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ISOTOPIC EVIDENCE FOR DIET IN THE SEVENTEENTH-CENTURY COLONIAL CHESAPEAKE

Douglas H. Ubelaker and Douglas W. Owsley

Excavations of colonial period sites in Maryland and Virginia have produced human remains dating to the seventeenth century. In this study, we analyze stable isotopes of carbon and nitrogen from these remains to explore aspects of the diets of the individuals represented. Analyses of both stable carbon and nitrogen isotopes were conducted on preserved protein while stable carbon isotope analysis was also conducted on preserved biological apatite. Carbon isotope values ($\delta^{13}C‰$) ranged from -10.5 to -20.5 for collagen and -5.1 to -12.5 for bioapatite. Nitrogen isotope values ($\delta^{15}N‰$) ranged from 9.9 to 14.4. The data suggest dietary diversity among the individuals examined. Three factors contribute to this diversity: the availability of maize, variation in immigration histories of the individuals, and the differing lengths of time they spent in the American colonies.

Excavaciones en Maryland y Virginia del periodo colonial han producido huesos humanos fechados en el siglo diez y siete. Este estudio utiliza un análisis de isótopos de carbono y nitrógeno para investigar varios aspectos de las dietas de los individuos representados. Los análisis de carbono y de nitrógeno fueron conducidos usando la proteína preservada y solo el análisis isotópico de carbono fue también conducido con apatita biológica preservada. Los resultados indican una dieta diversa. Tres factores contribuyen a esta diversidad; la presencia de maíz, la variación en las historias de inmigración de los individuos, y la variabilidad del tiempo que los individuos estaban ubicados en las colonias.

Diet represents one of the many adaptations faced by colonists arriving in the Chesapeake Bay area of the eastern United States during the seventeenth century. In their struggle to survive, these early colonists had to shift aspects of their diet to what was available in the New World. In particular, maize became a new important aspect of the colonial American diet.

This study presents initial isotope data gleaned from analysis of bone samples originating from human skeletons recovered from seventeenth-century Chesapeake Bay area sites in Maryland and Virginia. The isotope data reflect aspects of the diet of these early colonists and potentially provide information on their individual immigration histories. The analysis uses individual results to test for dietary differences between the two colonies, between the two sexes, and between adults and children. These differences are then interpreted in terms of the length of time these individuals spent in the New World and other possible factors.

Samples from the Colonial Period Chesapeake

Bone samples suitable for analysis of stable carbon and nitrogen isotopes were analyzed from human remains recovered from seventeenth-century archeological sites in the Chesapeake region of Maryland and Virginia. Specimens were examined from 16 of the 19 individuals excavated from the Patuxent Point Site (18CV271). This site, dated between 1658 and the mid-to-late 1680s, is located near Solomons, Maryland, in the vicinity of the Patuxent River (King and Ubelaker 1996). The exceptionally well-preserved remains are thought to represent individuals associated with a tobacco plantation at that site. Samples for isotopic analysis were removed from five adult females, six adult males, and five immature individuals. Skeletal analysis supported historical records indicating high morbidity and mortality, as well as harsh physical activity (King and Ubelaker 1996). Skeletal evidence suggested some individuals engaged in heavy lifting, pulling and pushing, as well as habitual kneeling.

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American Antiquity, 68(1), 2003, pp. 129–139

Bone samples were also analyzed from 11 individuals from two locations along the James and York Rivers in Virginia: 10 from Jamestown Island and one from Chischiak Watch (44YO466) near Yorktown (Owsley 1999a, 1999b; Owsley and Bruwelheide 1997; Owsley et al. 1997; Verano and Owsley 1991). Based upon archaeological evidence, all of these remains date between 1609 and 1675 (Cotter 1958; Kelso and Straube 2000; McKeown 2000). This group is comprised of eight males and three females, all adult (over the age of 15 years).

The Jamestown series was recovered by the Association for the Preservation of Virginia Antiquities (APVA) and the National Park Service. APV-1, APV-2, APV-4A, APV-5, APB-HR1, APV-HR7, and NPS-9 are from or near the "Third Ridge Cemetery." This cemetery likely includes individuals who perished during the so-called "starving time" of 1609–1610, a period when 88 percent of the original settlers perished (Kelso 1995), although there was continued use for at least another decade or two. Differences in burial orientation, occasional superimposition and disturbance of earlier graves, and the limited artifacts found in this area indicate continued use. With the early date of 1609, this cemetery dates to the first quarter of the seventeenth century.

