Symposium: Theory and Practice in Isotopic Dietary Studies – TAPIDS

Tamsin C. O'Connell and Suzanne M. M. Young

This symposium is designed to be a forum for discussion of recent work in the field of palaeodietary isotopic studies, as well as review of the present state of the field. The primary analytical techniques that will be discussed are carbon, nitrogen, and strontium isotopic analysis of consumer tissues.

The symposium, covering both theory and practice, has three main themes:

- experimental work on dietary theory (feeding experiments and field observations);
- new laboratory developments (particularly utilising small samples and new materials);
- applications to African and world archaeology.

After the papers have been presented, there will be a discussion session, in a workshop format. We will discuss theoretical developments in our understanding of palaeodiet, and in particular, how results from feeding experiments and field observations published recently and presented during this symposium add to the theoretical framework of this field. We hope that participants will raise any points or queries from the presentation of the symposium's papers, and consider what specific questions must now be addressed by researchers in this field, in order to 'fill in the gaps' in our current understanding. Participants, whether presenting a paper or not, are encouraged to bring data and results to show as overheads in this forum, if they feel that they will contribute to the discussion.

African human diet reconstruction with stable isotopes of collagen and apatite

Stanley H. Ambrose

Controlled diet experiments with rats raised on diets with purified macronutrient ingredients (protein, carbohydrates, fats) of known isotopic composition show that the carbon isotope composition of collagen mainly reflects that of dietary protein, but apatite carbonate accurately reflects the isotopic composition of the whole diet. Where the isotopic composition of protein and non-protein components of diets differ, collagen carbon isotopes will be biased toward that of dietary protein. Analysis of both apatite carbon and collagen carbon and nitrogen isotopes permits more accurate estimation of the protein and non-protein diet components.

Situations in which diet reconstruction based on collagen alone may be inaccurate include populations that exploit marine resources and pastoralists that consume the flesh of grazing herbivores but exploit wild plant foods. The analysis of recent and prehistoric human skeletal populations from Kenya, Tanzania, Uganda, Zaire and South Africa, representing pastoralists, farmers, hunter-gatherers and coastal foragers, will be used to illustrate how analysis of collagen and carbonate stable isotopes can add new dimensions to diet reconstruction. Historic and prehistoric Bantu-speaking farmers from eastern and southern Africa have remarkably uniform stable isotope ratios that differ significantly from those of other modes of subsistence.

The record process of a dietary change in hypsodont teeth: An isotopic study on bovine molars

Marie Balasse, Hervé Bocherens and André Mariotti

The aim of this approach is to understand how a dietary change is recorded in dental tissues. Dentine and enamel, once formed, are not renewed and preserve their original isotopic signature. Thus hypsodont teeth potentially contain a record of eventual dietary changes that occurred during their growth.
A study was conducted on five steers from an experimental farm where their diet had been planned from birth to death. Until the end of the weaning process the calves were raised on a C_3 diet, then they were fattened on a C_4/C_3 mixed fodder till slaughtering. Weaning, that was conducted as a natural process, should have been recorded in dentine collagen as a decrease of 15^N content. The abrupt change from the C_3 to the C_4 component diet should have been recorded both in dentine collagen and enamel carbonate hydroxyapatite as an increase of 13^C content. The three molars from each steer were sampled from the top to the bottom. Both dentine and enamel were analysed for nitrogen and/or carbon isotopic composition. The measured intratooth isotopic variations show that dental tissues contain an accurate record of dietary changes. The interpretation of such variations needs a good knowledge of dental growth mode.

