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SOURCES OF STABLE ISOTOPE VARIATION IN ARCHAEOLOGICAL DOG REMAINS*

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ABSTRACT

Assessment of the δ ^{15}N ratios and δ ^{13}C isotope values of archaeological dog and human bone collagen, ethnoarchaeological dog bone collagen, and ethnoarchaeological dog and human hair protein demonstrates that these tissues can be used to show subtle differences in diet between households at the same site. While δ ^{13}C isotope values for dog and human bone and hair protein can be used as evidence of C_4 photosynthetic plant foods, it is not necessarily an accurate measure for the presence or absence of maize in the diet. Less than 50% of the ethnoarchaeological dog and human samples from households that consumed an average of 0.01 kg of maize per day, had δ ^{13}C isotope values greater than –19‰.

INTRODUCTION

The diet of dogs in Ohio Valley prehistory is poorly understood. On the basis of mortuary features, previous investigators suggested that the diet of dogs

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changed through time as their role in human economy changed (Haag, 1948; Schwartz, 1997). This chronocline has been correlated with a shift from highly mobile foraging to an increase in sedentism and intensification of maize agriculture (Haag, 1948; Parmalee, 1962; Smith, 1975). In other words, the diet of dogs degraded as the economic value of hunting decreased through time. In this setting, dogs were reduced to scavengers and habitation guard animals.

If the changing diet of dogs is related to their role in human economy, then we should expect to find these changes reflected in the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values of their bone collagen. The isostopy of dog bone collagen from archaeological sites has been researched for more than 30 years (e.g., Allitt et al., 2008; Burleigh and Brothwell, 1978; Cannon et al., 1999; Clutton-Brock and Noe-Nygaard, 1990; Hogue, 2006). The $\delta\ ^{15}N$ isotope ratios of collagen are directly related to the consumption of meat protein and $\delta\ ^{13}C$ isotope values are directly related to the consumption of C_4 photosynthetic plant foods such as *Zea mays* (Schoeninger and Moore, 1992; Schurr 1992; Schwartz and Schoeninger, 1991). In this article, we examine the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values of dog remains from five archaeological sites in the Ohio River valley and from an ethnoarchaeological Mayangna/Miskito village site in Nicaragua. The objective of our analyses is to compare dogs from Nicaragua whose diets are known with those from unknown archaeological contexts in the Ohio River valley in order to better understand their relationship to the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values.

MATERIAL

We examined the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values of 51 dogs. Five of the dog samples were obtained from archaeological sites in the Ohio Valley (Figure 1) and 46 of the dog samples were collected from Arang Dak, an ethnoarchaeological Mayangna/Miskito village site in Nicaragua (Figure 2). All of the archaeological specimens came from dog skeletons from well-dated contexts including the Archaic-age Dupont (33Ha11) and Bullskin Creek (33Ct29) sites, the Woodland-age Newtown Firehouse site (33Ha419), and the Fort Ancient-age Stateline (33Ha58) and Schomaker (33Ha400) sites (Dalbey, 2007; Drooker, 1997; Vickery, 1976; Vickery et al., 2000). Five human skeletons were also sampled from the Newtown Firehouse site, including an individual that was interred with a dog. The ethnoarchaeological samples came from the skeletons of 12 dogs that died between 2004 and 2008 and the hair of 34 living dogs and 5 people in Arang Dak. Although hair is one of the most favorable tissues for isotopic measurement for dietary studies, it is rarely included in research (Panarello and Fernandez, 2002). The human samples were analyzed to provide reference data for the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values of the dog samples.

Figure 1. The geographic locations of archaeological sites in the Ohio River valley sampled: Bullskin Creek (33Ct29), Dupont (33Ha11), Newtown Firehouse (33Ha419), Schomaker (33Ha400), and Stateline (33Ha58).