The other NPS burials (10, 14A, and 15) come from the New Towne area, and date later. NPS-10 and NPS-14A date to the seventeenth century, likely after 1640, and are not as early as the Third Ridge burials. 44YO466-1 dates to the third quarter of the seventeenth century (A.D. 1650–1675) (Verano and Owsley 1991).

Dietary Reconstruction

Archival and archeological sources provide much information about aspects of diet in colonial America, although both approaches have limitations. For example, early documents (e.g., William Strachey and Captain John Smith writing in the early seventeenth century [Barbour 1986; Strachey 1953]) are selective in the information reported and generally lack comprehensive coverage of all groups in differing economic and social strata (Carr et al. 1991). Then, too, archeological studies of recovered faunal materials and related items are limited to the particular communities sampled, as well as by preservation factors (Hantman 1990; Ritchie 1969; Waselkov 1978).

Recent years have witnessed the emergence of new chemical approaches to dietary reconstruction of past populations (reviewed by Buikstra and Milner 1991; Katzenberg 1992; Schoeninger et al. 1983). The chemical approaches include analysis of trace elements and isotopes from samples of bone and teeth recovered archaeologically. Although these approaches also have limitations, they complement archival and archaeological methods by analyzing samples taken directly from the consumers.

Of these chemical approaches, analyses of the isotopes of carbon and nitrogen are especially relevant. Stable carbon isotopes quantified from preserved animal tissue indicate whether a diet was based on plants with a C_3 photosynthetic pathway and/or the animals that consume them, or on plants with a C_4 pathway and/or the herbivores that consume them. Consumption of marine foods produces results intermediate to those derived from consumption of C_4 and C_3 plants (Katzenberg 1992, 2000).

Plants with a C_3 pathway include all shrubs and trees and most leafy-type plants growing in temperate climates. The C_4 plants include grasses such as maize, millet, and sugarcane that have adapted to hot and dry climates. Since maize is the only C_4 plant that was a major dietary component within the Americas prior to European contact, analysis of stable carbon isotopes from archeologically recovered samples in the New World has proven especially important.

Recent studies have conclusively shown the relationship between diet and carbon isotope values. Analysis of human bone protein (collagen) from individuals consuming primarily C_3 plants produced $\delta^{13}C$ values of approximately –20‰. Less-negative values reflect consumption of C_4 plants, animals that consumed C_4 plants, and/or reliance on marine foods. Collagen from consumers of C_4 plants can produce carbon values as high as –6‰. Values from consumers of marine foods typically range from –10 to –15‰ (Katzenberg 1992, 2000; Schoeninger et al. 1983; Ubelaker et al. 1995).

In addition to the information derived from collagen, data on carbon isotope ratios also can be gleaned from analysis of the bioapatite in bone mineral (Ambrose and Norr 1993; Krueger and Sullivan 1984; Lee-Thorp and van der Merwe 1991; Lee-Thorp et al. 1989; Tieszen and Fagre 1993). Scholars have suggested that the $\delta^{13}C$ values derived from bioapatite represent the entire diet of the individual while values derived from bone collagen pri-

marily originate from the consumption of protein (Krueger and Sullivan 1984). Experimental studies also suggest that the spacing between the bioapatite and collagen carbon values provides information about trophic level. Basically, herbivores show greater spacing than do carnivores (Lee-Thorp et al. 1989).

Ratios of stable nitrogen isotopes provide additional information about trophic level. Of foods available to humans, leguminous plants have the lowest nitrogen values. Higher values result with movement up the food chain (Schoeninger and DeNiro 1984). For example, humans with diets of primarily maize show $\delta^{15}N$ values of approximately 9.6‰ while those from coastal areas consuming abundant seafood have values as high as 15‰ (DeNiro 1987).

Isotopic evidence also can be used to address issues of immigration and locality (Sealy et al. 1991, 1995). The colonial Chesapeake diet included substantial amounts of the C_4 plant material. If immigrants to the colonies originated from areas lacking C_4 plant foods in the diet, they likely experienced a shift in C_4 consumption after arrival in the Chesapeake area (Miller 1984). Such a dietary shift may be detected through isotope analysis. For example, carbon isotope values of northwest Europeans are centered around –18 to –21‰ due to the lack of natural C_4 terrestrial vegetation (Katzenberg 1991; Kennedy 1989; Mays 1997; Schoeninger 1989). Values of carbon isotopes derived from collagen among maize agriculturalists in the New World are typically greater than –10‰ (Schoeninger et al. 1983).

