\delta^{13}C$	$\delta^{15}N$	C:N[b]	% coll.[c]	Sex[d]	Age[e]
SG 1229	−19.2	12.1	3.3	8.5	F	OA
SG 1253	−20.1	10.9	3.4	6.6	?F	OA
SG 1268	−19.8	12.2	3.4	5.2	M	OA
SG 1271	−18.8	13.1	3.3	7.5	M	MA/OA
SG 1272	−18.9	12.4	3.3	5.2	M	MA/OA
SG 1276	−19.0	12.2	3.5	5.5	M	MA/OA
SG 1280	−19.3	13.0	3.3	7.1	?M	MA
SG 1401	−18.3	13.0	3.3	9.3	?F	MA
SG 1407	−18.7	13.0	3.4	6.6	M	OA
SG 1423	−18.5	13.4	3.3	10.4	M	OA
SG 1449	−19.0	12.5	3.4	9.3	?M	MA
SG 1483	−18.7	13.8	3.2	6.6	M	MA
SG 1523	−18.7	13.2	3.4	2.1	M	YA/MA
SG 1536	−19.9	12.1	3.4	8.2	?	12-17
SG 1542	−19.6	11.2	3.3	5.8	?	MA/OA
SG 1659	−18.8	13.0	3.3	7.8	M	MA
SG 1710	−19.7	11.9	3.3	12.5	F	YA/MA
WR 5274	−20.3	11.7	3.4	2.9	F	MA
WR 5299	−20.4	11.2	3.2	16.5	F	OA
WR 5315	−20.3	10.9	3.3	8.5	M	OA
WR 5325	−19.9	11.0	3.3	8.3	M	MA
WR 5347	−20.5	11.1	3.3	9.7	F	OA
WR 5370	−20.1	11.6	3.4	5.5	M	OA
WR 5402	−20.5	12.3	3.6	1.1	M	MA
WR 5428	−19.3	11.9	3.4	5.6	F	OA
WR 5444	−19.0	13.7	3.5	3.4	M	MA/OA
WR 5521	−20.0	12.3	3.4	8.7	M	MA
WR 5573	−19.4	12.2	3.3	2.5	F	MA
WR 5613	−19.6	12.4	3.3	12.0	F	MA
WR 5636	−18.8	13.3	3.4	4.4	M	OA
WR 5649	−20.6	11.0	3.4	1.2	F	OA
WR 5652	−19.8	10.6	3.5	1.4	F	YA
WR 5688	−19.8	11.1	3.5	6.9	?F	OA
WR 5710	−19.3	13.9	3.4	1.1	M	OA
WR 5724	−19.4	12.9	3.5	3.8	M	OA
TW 1	−18.9	13.2	3.3	3.3	M[f]	
TW 2	−19.2	12.4	3.2	9.2	M[f]	
TW 3	−19.7	12.1	3.4	11.3	M[f]	
TW 4	−19.6	13.6	3.1	4.0	M[f]	
TW 5	−19.5	11.8	3.2	3.8	M[f]	
TW 6	−19.7	14.0	3.4	11.4	M[f]	
TW 7	−20.2	12.1	3.4	1.0	M[f]	
TW 8	−19.2	13.1	3.3	12.8	M[f]	
TW 9	−18.3	12.8	3.2	11.0	M[f]	
TW 10	−19.1	12.1	3.3	8.2	M[f]	
TW 11	−19.9	12.4	3.4	2.9	M[f]	

Samples were taken mostly from ribs, only where no ribs were present, from long bones. For the Towton individuals, samples were extracted from disarticulated right patellae. (For full details see [42]).

[a] SG = St. Giles humans; WR = Warrington humans; TW = Towton humans.

[b] Atomic C:N ratio (see [61]), acceptable range 2.9–3.6.

[c] mg/g of bone (see [61]). Note that the use of ultrafilters (as described under Methods) lowers the "collagen" yield by about 50% or more [43].

[d] M = male; ?M = probably male; F = female; ?F = probably female.

[e] YA = Young adult (ca. 18–25); MA = middle adult (ca. 26–45); OA = old adult (45+).

[f] Sex inferred from all male composition of the grave.