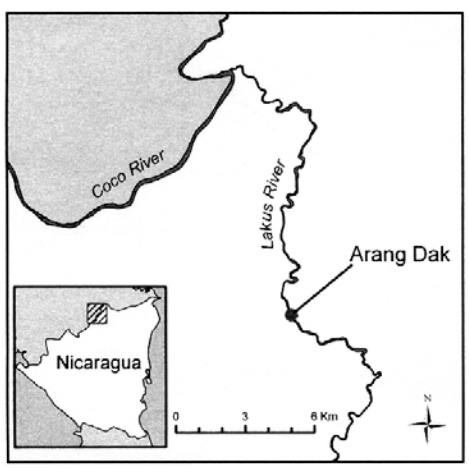

Figure 2. The geographic location of the ethnoarchaeological location of Arang Dak in Nicaragua.

Both the archaeological and ethnoarchaeological dog burials were well-preserved, fully articulated skeletons. Traditionally, dogs were deliberately buried with their owners in Arang Dak, along with all the personal property of the deceased in order to assure him a livelihood and good journey to the other world (Conzemius, 1932:155). Today, dogs are buried in their own graves. With the exception of a single juvenile individual from the Newtown Firehouse site, all of the archaeological dogs examined in this study were mature adults based on complete epiphyseal fusion of the long bones. Pathologies associated with stress were found on only two individuals, both from Fort Ancient contexts. Periostitis was present on the left tibia of a dog from the Schomaker site and porotic hyperstosis on the *os frontale* of the dog cranium from the Stateline site. These pathologies may be related to nutritional deficiencies (i.e., deficient in iron, protein, or both), trauma, or an infection.

Sex and household determinations were made for all of the ethnoarchaeological dogs sampled. The dog bone samples were obtained from 7 different households and the hair from 22. Approximately 33% of the dog skeletons were females and 67% were males. Roughly 60% of the dog hair samples were obtained from females and 40% from males. Age determinations were also obtained for all of the living dogs. Approximately 74% of the dogs were juveniles, one year old or younger, and 26% of the dogs were adults between 2 and 8 years old.

METHODS

Dense sections of cortical dog bone from both archaeological and ethnoarchaeological contexts were selected for the analysis of $\delta\ ^{15}N$ and $\delta\ ^{13}C$ isotopes. Removal of possible humic contaminants and collagen extraction followed the protocol used by Tankersley et al. (2009). Selected bones tissue samples were first cleaned with distilled, deionized, and demineralized water. Approximately 250 mg of clean bone tissue was demineralized in 1 M hydrochloric acid (HCl) at room temperature for 20 minutes. Following a wash in distilled, deionized, and demineralized water and filtration, the sample was soaked in 0.125 M sodium hydroxide (NaOH) for 20 hours. The remaining solid was gelatinized at 100°C for 17 hours at a pH of 2, washed in distilled, deionized, and demineralized water, and filtered. Following filtration, the sample was freeze-dried with liquid nitrogen and hand pulverized. The stable $\delta\ ^{15}N$ ratios and $\delta\ ^{13}C$ isotopic values of the collagen were measured with a mass-spectrometer relative to the atmospheric nitrogen and Pee Dee Belemnite carbonate standards.

Dog and human hair protein from ethnoarchaeological contexts were pretreated with organic solvents to remove lipids such as fat and oils prior to the analyses of $\delta\ ^{15}N$ and $\delta\ ^{13}C$ isotopes. The samples were soaked for 12 hours in a solution of 7 parts dichloromethane (DCM) and 1 part methyl alcohol (MeOH). The samples were then rinsed twice with dichloromethane.

ISOTOPES

The δ ^{15}N ratios and δ ^{13}C isotope values for archaeological bone collagen are presented in Tables 1, 2, and 3, ethnoarchaeological dog bone collagen in Table 4, and ethnoarchaeological hair protein samples in Table 5. Following Ketchum et al. (2009), triplicate runs were made for all hair protein and bone collagen samples. Means are reported in Tables 1, 2, 3, 4, and 5 with a reproducibility of 0.08 % for δ ^{15}N (Air) and 0.03% for δ ^{13}C (VPDB).