Carbon isotope values derived from Late Woodland period Native American skeletons from Virginia are not quite that positive, but clearly reflect subsistence economies based on horticulture, combined with gathering and the hunting of deer and small game (Hantman 2001; Trimble and Macko 1994). Maize continued to be an important food, as well as an item of trade, during the post-1607 era.

Although bone isotope values may reflect factors of individual food access and preference among the colonists, the carbon isotope values likely reflect the length of time lived in the Chesapeake area. Because it takes approximately two decades for bone collagen to be completely replaced (Katzenberg 1991; Stenhouse and Baxter 1979), collagen values reflect the diet in the 20 years prior to death. Thus, the measures of collagen isotopes of skeletal remains of immigrants may derive not only from their diets in the Chesapeake area, but also from their diets in their homeland. The amount their pre-immigration diets contributed to their collagen isotope values would be influenced by the length of time they had been in the colonies. For those who died relatively soon after their arrival, their isotope values would reflect primarily their diets prior to immigration. In contrast, values for individuals born in the New World would reflect an exclusively New World diet, which likely contained substantial amounts of maize.

A complicating factor in interpretation can be differential access to maize, producing within-group variability as shown by the Ubelaker et al. (1995) study of a precontact population from the highlands of Ecuador. Significant differences in collagen-based carbon isotopes were found among individuals from a single site. This variability apparently reflected differential status-based access to maize and/or maize products and illustrates the importance of culture in influencing isotope values.

Significant variation has been reported among aboriginal American skeletal samples due to reliance on marine foods and dietary components other than maize (e.g., Buikstra and Milner 1991; Larsen et al. 1992; Walker and DeNiro 1986). For example, studies of coastal and inland aboriginal groups in British Columbia that lacked maize detected carbon collagen values ranging between –13‰ in those dependant on marine resources to –20‰ in those consuming terrestrial foods. Bourque and Krueger (1994) have used isotopic evidence to assess the extent of marine foods in the diet in samples from coastal New England.

Working with samples from the Georgia coast, Larsen et al. (1992) documented a temporal trend extending through the prehistoric-historic periods of a dietary shift in favor of maize at the expense of marine sources.

In similar fashion, isotopic analyses of human remains from Europe have been used to study the relative importance of marine resources in ancient diets (Mays 1997). Although maize was not present in early British diets, marine foods were important sources of protein, with smoked and pickled herring representing a major protein source for the poor during the winter months (Spencer 2000). Furthermore, an Act of Parliament in 1548 establishing Saturday as "fish day" could have had some effect on carbon isotope values. Also potentially significant for interpretation of both English and colonial diets is

Spencer's (2000) note that the poor supplemented their diets by gathering considerable wild food.

Foods collected from brackish water such as harbors and inlets present carbon isotope values largely reflecting the amount of seawater in their environments. In a New England study, for example, Medaglia et al. (1990) found that although carbon isotope values approached terrestrial levels in upstream tidal creeks (–20‰), they increased to –13‰ in animals collected from the more saline harbors. Values of $\delta^{13}C$ in marine animals (fish, shrimp, stomatopods, polychaetes, bivalves, and crabs) feeding in sea grass meadows have been found to be substantially less negative than those feeding offshore (Fry and Parker 1979; Sackett 1989).

Keegan and DeNiro (1988) provide data from the Caribbean. In a sophisticated study of isotope values from prehistoric remains and an analysis of the variety of foods likely comprising their diets, they suggest a carbon human collagen range from –9.6 to –19.1. The variation reflects local selection of particular available foods and unusual enrichment of ^{13}C and depletion of ^{15}N in the local sea grass and coral reef environments.

Regarding interpretation of nitrogen isotope levels among the Chesapeake remains, it is important to remember that higher nitrogen isotope values can be produced within individuals as a result of extreme physiological stress and/or wasting-type diseases (Katzenberg 2000; Katzenberg and Lovell 1999). Such "protein stress" could have been present during immigration voyages and the trying times of early colonial life in the Chesapeake region.

Methods

The sex and ages at death of the individuals were estimated using standard techniques (Bass 1987; Ubelaker 1989). Sex of adult individuals was estimated from features of the pelvis and general indicators of bone size. Estimates of ages at death relied primarily on dental formation in immature individuals but considered all information available on each set of remains.