Table 2
Faunal samples: isotopic results and species identification

Sample no.	Species	$\delta^{13}C$	$\delta^{15}N$	C:N	wt.% coll.
SG-A 2	Cattle	−21.9	6.0	3.4	4.3
SG-A 4	Cattle	−21.9	5.4	3.2	2.8
SG-A 9	Cattle	−21.2	4.5	3.4	12.4
SG-A 10	Cattle	−21.4	4.1	3.4	4.7
SG-A 15	Cattle	−21.7	5.8	3.2	6.1
SG-A 17	Cattle	−21.6	4.3	3.4	5.9
SG-A 6	Cattle[a]	−23.9	4.0	3.2	2.5
SG-A 18	Cattle[a]	−21.3	4.9	3.1	3.5
SG-A 22	Pig	−21.4	7.2	3.2	14.2
SG-A 8	Pig[b]	−20.6	8.4	3.2	8.7
SG-A 14	Pig[b]	−21.1	7.8	3.1	13.6
SG-A 16	Pig[b]	−21.8	6.2	3.4	3.5
SG-A 1	Red deer	−22.0	4.0	3.4	5.3
SG-A 3	Sheep	−22.2	5.8	3.6	2.7
SG-A 5	Sheep	−21.8	4.9	3.4	7.1
SG-A 7	Sheep	−21.6	5.5	3.4	5.9
SG-A 11	Sheep	−21.9	5.8	3.3	13.3
SG-A 12	Sheep	−21.3	6.4	3.3	8.9
SG-A 13	Sheep	−21.5	6.4	3.3	8.9
SG-A 19	Sheep	−21.7	4.5	3.4	5.9
SG-A 20	Sheep	−21.6	8.8	3.4	1.3
SG-A 21	Sheep	−21.4	6.4	3.2	9.2
WP-A 5	Cat	−21.0	7.3	3.3	11.9
WP-A 9	Cat	−20.7	8.1	3.5	3.6
WP-A 12	Cat	−21.1	6.0	3.2	4.5
WP-A 23	Cattle	−22.0	5.2	3.4	2.9
WP-A 24	Cattle	−21.9	3.5	3.5	2.2
WP-A 26	Cattle	−21.9	4.6	3.4	4.8
WP-A 22	Cattle[a]	−22.1	5.8	3.2	4.4
WP-A 25	Cattle[a]	−21.4	5.5	3.2	4.1
WP-A 2	Dog	−20.7	9.5	3.2	5.1
WP-A 3	Dog	−20.1	7.9	3.2	4.3
WP-A 4	Dog	−20.1	8.5	3.3	6.8
WP-A 7	Dog	−21.3	6.7	3.2	2.7
WP-A 10	Dog	−20.9	9.2	3.3	6.5
WP-A 11	Dog	−20.2	8.4	3.1	7.5
WP-A 13	Domestic fowl	−20.2	7.2	3.2	2.0
WP-A 14	Domestic fowl	−20.3	8.6	3.2	3.7
WP-A 15	Domestic fowl	−20.4	7.4	3.3	5.3
WP-A 1	Horse	−23.0	7.0	3.5	5.1
WP-A 6	Horse	−22.9	7.1	3.2	3.1
WP-A 8	Horse	−22.6	5.2	3.3	4.1
WP-A 32	Horse	−23.1	5.0	3.6	2.9
WP-A 16	Pig	−21.3	6.4	3.4	6.9
WP-A 17	Pig	−21.2	6.1	3.6	4.9
WP-A 18	Pig	−21.1	4.9	3.6	5.7
WP-A 19	Pig	−21.5	9.7	3.5	3.7
WP-A 20	Pig	−21.9	7.0	3.2	7.0
WP-A 21	Pig	−20.7	5.5	3.4	5.8
WP-A 27	Sheep/goat	−22.2	5.7	3.2	4.4
WP-A 28	Sheep/goat	−22.0	5.0	3.0	6.2
WP-A 29	Sheep/goat	−21.6	5.3	3.2	4.5
WP-A 30	Sheep/goat	−21.9	7.6	3.4	3.5
WP-A 31	Sheep/goat	−21.4	5.8	3.4	6.8
BVY 14	Cyprinid	−18.6	10.2	3.4	6.3
BVY 1	Eel	−17.6	10.6	3.3	9.7
BVY 13	Eel	−22.7	12.8	3.2	10.2
BVY 19	Eel	−22.9	11.0	3.2	6.0
BVY 23	Eel	−21.7	11.7	3.3	8.7
BVY 30	Eel	−23.5	11.8	3.3	9.9
BVY 32	Eel	−24.9	11.9	3.3	10.2
BVY 5	Flatfish	−13.2	11.7	3.3	5.4