Archaeological Samples

The δ ^{15}N isotope ratios for dog bone collagen samples from archaeological sites in the Ohio Valley ranged from 6.5 to 11.6‰ and the δ ^{13}C isotope values ranged from –20.6 and –11.0‰ (Table 1). The δ ^{15}N isotope ratios increase with age, that is, the Archaic-age dogs have the highest δ ^{15}N ratios (10.01 to 11.6‰). With the exception of the juvenile dog from the Woodland-age Newtown Firehouse site, all of the δ ^{13}C isotope values are above –19‰.

In addition to δ ^{15}N isotope ratios and δ ^{13}C isotope values obtained for collagen extracted from the dense cortical bone of a juvenile dog from the Woodland-age Newtown Firehouse site, comparable data were obtained for collagen extracted from the dense cortical bone of five human skeletons for dietary isotopic data comparisons. The δ ^{15}N isotope ratios for the human bone samples ranged from 2.6 to 7.4‰ and the δ ^{13}C values ranged from –22.5 and –20.1‰ (Table 2). The δ ^{15}N isotope ratios and δ ^{13}C isotope values for an adult male from the Newtown Firehouse (δ ^{15}N = 6.5‰, δ ^{13}C = –20.3 ‰) are almost identical to those of the juvenile dog (δ ^{15}N = 6.5‰, δ ^{13}C = –20.6‰), which was interred in the same burial pit.

Table 1. Stable Carbon and Nitrogen Isotope Data from Dog Bone Collagen from Archaeological Sites in the Ohio River

Site	δ ^{15}N‰ (Air)	δ ^{13}C‰ (VPDB)	RCYBP (Lab Number)[a]
33Ha400	7.15	–10.97	720 ± 60 (Beta-14996)
33Ha58	7.37	–13.68	785 ± 60 (UGa-2153)
			715 ± 55 (UGa-2154)
			695 ± 60 (UGa-2152)
33Ha419	6.52	–20.60	1620 ± 40 (Beta-247819)
33Ha11	10.08	–13.82	4485 ± 75 (UGa-928)
			4435 ± 70 (UGa-1344)
			4125 ± 65 (UGa-1342)
			4100 ± 65 (UGa-1343)
33Ct29	11.58	–14.87	4550 ±355 (UGa-930)
			4470 ± 75 (UGa-931)

[a]After Dalbey, 2007; Drooker, 1997; Vickery, 1976; Vickery et al., 2000; and this report.

Table 2. Stable Carbon and Nitrogen Isotope Data for Human and Dog Bone Collagen from Site 33Ha419

Sample	Sex	Age (Years)	$\delta\ ^{15}N$ (Air)	$\delta\ ^{13}C$ (VPDB)
Human Burial 1	Male	44-54	2.7	–22.4
Human Burial 2	Male	30-45	7.4	–20.4
Human Burial 3	Male[a]	>25	6.5	–20.3
Human Burial 4	Female	25-40	9.4	–20.7
Human Burial 5	Female	35-50	3.2	–20.4
Dog Burial	Unknown	Juvenile	6.5	–20.6

[a]Associated with dog burial.

Table 3. Stable Carbon Isotope Data for Burials from the Newtown Firehouse Site (33Ha419)

Burial	$\delta\ ^{13}C$ vs VPDB	CO_2 Peak Area	Nitrogen (%)	Carbon (%)	Weight (mg)
1	–23.1	14.6	2.7	10.1	1.441
1	–23.3	17.5	3.8	13.3	1.301
1	–20.9	22.5	1.2	6.0	3.577
1 Average	–22.4		2.7		
2	–20.8	39	9.4	27.7	1.369
2	–20.8	29.7	9.4	27.4	1.059
2	–20.0	30.8	3.3	11.3	2.577
2 Average	–20.4		7.4		
3	–19.6	12.4	2.9	10.3	1.201
3	–20.4	20.1	4.8	15.1	1.312
3	–20.8	89.9	11.8	31.1	2.554
3 Average	–20.3		6.5		
4	–20.8	34.1	10.6	30.7	1.084
4	–20.6	45.2	7.9	23.9	1.829
4	–20.7	104.2	9.8	25.7	3.521
4 Average	–20.7		9.4		
5	–20.8	26	3.9	13.2	1.929
5	–20.6	25.3	3.7	12.9	1.925
5	–19.9	28.3	1.9	7.7	3.473
5 Average	–20.4		3.2		
Reproducibility (1-sigma, ‰)	0.03		0.08		