Cortical bone fragments weighing approximately 2.0 g were prepared for isotopic analysis by Michael Chapman of the Stable Isotope Lab, Augustana College, Sioux Falls, South Dakota using appropriate techniques and reference standards (Chapman 2001; DeNiro 1985; DeNiro and Epstein 1981; Schoeninger and DeNiro 1984). The process included removal of contaminants, lipids, and preservatives, demineralization to produce a collagen pseudomorph, additional cleaning to remove humic acids and remaining lipids, solubilization and filtering to produce a gelatin, freeze drying of the purified collagen, and analysis by mass spectrometer (Chapman 2001; Sandness 1992). Reported results include the $\delta^{13}C$ and $\delta^{15}N$ values, an assessed ranking of the quality of the pseudomorph, the percent carbon and percent nitrogen of the gelatin, and the C/N molar ratio of the gelatin. The apatite $\delta^{13}C$ value is derived from a parallel process that removes the organic composition and collects CO_2 from the specimen by cryogenic distillation for analysis by mass spectrometry (Chapman 2001).

Soil and any visible contaminants are manually removed from the bone samples followed by submersion in a methanol/chloroform/water (2/1/.8) solution. Collagen extraction for carbon and nitrogen analysis is done following methods described by Tieszen and Fagre (1993) and Tieszen et al. (1992) and as outlined in Chapman (2001).

Samples are combusted in a Carlo Erba Carbon and Nitrogen analyzer. For carbon, a triple trapping system of a Stable Isotope Ratio Analyzer (SIRA) 10 isotope ratio mass spectrometer captures the CO_2 and cryogenically purifies and analyzes it utilizing a reference gas of known isotopic composition. Working references, values and laboratory standards are verified by routine analysis of National Institute of Standards and Technology (NIST) standard United States Geological Survey (USGS) 24. Laboratory precision for carbon is < .1‰. A continuous flow system on the same mass spectrometer is used for nitrogen extraction using the International Atomic Energy Agency (IAEA) N1 standard (amonium sulfate). Laboratory precision for nitrogen is < .2 ‰.

The bone apatite samples are presented separately and cryogenically purified off-line. The evolved CO_2 is introduced to the mass spectrometer and measured against a reference gas of known composition (NIST standards NBS 19-limestone). Laboratory precision for apatite is < .2 ‰.

Results

Table 1 summarizes information on age, sex, and data from isotopic analysis for each of the 27 individuals in the Maryland and Virginia samples. The ratio of carbon to nitrogen provides important information on the relative preservation of collagen. Research

Table 1. Information of Sex, Age at Death, and Isotope Data from the 27 Maryland and Virginia Skeletons.

Number	Sex	Age	$\delta^{13}C_{collagen}$	$\delta^{13}C_{bioapatite}$	$\delta^{13}C_{collagen}$ $\delta^{13}C_{bioapatite}$ Spacing	$\delta^{15}N$	C/N	%N	%C
18CV271-1	Female	24	-12.69	-8.52	4.17	10.40	3.18	11.10	29.93
18CV271-2	Female	55-60	-13.01	-9.13	3.88	11.42	3.33	9.37	26.75
18CV271-3	Female	37-43	-15.94	-10.15	5.79	11.51	3.29	9.50	26.77
18CV271-6	Unknown	8-9	-11.46	-7.34	4.12	10.60	3.24	11.13	30.91
18CV271-8	Male	28-33	-14.68	-9.50	5.18	11.32	3.33	9.85	28.11
18CV271-9	Unknown	10-11	-13.02	-7.89	5.13	11.24	3.30	7.93	22.40
18CV271-10	Male	30-35	-12.02	-7.45	4.57	10.52	3.21	9.76	26.86
18CV271-11	Unknown	5	-12.31	-8.14	4.17	11.18	3.22	11.79	32.60
18CV271-12	Male	27-32	-16.22	-9.39	6.83	12.50	4.08	8.08	27.71
18CV271-13	Unknown	13	-12.20	-7.64	4.56	11.20	3.65	9.15	28.63
18CV271-14	Male	33-38	-18.37	-9.70	8.67	13.61	3.47	7.24	21.54
18CV271-15A	Female	26-32	-16.81	-9.07	7.74	11.69	3.29	10.62	29.98
18CV271-16	Unknown	13-14	-19.35	-9.39	9.96	12.39	3.18	15.13	40.85
18CV271-17	Female	25-30	-19.29	-10.60	8.69	13.34	3.31	10.08	28.28
18CV271-18	Male	15-17	-18.98	-10.63	8.35	12.04	3.58	4.87	14.94
18CV271-19	Male	38-45	-17.57	-10.61	6.96	10.83	3.23	13.05	35.67
44YO466-1	Male	30-34	-16.02	-11.76	4.26	11.62	3.15	13.85	37.37
JAMES-APV-1	Male	20-24	-20.51	-12.51	8.00	12.62	3.30	5.30	15.00
JAMES-APV-2	Female	15-35	-19.61	-12.06	7.55	11.75	3.22	10.71	29.57
JAMES-APV-4A	Female	16.5-17.5	-19.92	-11.30	8.62	11.99	3.35	2.68	7.70
JAMES-APV-5	Female	25-29	-20.17	-11.72	8.45	14.40	3.44	5.93	17.48
JAMES-APV-HR1	Male	25-29	-19.78	-10.68	9.10	11.94	3.30	8.65	24.48
JAMES-APV-HR7	Male	16.5-17.5	-21.98	-10.97	11.01		6.62	0.14	0.80
JAMES-NPS-9	Male	30-34	-19.30	-9.45	9.85	13.55	3.19	11.38	31.16
JAMES-NPS-10	Male	25-29	-11.03	-8.03	3.00	11.26	3.50	6.19	18.56
JAMES-NPS-14A	Male	30-34	-14.44	-7.78	6.66	8.69	3.97	1.31	4.45
JAMES-NPS-15	Male	30-34	-10.52	-5.11	5.41	9.94	3.18	13.52	36.82