(*continued on next page*)

Table 2 (*continued*)

Sample no.	Species	$\delta^{13}C$	$\delta^{15}N$	C:N	wt.% coll.
BVY 24	Flatfish	−12.4	13.7	3.2	6.1
BVY 3	*Gadidae* sp.	−12.6	13.8	3.4	5.2
BVY 8	*Gadidae* sp.	−11.8	16.9	3.5	2.6
BVY 10	*Gadidae* sp.	−12.9	11.3	3.5	9.0
BVY 22	*Gadidae* sp.	−14.1	14.4	3.4	3.8
BVY 28	*Gadidae* sp.	−12.7	14.8	3.2	3.1
BVY 16	Haddock	−13.0	12.6	3.3	4.1
BVY 27	Haddock	−13.2	13.3	3.3	8.2
BVY 2	Herring	−16.1	10.1	3.3	7.2
BVY 9	Herring	−14.2	10.4	3.3	9.0
BVY 26	Herring	−15.4	11.5	3.3	5.6
BVY 25	Ling	−12.4	17.2	3.3	4.4
BVY 6	Pike	−24.5	23.4	3.2	8.1
BVY 15	Pike	−23.4	16.7	3.3	4.2
BVY 17	Ray	−12.0	14.7	3.4	4.0
BVY 7	Whiting	−12.0	12.7	3.1	6.2
BVY 11	Whiting	−13.6	14.5	3.5	4.0
BVY 20	Whiting	−12.4	14.4	3.2	6.0
BVY 21	Whiting	−12.4	14.2	3.3	5.3
BVY 29	Whiting	−12.9	14.3	3.3	4.8

SG-A = St. Giles animals; WP-A = Wharram Percy animals; BVY = Beverley fish.
All mammal bone samples were taken from long bone epiphyses, fish samples from vertebrae.
Ageing was undertaken by epiphyseal fusion. Unless otherwise indicated, all individuals were adults.
Only one sample per species was taken from any archaeological context. Fish bone data may represent average of more than one individual.
[a] Subadult.
[b] Subadult, but according to bone size at least one year or older.

7.1. Animal bone samples

$\delta^{13}C$ and $\delta^{15}N$ ratios for animal bone samples from St. Giles and Wharram Percy are in excellent agreement, with differences between the mean values for species less than 0.5‰. They are also well consistent with other faunal isotope data from the British Holocene which were collected mostly in southern England [47,49] (Fig. 3). Differences in the human isotope data are therefore caused by dietary variation rather than regional or diachronic fluctuations in isotopic base-line values.

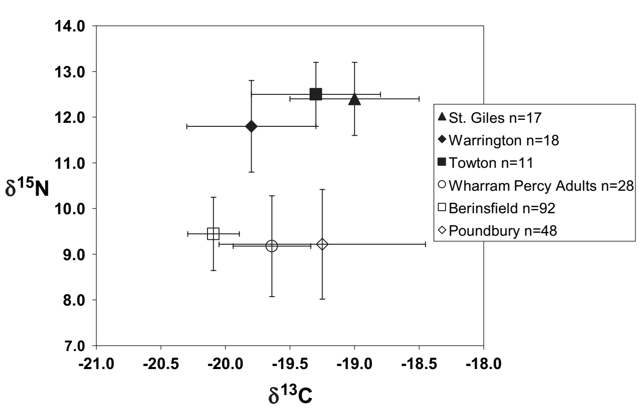

Fig. 2. Mean isotopic values for humans from St. Giles, Warrington and Towton in comparison with isotope data from Wharram Percy [51], Berinsfield [47] and Poundbury [50], (all means ± 1σ). Note that the $\delta^{15}N$ ratios for the three later medieval populations are significantly different from those of the other sites.

7.2. Omnivore protein or freshwater resources?

When uncommonly high $\delta^{15}N$ ratios combined with an entirely terrestrial carbon signal are observed in palaeodietary studies, two possible explanations are usually discussed: the consumption of omnivore protein, e.g. from pigs feeding on animal products, or the use of freshwater resources (e.g. [11,47]).