Table 4. Stable Carbon and Nitrogen Isotope Data from Dog Bone Collagen from Arang Dak, an Ethnoarchaeological Site in Nicaragua

Dog burial	$\delta\ ^{15}N$ (Air)	$\delta\ ^{13}C$ (VPDB)	Sex	Year (death)	Household
1	10.56	–13.17	Male	2007	29
2	10.56	–20.11	Female	2006	29
3	8.65	–20.32	Male	2008	12
4	9.43	–19.32	Male	2006	12
5	12.57	–14.24	Female	2006	12
6	11.45	–21.18	Male	2006	12
7	10.08	–20.25	Male	2006	16
8	10.56	–18.57	Male	2005	24
9	9.92	–11.60	Male	2006	4
10	7.57	–20.20	Male	2004	1
11	10.56	–12.08	Female	2007	29
12	10.46	–22.22	Female	2005	21

Ethnoarchaeological Samples

The $\delta\ ^{15}N$ isotope ratios for the dog bone collagen samples from Arang Dak ranged from 7.6 to 12.6‰ and the dog hair protein ranged from 8.1 to 8.4‰ (Tables 4 and 5). The $\delta\ ^{13}C$ isotope values for the dog bone samples ranged from –22.2 to –11.6‰ and the dog hair ranged from –24.0 to –18.1‰ (Tables 4 and 5). In addition to dog bone and hair protein samples, $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ isotope values were obtained for a small sample of human hair protein from five sibling individuals living in the same household as one of the dogs sampled. The $\delta\ ^{15}N$ isotope ratios for the human hair samples ranged from 8.0 to 8.4‰ and the $\delta\ ^{13}C$ isotope values ranged from –24.2 to –22.6‰ (Table 5).

Like the archaeological bone samples from the Newtown Firehouse site, the $\delta\ ^{15}N$ isotope ratios and $\delta\ ^{13}C$ values obtained for people are comparable to those for dogs living in the same household. The $\delta\ ^{15}N$ isotope ratios obtained for dog hair samples from household 16 ranged from 8.5 to 8.8‰ and the $\delta\ ^{13}C$ values ranged from –21.9 to –23.6‰. The $\delta\ ^{15}N$ isotope ratios obtained for hair samples from people living in household 16 ranged from 8.0 to 8.4‰ and the $\delta\ ^{13}C$ values ranged from –22.6 to –24.2‰.

Table 5. Stable Carbon and Nitrogen Isotope Data from Human and Dog Hair from an Ethnoarchaeological Mayangna/Miskito Village Site in Nicaragua