reported by DeNiro (1985) suggests that values between 2.9 and 3.6 indicate that collagen is well preserved. One value, that of 3.7 from 18CV271-13 is at the upper border of the acceptable range. Three values, from 18CV271-12, James APV-HR7, and James-NPS-14A, were considered potentially less reliable and were excluded from the analysis. All other values obtained from this study fall within the acceptable range.

Summary statistics for the Maryland and grouped Virginia data are presented in Table 2. For Maryland, the $\delta^{13}C_{collagen}$ values range from –11.5 to –19.4 with a mean of –15.2. For the Virginia samples, the range is even greater (–10.5 to –20.5) with a mean of –17.4. Similar ranges and differences between the two samples are seen with the $\delta^{13}C_{bioapatite}$ values. These data are also presented graphically in Figures 1 and 2.

For perspective, humans consuming mostly C_3 plants can be predicted to have $\delta^{13}C$ values in the vicinity of –20‰. Human consumption of C_4 plants and herbivores that consumed C_4 plants increases the $\delta^{13}C$ values to as high as –6‰. Humans eating primarily marine sources also show less negative values, ranging from –10 to –15‰ (Schoeninger et al. 1983). Both the Maryland and Virginia samples show variation in the spacing between the carbon values from collagen and bioapatite. The spacing suggests considerable diversity in the proportion of meat to plant products in the individual diets.

The $\delta^{15}N$ values provide additional information about the diversity of diets among the Maryland and Virginia colonists. As noted in Tables 1 and 2, these values range from a relatively low 9.9‰ for a Virginia adult male to 14.4‰ for a Virginia adult female. The low value approaches levels documented for human groups eating mostly maize while the higher value falls close to levels expected from coastal peoples consuming mostly marine foods (DeNiro 1987). Comparison of mean values of $\delta^{15}N$ between the two regional samples reveals minimal differences, even though those from Virginia show much more diversity.

Table 3 presents the isotopic information for the Maryland and Virginia samples combined and grouped into adult male, adult female, and subadult categories. The greatest differences among the three groups are found in the carbon values from both collagen and bioapatite. Females show slightly lower (more negative) values than males from both collagen and bioapatite sources. Both males and females show substantially lower values than subadults. Variation in isotope values is also apparent when the spatial arrangement of human remains from the Maryland site is considered. Excavations at Patuxent Point revealed two main clusters of burials approximately 33 feet apart (King 1996). Cluster (A) contained Burials 1 through 6 and 8 through 13. Cluster (B) contained four burials, numbers 16 through 19 (King 1996). Isotope information is not available for two infants (Burials 4 and 5) of Cluster A.