In the medieval periods, pigs were usually herded on fallow land or in the forest to fatten on beech and acorn mast. Especially in towns, however, they are known to have been kept in back yards or roaming the streets, feeding on scraps and waste [29,53].

Most freshwater fish was rather expensive and therefore not widely available in later medieval England [23]. Fishing rights in local streams and rivers were reserved to the lords and leased out for significant rents, although these restrictions were a constant source of conflict [34]. Some riverine species and especially eels nevertheless played a part even in lower class diet [63].

Stable isotope analysis of pig bones from St. Giles and Wharram Percy shows that most pigs plot within the herbivore range (Fig. 4). With a $\delta^{15}N$ ratio of 9.7‰, WP-A 19 is a notable exception. This fully adult pig must have acquired most of its dietary protein from animal products, which is the more surprising since the pig was kept in a rural environment. SG-A 8 appears likewise enriched in ^{15}N. Preservation did not allow ageing by epiphyseal fusion, however, although according to bone size, this specimen was probably at least a year old. The elevated $\delta^{15}N$ ratio of 8.1‰ could therefore be a weaning signal (see [32]).

From the pig isotope data obtained so far, it appears unlikely that the consumption of pork alone can account for the observed human isotope values. The results nevertheless highlight the potential of isotope analysis to contribute to another important aspect of animal husbandry in the past [48].

As expected from modern analogues (e.g. [21]), the isotopic signals of the archaeological freshwater and migratory fish species from Beverley are very variable (Fig. 3). The majority of these fishes would have been caught in the River Humber and its tributaries, although there is also reference to fishponds and fisheries within the precinct of the priory [44]. The pike BVY 6, with a $\delta^{15}N$ ratio of 23.4‰ which greatly exceeds those reported for modern lake specimens [6], may have been raised in such a fishpond. These required specialised skills for maintenance and their water supply was sometimes directly linked with the sewages which

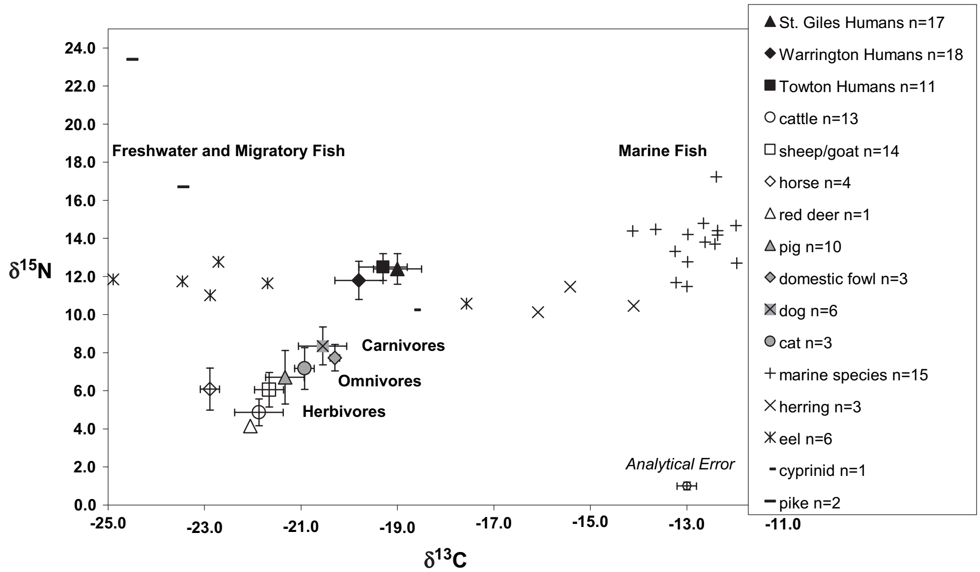

Fig. 3. Human and animal bone isotope data from Northern England (all means $\pm$ 1σ). On grounds of the faunal data, a combination of terrestrial animal, freshwater and marine protein appears as the most likely explanation for the unusual human isotope values.

would probably have created a very distinctive isotopic system [4].