Hair sample	Sex	Age (years)	Household	$\delta^{15}N$ (Air)	$\delta^{13}C$ (VPDB)
Human 1	Female	6	16	8.44	–22.92
Human 2	Female	8	16	8.04	–23.31
Human 3	Female	9	16	8.37	–22.57
Human 4	Male	3	16	8.07	–24.23
Human 5	Female	3	16	8.36	–23.68
Dog 1	Male	1	22	8.96	–22.59
Dog 2	Female	4	22	8.28	–23.53
Dog 3	Male	5	8	8.80	–23.88
Dog 4	Male	0.5	21	7.76	–18.06
Dog 5	Male	1	29	8.82	–22.74
Dog 6	Female	0.5	7	8.61	–21.50
Dog 7	Female	0.5	29	9.08	–21.33
Dog 8	Male	1	29	8.81	–21.73
Dog 9	Male	8	4	9.19	–24.02
Dog 10	Female	0.5	21	7.36	–19.17
Dog 11	Male	1	16	8.83	–23.62
Dog 12	Male	0.5	23	8.77	–22.33
Dog 13	Female	0.5	21	7.11	–19.57
Dog 14	Female	1	24	9.48	–22.47
Dog 15	Female	0.5	19	7.61	–20.84
Dog 16	Male	0.5	20	8.32	–21.93
Dog 17	Female	0.5	13	8.48	–22.57
Dog 18	Female	3	16	8.53	–21.91
Dog 19	Female	0.5	10	8.54	–20.72
Dog 20	Male	0.5	9	8.44	–20.75
Dog 21	Female	2	2	9.57	–20.80
Dog 22	Female	2	5	8.61	–22.46
Dog 23	Female	0.5	26	8.57	–21.41
Dog 24	Female	0.3	11	9.04	–20.75

Table 5. (Cont'd.)

Hair sample	Sex	Age (years)	Household	δ ^{15}N (Air)	δ ^{13}C (VPDB)
Dog 25	Female	3	17	8.63	–23.03
Dog 26	Male	0.5	17	8.45	–21.75
Dog 27	Male	0.5	5	10.09	–19.95
Dog 28	Female	0.3	33	9.06	–21.43
Dog 29	Female	1	12	9.36	–21.99
Dog 30	Male	2	12	9.01	–22.50
Dog 31	Female	0.5	24	8.25	–22.27
Dog 32	Female	4	11	8.93	–21.73
Dog 33	Male	1	24	9.55	–23.00
Dog 34	Female	0.5	27	8.21	–18.94

DISCUSSION

Ethnographic studies show that human feces are consumed (i.e., coprophagia) as a warm meal or a cold, hard, and chewy snack by dogs on a regular basis in pre-industrialized hunter-gatherer, horticultural, and agricultural based economies. Dogs also lick feces from babies' butts to clean them, thereby ingesting all of the human dietary's components (Stern, 1965). In the case of Arang Dak, dogs do not regularly eat human feces because of the use of latrines. However, Mayangna/Miskito dogs eat the same food that has been prepared in households for human consumption (Koster, 2008a). Human food scraps and small critters that also ate human food scraps may have been significant contributions to the isotope signals in dogs. Thus, ethnographic observations provide possible explanatory models for analogous human and canine intake.

Although the Woodland-age Newtown Firehouse site is a single case, comparable δ ^{15}N isotope ratios and δ ^{13}C isotope values obtained from the bone collagen of a juvenile dog and an adult human male interred in the same burial pit support the position that the isotopic composition of dog bone collagen is comparable to human diet (Allitt et al., 2008; White et al., 2001). Support for this position is further strengthened by the similarity of δ ^{15}N isotope ratios and δ ^{13}C isotope values obtained on dog and human hair samples from a single Mayangna/Miskito household in Arang Dak.

Variation in Households

Although the Mayangna and Miskito are integrated into the market economy, the household economy is primarily subsistence-oriented. While the consumption of hunted game, fish, and domesticated animals provides protein, staple crops such as bananas and manioc provide the majority of the calories, there is considerable dietary variation between households (Koster, 2008b). For example, some households cultivate considerable maize whereas others may plant none, focusing instead on rice and beans. Meanwhile, the household harvest of meat depends in large part on the possession of good dogs or a rifle. Throughout the Neotropics, there is abundant ethnographic evidence that talented hunting dogs generally receive better care than their unskilled peers, and that also appears to be true for the dogs in Arang Dak.