Isotopic analysis of dietary change: A new approach using bone density fractionation

Lynne Bell, Glenda Cox and Judy Sealy

A number of recent studies have attempted to trace diet at different stages in an individual's life by comparing isotopic ratios taken from different gross anatomical sites within the skeleton. In this study we develop this approach further by applying the bone density fractionation method to extract bone of differing mineral densities, where each bone fraction represents a unit of time. More specifically, since bone is continuously turning over throughout life, each bone fraction recovered by this method, represents a period of bone formation and maturation, where younger bone will be less mineralised and therefore less dense than relatively older packets of bone. Once bone fractions were recovered by stepped ultracentrifugation in organic solvents of known density, collagen and stable isotopes were recovered by dilute acid dissolution, and stable isotope ratios measured on the mass spectrometer. Bone density microstructure was checked for bacterial remodelling using SEM/BSE imaging. Our results indicate that the bone density fractionation method is applicable to archaeological material, here extending to a maximum of 5000 years BP and that collagen can be successfully extracted from such fractions. The carbon isotope values for bone fractions of different densities pattered out as expected in the modern control bone and in archaeological material that had been examined prior to this study. This approach allows greater resolution of diet than has hitherto been possible.

Dietary and seasonal variability from isotopic ratios in small enamel samples of wild and domestic fauna

Julia Lee-Thorp, Mat Sponheimer, Jeannette Smith and Simon Hall

Recent progress in mass spectrometry has allowed the development of microsampling strategies for analysis of tooth enamel and bone. Together with improved understanding of the isotopic pathways of carbon and oxygen in plants and animals, these developments provide new tools for examining small-scale variability related to diet and environment across seasonal boundaries, using sequential isotopic analyses of small, intra- and inter-tooth enamel samples. In this paper we determine 'natural' seasonal variability in a variety of wild bovids from the Northern Province and Mpumalanga, and compare the patterns with those derived from domestic animals of archaeological age. We suggest that this kind of comparison can be used to extract information about management practices of herders and agriculturalists in the past.

Chicken and egg: Laboratory testing of the effects of carnivory and herbivory on collagen, carbonate and related tissue isotopic values

Tamsin C. O'Connell and Robert E.M. Hedges

Field observations of carbon isotopic values of bone carbonate and collagen demonstrate a shift in the difference between these two values ($\Delta^{13}C_{ca\text{-}co}$) with trophic level of the animal analysed, although no clear-cut reason for this exists. Current explanations are based on laboratory based animal feeding experiments, which have demonstrated that bone collagen $\delta^{13}C$ values primarily reflect the isotopic composition of the dietary protein intake, whereas bone carbonate (apatite) $\delta^{13}C$ values are isotopically representative of the whole diet consumed. It is therefore suggested that variations of $\Delta^{13}C_{ca\text{-}co}$ with trophic level can be ascribed to the variation in diet composition between herbivores and carnivores, and the resulting differential use of dietary macronutrients in protein synthesis and energy provision.

This paper presents preliminary results of a study to assess whether diet alone influences the $\Delta^{13}C_{ca\text{-}co}$ spacing. We have attempted to replicate the observed ranges of $\Delta^{13}C_{ca\text{-}co}$ in field specimens of herbivores and carnivores in a controlled environment. To eliminate considerations of differing metabolism and physiology, the $\Delta^{13}C_{ca\text{-}co}$ spacing has been measured in carnivorous and herbivorous individuals of the same species. Egg laying hens were fed on a carnivorous diet, a herbivorous diet, and a mixture of the two. The $\Delta^{13}C_{ca\text{-}co}$ spacing was measured in individuals over a period of time. As well as analysing bone carbonate and collagen, isotopic 'proxies' were analysed: egg shell carbonate (metabolically and isotopically related to bone carbonate) and egg white proteins (metabolically and isotopically related to bone collagen).

Strontium isotopes: A new tool for the study of human migration

T. Douglas Price

The study of human migration in the past remains a quintessential question in human prehistory. Past studies have focused on various artifacts as proxies for humans in the study of movement, but artifacts can be either carried or traded by their makers. Studies that more directly measure movement in past humans can tell us specifically if people moved. Several new techniques have recently appeared to examine this question of human mobility. Of these, strontium isotopes in tooth enamel and bone appear to be the most promising. Two case studies, from late Neolithic Europe and from the Classic period of highland Mexico, will be presented to

document the utility of the technique and suggest some of the potential for future investigations. Investigations in Neolithic Europe concern the Bell Beaker period in Bavaria. Analyses of human remains from a series of cemeteries in this area suggest that migration rates during the Bell Beaker period were greater than 25%. Studies of human remains from the Classic city of Teotihuacan in the Valley of Mexico document the residence of individuals from distant areas such as Monte Alban and the Gulf Coast.