Values for carbon collagen from the four individuals in Cluster B range from –17.6 to –19.4‰ with a mean of –18.8‰ and standard deviation of .83. Those values from the nine individuals represented in Cluster A range from –11.5 to –15.9‰ with a mean of –13.0‰ and standard deviation of 1.41. Those from Cluster B are more negative and the ranges do not overlap.

Similar differences are found with the carbon bioapatite data. Carbon values from Cluster A ranged from –7.3 to –10.2‰ with a mean of –8.4‰ and standard deviation of .98. The Cluster B values ranged from –9.4 to –10.6‰ with a mean of –10.3‰ and standard deviation of .61. Although these ranges slightly overlap, the values from Cluster B are considerably more negative than those of Cluster A.

Differences are also apparent in carbon isotope spacing information. In the samples from Cluster A, the spacing between the collagen and bioapatite carbon values ranged from 3.9 to 5.8‰ with a mean of 4.6‰ and standard deviation of .63. Values from Cluster B ranged from 7.0 to 10.0‰ with a mean of 8.5‰ and standard deviation of 1.23. These differences suggest variation in dietary trophic level between the two samples with greater consumption of products on the lower end of the food chain by individuals in Cluster B. This interpretation is not supported by the nitrogen isotope values however. Nitrogen values range from 10.4 to 11.5‰ in Cluster A with a mean of 11.0‰ and standard deviation of .42. Nitrogen values from Cluster B are very similar and even slightly higher with a range of 10.8 to 13.3‰, mean of 12.2‰ and standard deviation of 1.04.

Discussion

Carbon isotope values for the Maryland and Virginia colonists show considerable diversity relative to most population samples, particularly northwest Euro-

Table 2. Summary Statistics of Isotope Information for the Maryland and Virginia Samples.

		$\delta^{13}C_{collagen}$ ‰			$\delta^{13}C_{bioapatite}$			$\delta^{13}C_{collagen}$ $\delta^{13}C_{bioapatite}$ Spacing			$\delta^{15}N$ ‰		
Sample	N	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
Maryland	15	-15.18	2.98	-11.46 – -19.35	-9.05	1.17	-7.34 – -10.63	6.13	2.06	3.88 – 9.96	11.55	.95	10.40 –13.61
Virginia	9	-17.43	3.99	-10.52 – -20.51	-10.29	2.40	-5.11 – -12.51	7.14	2.36	3.00 –9.85	12.12	1.30	9.94 –14.40

Table 3. Summary Statistics of Isotope Information for Males, Females, and Subadults of the Combined Samples.

	$\delta^{13}C_{collagen}$ ‰				$\delta^{13}C_{bioapatite}$ ‰				$\delta^{13}C_{collagen}$ $\delta^{13}C_{bioapatite}$ Spacing				$\delta^{15}N$ ‰			
Sample	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range
Males	11	-16.25	3.66	-10.52 – -20.51	11	-9.58	2.09	-5.11 – -12.51	11	6.67	2.28	3.00 –9.85	11	11.75	1.17	9.94 –13.61
Females	8	-17.18	3.07	-12.69 – -20.17	8	-10.32	1.32	-8.52 – -12.06	8	6.86	1.98	3.88 –8.69	8	12.06	1.24	10.40 –14.40
Subadults (younger than age 15)	5	-13.67	3.22	-11.46 – -19.35	5	-8.08	.79	-7.34 – -9.39	5	5.59	2.48	4.12 –9.96	5	11.32	.65	10.60 –12.39