From the available faunal data, a mixture of terrestrial, freshwater (eel?) and marine protein, appears as the most likely explanation for the observed human collagen values. This is perhaps less surprising, since both the St. Giles hospital and the Warrington Friary are situated directly on rivers, the Swale and the Mersey, respectively. Nevertheless, comprehensive sieving during the St. Giles excavation had retrieved only few fish bones, and freshwater species were far outweighed by marine specimens [15]. Similarly, the literary evidence for later medieval England suggests that sea fish in general was consumed in greater quantities than freshwater fish [31,63].

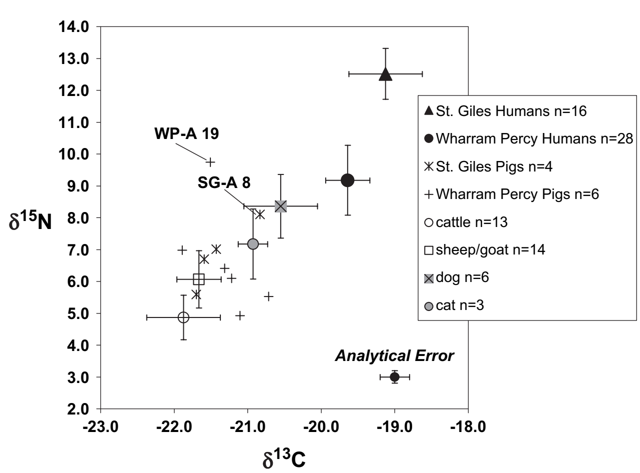

Fig. 4. Pig isotope data from St. Giles and Wharram Percy in comparison with herbivores, carnivores and humans from both sites (all means $\pm$ 1σ). Refer to text for details.

The isotopic results for the Towton individuals, which are on average the most enriched in ^{15}N of all three groups, nonetheless seem to indicate that the apparent "freshwater signal" in later medieval diet was not confined to few locations only: the soldiers fighting in the Battle of Towton had been drafted from various social backgrounds and from all over England [8]. This social and regional heterogeneity within the group may be reflected in the extremely poor linear relationship between δ^{13}C and δ^{15}N ratios of the Towton samples (r^2 = 0.02), compared with those of the resident populations St. Giles (r^2 = 0.68) and Warrington (r^2 = 0.39). Nevertheless, their long-term diet, as indicated by stable isotope analysis, was, rather similar.

8. Conclusions

The diet revealed by stable isotope analysis of bone collagen for three socially diverse groups in later medieval England is somewhat different from what would have been expected on grounds of historical and archaeological background information. In particular, the results show little dietary variation between the sites but emphasize the role of aquatic resources in everyday subsistence.

The isotopic values presented here are significantly different from those reported for other English sites. Although it is too early to say, whether this represents a general dietary change, it is appealing to interpret it as a consequence of the fasting regulations imposed by the church, which proscribed the consumption of meat for nearly half the days of the year [63]. Stable isotope data

could therefore illustrate the enormous impact of religious dietary rules on the wider population.

While both the Romano-British burial ground at Poundbury [50] and the Anglo-Saxon cemetery at Berinsfield [47] are much earlier than the sites investigated here, the sampled burials from the medieval parish of Wharram Percy can be dated only broadly between the 10th and 16th century and may be contemporary with or slightly earlier than St. Giles, Warrington and Towton [51]. The inhabitants of Wharram Percy were mostly ordinary peasants, and since the lower classes usually substituted meat with dairy products rather than fish on fast days, the observed dietary differences between the village and the other three sites may therefore be social [24]. Alternatively, they could simply be determined by settlement location and access to a variety of foodstuff, as Wharram Percy was situated rather remotely and away from any major river systems in the Yorkshire Wolds. Although much more work remains to be done in order to investigate these possibilities, these points serve to illustrate how stable isotope analysis with its capacity to target specific populations and individuals can be a valuable addition to more traditional methods of dietary reconstruction in the historical periods.

Some caution for future applications is nevertheless called for: although on grounds of the available faunal data, the consumption of freshwater animals is the most likely explanation for the unusual human data presented here, it follows from the discussion that this result is not unambiguous. This raises the question of whether the two isotopic systems of carbon and nitrogen which are currently routinely used in palaeodietary studies are sufficient to cope with the multitude of dietary sources available in many market-based economies.

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