Rooting our family tree: C_4 plants, wetland habitats and early hominid evolution

Catherine Cockshutt Smith

To ascertain the form(s) in which C_4 foods were ingested and the ramifications of their exploitation by earlyhominids, isotopic, nutritional, and behavioural-ecological evaluation of possible C_4-based comestibles was undertaken. C_4 plants and the consumers of such plants were studied as potential hominid food sources and this resulted in the recognition of sedges as a particularly viable resource.

As fallback foods, these sedges and the underground parts of other wetland plants would have been ideal since they are available at times when open, seasonal habitats are low in above-ground food sources. They are nutrient rich, locally abundant, and regenerate seasonally. Furthermore, the new shoots and pithy stalks of such plants might have served as a natural means through which wetland resources were introduced to early hominids, while the biomechanical properties of these small, hard, and gritty tubers are functionally in keeping with the macro- and micro-structural properties and wear patterns of early hominid dentition.

If, as has been suggested, the evolution of hominids took place in a C_4 world, this is not because of the oft-cited expansion of C_4 savannah grasslands but because of the concomitant expansion of C_4 sedge habitats. The productivity and viability of these wetland resources benefitted early hominids faced with an increasingly seasonal food supply.

Biochemical Basis of $\delta^{13}C$ in bone collagen and the interpretations of ancient diets

Noreen Tuross and Marilyn Fogel

The magnitude of the variability (approximately 20‰) in $\delta^{13}C$ values found in the individual amino acids of human bone collagen from all individual contemporary and ancient sources exceeds the total range of all published values of whole collagen from human bone. When the noise within the analytical value of interest (e.g. $\delta^{13}C_{collagen}$) exceeds the signal, it is imperative to understand the nature, plasticity, inputs, variability and control of the noise in question. Osteoblastic bone cell cultures (human and bovine) were grown under controlled conditions such that the excreted collagen became mineralized, and served as a proxy for newly biosynthesized bone collagen. Labelled ^{13}C glucose was added to one set of cultures, and the incorporation of label into the amino acids in excreted collagen is compared to control cultures. These biochemical interpretations will them be used in the context of interpreting ancient diets, particularly the resolution of marine vs. C4 (e.g. maize) as contributors to bone collagen isotopic values.

How are you what you eat? Amino acids and dietary tracing by stable isotopes analysis of consumer tissues

Suzanne M. M. Young , Nikolaas J. van der Merwe and Alva D. Mitchell

While tracking the spread of maize (a C_4 plant) into the C_3 biomes of the Americans, contradictions between isotope data and other evidence suggest that the relationship between the dietary importance of maize and the carbon isotope ratios of consumer bone collagen is not linear. Recent experiments showing consumer apatite carbonate to reflect whole diet and consumer collagen to be dominated by dietary protein demonstrate the failing of the alternative routing model.

Experimental diets in this study have been designed to simulate the introduction of maize to C_3 biomes in the Americas. We measured natural stable isotope ratios in the tissues of pigs (large omnivores with the same essential amino acids as humans) to study the biochemical routing from dietary components to consumer tissue. We raised female pigs on 13 different diets to identify the dietary components used in the synthesis of pig protein tissues, particularly where more than one protein source (animal and/or plant) is available, and to determine whether dietary carbon is averaged during the formation of mineral bone carbonate. These pigs were bred, giving us 67 pigs continued on the diets, thus providing us with tissues less than 1% affected by the diets of their mothers prior to the experiment.

Amino acid physiological use and biosynthesis, as well as, requirements for a new biochemically informed model will be discussed. Final results will make it possible to interpret isotopic dietary signatures in archaeological human skeletons with greater accuracy in most dietary situations.