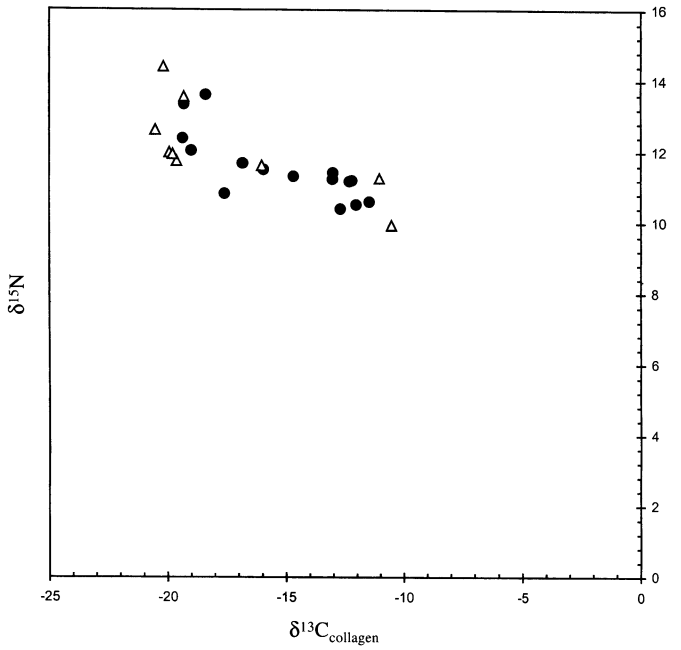

Figure 1. $\delta^{13}C_{collagen}$ plotted with $\delta^{15}N$ values. Triangles represent Virginia individuals. Darkened circles represent Maryland individuals.

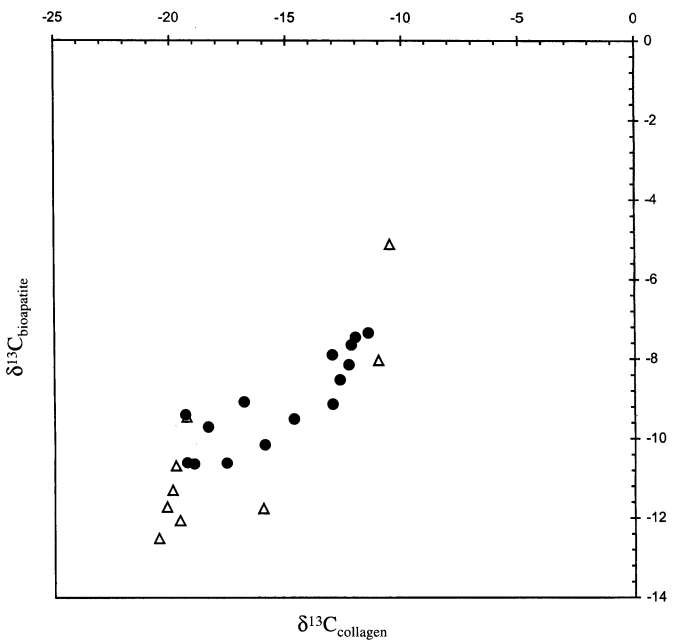

Figure 2. $\delta^{13}C_{collagen}$ plotted with $\delta^{13}C_{bioapatite}$. Triangles represent Virginia individuals. Darkened circles represent Maryland individuals.

peans (Katzenberg 1991; Kennedy 1989; Mays 1997; Schoeninger 1989). The observed variation in the Chesapeake could have been produced by a variety of dietary factors, with some variables being particularly important. Carbon collagen values approaching –20‰ suggest a diet concentrated on C_3 plants.

Values less negative reflect increasing consumption of C_4 plants, and/or marine foods. Since maize, a C_4 plant, was a well-documented staple food in the seventeenth-century Chesapeake area, it is not surprising to find relatively high (less-negative) carbon isotope values in the colonial samples presented here. Although none of the individual values approaches those of horticulturists who consumed mostly maize, many do suggest significant amounts of C_4 plants and/or marine foods in the diet. This is more apparent in the samples from Maryland than Virginia and from children in contrast to adults.

Although these differences might be explained by variation in individual food access and preference among the colonists, the bone collagen results more likely reflect the length of time lived in the Chesapeake area. The relatively high carbon isotope values of the children from the Maryland site are consistent with an interpretation that their lifelong diets included substantial amounts of maize and therefore that they were not immigrants but had been born in the area. Due to the complex factors influencing the isotope values and the unknown life histories of the individuals recovered from the Maryland and Virginia sites, it is not possible to determine exactly the details of diet or immigration origin of any one individual. However, it does seem reasonable to assume that the length of time spent in the colonies by these individuals is reflected in various ways by the isotopic values reported. In the Chesapeake data presented here, we believe that the length of time in the colonies and the availability of maize in colonial diets are obvious factors shaping the values presented. Less clear are the dietary contributions made by marine foods, local gathering of wild foods and cultural factors possibly impacting the consumption of C_4 plants. Although the present sample is small, it shows considerable diversity in nitrogen and especially carbon isotope values. Recent excavations in Maryland and Virginia, including Jamestown's "Third Ridge Cemetery," have recovered more remains that are being analyzed. An expanded data base will clarify site and regional patterning and the bases of variation. Chemical approaches to dietary reconstruction hold considerable potential to help reveal the complexity of life during the seventeenth century in the Chesapeake region.

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