

Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate

by Stanley H. Ambrose and Lynette Norr^a

1 Introduction: Are You What You Eat?

The use of stable carbon isotopes for diet reconstruction is predicated on the assumption that you are what you eat. In other words, the carbon isotopic composition of animal tissues is assumed to be a direct and constant function of the diet. Is this assumption valid? Precise dietary reconstruction requires as accurate knowledge of the isotopic composition of locally available dietary resources, as well as an adequate understanding of the effects of nutrition, environment, and physiology on the diet-tissue function (van der Merwe 1982, 1989; Chisholm 1989; Norr 1990; Matson and Chisholm 1991; Tieszen 1991; Ambrose 1992). There is a systematic but poorly defined difference between the isotopic composition of the consumer tissues and that of the diet (an enrichment factor, expressed as $\Delta_{\text{diet-tissue}}$). Given the isotopic composition of a specific tissue, that of the diet or of other tissues may be calculated if the $\Delta_{\text{diet-tissue}}$ difference factors are known. The dietary proportions of isotopically distinct food resources (e.g., C_3 vs C_4 , or C_3 vs marine) have thus been calculated from the $\delta^{13}\text{C}$ value of bone collagen ($\Delta^{13}\text{C}_{\text{d-co}}$) and bone apatite carbonate ($\Delta^{13}\text{C}_{\text{d-ca}}$). Deviations from actual or assumed average $\delta^{13}\text{C}$ values for dietary endmembers, and incorrect values for diet-to-tissue isotopic relationships, will lead to errors in the estimation of consumption of specific classes of resources. Experiments and observations designed to determine the diet-to-collagen stable isotope functions ($\Delta^{13}\text{C}_{\text{d-co}}$), however, have provided widely different values.

^a Department of Anthropology, University of Illinois at Urbana-Champaign (UIUC), 607 South Mathews Avenue, Urbana, Illinois 61801 USA

A second major area of uncertainty in diet reconstruction with stable isotopes is the effect of nutrient composition on the relationship between the isotopic composition of diet and bone. Which parts of the diet are reflected in the carbon atoms of bone collagen and other proteins, and which are reflected in the carbon atoms of bone and tooth carbonate (van der Merwe 1982; Krueger and Sullivan 1984; Klepinger and Mintel 1986; Lee-Thorp et al. 1989a)? Is dietary protein routed to synthesis of consumer tissue proteins (Chisholm et al. 1982; Schwarcz 1991), and energy (carbohydrates and lipids) routed to bone carbonate (Krueger and Sullivan 1984; Lee-Thorp et al. 1989a), or are carbon atoms from all dietary biochemical fractions scrambled and resynthesized in consumer tissues (Schoeninger 1989)? In carnivores, proteins are necessarily used for energy, and herbivores and omnivores may also use excess protein for energy (Krueger and Sullivan 1984). If protein-to-protein routing of carbon atoms occurs, then the simple method of diet reconstruction, which assumes all dietary carbon atoms are scrambled, would be inaccurate when the components of a diet that differ significantly in their isotopic compositions also differ in their nutrient compositions (e.g., C_3 protein vs C_4 energy, or marine animals vs terrestrial C_3 plants). If controlled diet experiments can clearly demonstrate whether routing does occur, then the dietary interpretations of isotopic data from many previous studies may have to be revised. This chapter reports on the partial results of the first experimental study to determine whether biochemical pathways from diet to tissues are routed or scrambled. These results demonstrate that dietary protein is routed to collagen, while all nutrient biochemical fractions are scrambled and integrated in bone carbonate.

1.1 Carbon Isotope Variation in Foodwebs

Carbon isotopes can be used to distinguish C_4 and C_3 plants. C_4 plants include sorghum, millets, maize, sugar cane, and tropical pasture grasses. C_3 plants include wheat and rice, forest, montane, wetland grasses, and most dicotyledonous plants, including all root crops, legumes, vegetables, trees and