The $\delta\,^{15}N$ isotope ratios and $\delta\,^{13}C$ isotope values of dog hair protein samples from Arang Dak show significant differences between households (Table 5). Following Goldstein (2003), the variance partition coefficient for the $\delta\,^{15}N$ isotope ratios in the hair samples is 0.438. In other words, about 44% of the total variance in the hair sample may be attributed to differences between households. At 0.601, the variance partition coefficient for the $\delta\,^{13}C$ isotope values is even more pronounced, suggesting that approximately 60% of the variation in the hair samples is explained by household membership. Similar relationships seem to characterize the $\delta\,^{15}N$ isotope ratios and $\delta\,^{13}C$ isotope values of dog bone samples from Arang Dak (Table 4).

Independent *t*-tests of the $\delta\,^{15}N$ isotope ratios and $\delta\,^{13}C$ isotope values of dog hair protein were used to determine if the diets of dogs of Arang Dak varied by sex. The average $\delta\,^{15}N$ isotope ratio for female dog hair protein is 8.6‰ while the average for males is 8.8‰. There appears to be no significant difference between these means ($t = -1.29$, $p = 0.21$, df = 32). The average $\delta\,^{13}C$ isotope value for female dog hair protein is –21.4‰ while the average for males is –22.1‰. Again, a *t*-test revealed no significant difference between these means ($t = 1.318$, $p = 0.20$, df = 32).

Pearson's correlation coefficient was calculated using $\delta\,^{15}N$ isotope ratios and $\delta\,^{13}C$ isotope values to determine if the dogs in Arang Dak varied by age. Whereas the $\delta\,^{15}N$ isotope ratios of dog hair protein are apparently not correlated with age (Pearson's $r = 0.19$, $p = 0.29$), there is a significant negative relationship between age and the $\delta\,^{13}C$ values (Pearson's $r = -0.54$, $p = 0.001$). In other words, the $\delta\,^{13}C$ isotope values of dog hair decline with the age of the dogs sampled. The $\delta\,^{15}N$ isotope ratios of dog bone collagen increase with age at death (Pearson's $r = 0.574$, $p = 0.05$, $n = 12$). Likewise, there is a significant positive correlation between the $\delta\,^{13}C$ isotope values obtained on dog bone collagen and age (Pearson's $r = 0.736$, $p = 0.006$, $n = 12$). This result is contrary to our findings on dog hair protein for which we noted a significant negative correlation. This finding suggests that bone collagen may have a different isotopic memory of diet than hair protein.

In addition to the variation in age-related carbon values, other differences between dog hair and bone collagen were evident. For the dog hair protein samples, the average δ ^{15}N isotope ratio is 8.7‰ whereas the average for the dog bone collagen samples is 10.2‰. There is a significant difference between these means (Welch's $t = 3.97$; $p = 0.002$; df = 12). Similarly, the average δ ^{13}C isotope values for dog hair protein is –21.7‰ whereas the average for the bone collagen is –17.1‰. Again, there is a significant difference between these means (Welch's $t = –3.75$; $p = 0.003$; df = 11). These ethnoarchaeological data demonstrate that either the diets of the deceased dogs differed from the living dogs, or bone collagen has a different isotopic memory than hair protein.

Discrepancies between the δ ^{15}N isotope ratios and δ ^{13}C isotope values in the ethnoarchaeological dog hair and bone collagen may be related to the isotopic memory of the samples. Petzke et al. (2005) have shown that the bulk isotopic abundance of hair can be used as an accurate biomarker for dietary assessment. Furthermore, δ ^{13}C isotope values in hair are particularly homogeneous in carnivores (Panarello and Fernandez, 2002). Witt and Ayliffe (2001) have shown, however, that the δ ^{15}N isotope ratios and δ ^{13}C isotope values of hair protein assesses more recent diet in individuals, whereas bone collagen retains a more prolonged isotopic memory. Kellner and Schoeninger (2007) demonstrated that the isotopic memory of carnivore bone collagen is directly related to their digestive physiology. That is, they do not employ fore or hindgut fermentation in the metabolism of their food. Indeed, Mekota et al. (2006) found that the isotopic composition of hair reflects dietary change within days.

Differences in the isotopic memories of ethnoarchaeological dog hair and bone collagen can be found in the δ ^{13}C isotope values associated with the consumption of C_4 photosynthetic plant foods such as maize (*Zea mays*). Most archaeologists associate the consumption of C_4 photosynthetic plant foods such as *Zea mays* with a δ ^{13}C isotope value that is greater than –19‰ (Schoeninger and Moore, 1992; Schurr, 1992; Schwartz and Schoeninger, 1991).

The question of how accurately δ ^{13}C values greater than –19‰ indicate the presence or absence of maize in the diet of human populations is of more than a little archaeological interest. At Arang Dak, The Nature Conservancy (1997) reported an average of 24.3 sacks of corn cobs per household. Each sack holds approximately 46 kg of maize cobs. In other words, about eight pounds of maize was consumed per year, which is likely more than that consumed by Middle Woodland, Hopewell populations in the Ohio River valley. Koster (2007) found that the average consumer in Arang Dak ate 0.01 kg of maize per day. Over a year-long study period, in household 16 (Table 5), from which our human and dog hair samples were obtained, maize was consumed approximately 22 days of the year (about 6%). The average percentage of maize consumption for the other households was about 7%, which suggests that household 16 is representative of the households in Arang Dak (Koster, 2007).

Neither human nor dog hair protein samples from household 16 produced δ ^{13}C isotope values that were greater than –19‰. Furthermore, only 2 of the 34 (6%) living dogs sampled from Arang Dak produced δ ^{13}C isotope values associated with the consumption of maize. On the other hand, 5 of the 12 dog bone collagen samples (42%) produced δ ^{13}C isotope values that were greater than –19‰ (–18.6 to –11.6‰). While bone collagen clearly provides more substantial evidence for the consumption of maize, it is noteworthy that 7 of the 12 dog skeletons sampled (58%) failed to produce δ ^{13}C isotope values that were greater than –19‰ (–22.2 to –19.3‰).

Our ethnoarchaeological data suggest that a significant amount of maize needs to be consumed in order to produce δ ^{13}C isotope values that are greater than –19‰. A similar result was found in the archaeological dog and human bone collagen sample from the Woodland-age Newtown Firehouse site (Tables 2 and 3). Although carbonized maize was abundant in the same pit feature, which contained dog and human skeletons, none of the bone collagen samples produced δ ^{13}C isotope values that were greater than –19‰. Rather, the δ ^{13}C isotope values are comparable to those found in human bone collagen from other Woodland-age sites (Tankersley and Tench, 2009).

While isotopic dietary signatures for the consumption of maize were found in the Fort Ancient-age Stateline (δ ^{13}C = –13.7‰) and Schomaker (δ ^{13}C = –11.0‰) sites, they were also found in the Archaic-age Dupont (δ ^{13}C = –13.8‰) and Bullskin Creek (δ ^{13}C = –14.9‰) sites. Both of these sites date more than 2,000 years before the introduction of maize in the Ohio Valley. In other words, the high δ ^{13}C isotope values in Archaic-age dog bone collagen suggests that indigenous C_4 or CAM photosynthetic plant foods were consumed. However, it is also possible that the high δ ^{13}C isotope values resulted from opportunistic omnivore behavior or diagenetic changes in the bone collagen. This finding is a significant caveat in using δ ^{13}C isotope values as dietary measurement for maize consumption and requires further investigation.

CONCLUSION

Archaeological and ethnoarchaeological samples of dog tissues demonstrate that the δ ^{15}N isotope ratios and δ ^{13}C isotope values vary from household to household. The consumption of C_4 plants was not apparent in the δ ^{13}C isotope values obtained from a living population of maize consuming dogs and humans. Bone collagen has a longer isotopic memory than other tissues such as hair and is more likely to provide evidence of C_4 plant foods. However, less than 50% of the samples of human and dogs that consumed maize had a δ ^{13}C isotope value greater than –19‰. This caveat suggests that archaeological interpretations of δ ^{13}C isotope values should be made in conjunction with paleobotanical analyses.

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