Turkeys on the fringe: Variable husbandry in “marginal” areas of the prehistoric American Southwest

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ABSTRACT

Previous research reporting stable carbon (δ13C) and nitrogen (δ15N) isotope values of prehistoric turkey (Meleagris gallopavo) remains from the American Southwest indicates that these birds were husbanded in consistent ways: the majority of samples suggest a diet dominated by maize, a domesticate that uses the C4 photosynthetic pathway. However, most of these studies have focused on turkey remains from locations where maize production may have been marginal. The Tijeras Pueblo turkeys display a unique carbon isotope pattern in both bone collagen and bone apatite, with half the samples indicating a predominately C3 diet (a signature characteristic of modern wild turkeys) and the other half predominately C4, even though the majority of samples belong to the Southwestern domestic turkey mtDNA lineage identified by Speller et al. (2010). Comparative collagen samples from the Albuquerque Basin and the Gallina region do not follow this pattern. Apatite-collagen δ13C spacing in the Tijeras turkeys suggests these birds were acquiring carbohydrates and protein from a mixture of C3- and C4-based resources. We propose that the C3 Tijeras turkeys were free-ranged, and that the presence of two distinct turkey husbandry regimes at Tijeras Pueblo may reflect Tijeras’ geographic location on a cultural boundary between the Plains and Pueblo regions.

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1. Introduction

The nature of the human–turkey (Meleagris gallopavo) relationship in the prehistoric American Southwest has long been a matter of debate. Were turkeys domestic or wild (Beacham and Durand, 2007; Grimstead et al., 2014)? If domestic, were they domesticated independently (McKusick, 1986) or imported from domestic flocks maintained by prehistoric Mesoamericans? Did Ancestral Puebloans use turkeys for food or for ritual purposes, and did this use change through time (Badenhorst and Driver, 2009; Lipe et al., 2016; McKusick, 2001)? In recent years, ancient DNA (aDNA) research has addressed some of these questions, establishing the presence of a distinct turkey lineage — separate from both the Mexican domestic turkey and the wild Merriam’s turkey (M. gallopavo merriami) — in the American Southwest as far back as the Basketmaker period (A.D. 1; Speller et al., 2010). Isotope-based studies (Kellner et al., 2010; McCaffery et al., 2014; Rawlings and Driver, 2010; also see Grimstead et al., 2014 for a different approach) provide further support for domestication: these studies have established a remarkably consistent picture of turkey husbandry in the prehistoric Southwest, with the vast majority of turkey samples having δ13C values indicative of diets dominated by C4 plants (presumably maize), a few individuals showing values in the C3 range, and no turkeys with the intermediate δ13C values that would be consistent with a diet of mixed C3 and C4 resources (Fig. 2; Kellner et al., 2010; McCaffery et al., 2014; Rawlings and Driver, 2010). Turkeys with δ13C values indicative of a C4-based diet match those of contemporaneous humans, suggesting that these turkeys were eating diets similar to those consumed by the people who husbanded them (e.g., Coltrain and Janetski, 2013). The few turkeys with δ13C values indicative of a C3-based diet have been interpreted as reflecting the occasional presence of local wild Merriam’s turkey, a reasonable argument given that isotopic studies of wild turkeys indicate a diet dominated by C3 resources (e.g., Stearns, 2010).

However, many questions about turkey husbandry in the American Southwest remain. One such question involves the cost of maintaining domestic turkeys in areas with variable or low agricultural productivity. Maize was the staple food for prehistoric people as well as for domestic turkeys (Coltrain et al., 2007; Cordell and McBrinn, 2012; Geib, 2011; Matson and Chisholm, 1991). If maize availability was restricted in a...
particular year, turkey growers would have faced a choice: feed people or feed turkeys. This problem would likely have been a relatively common one in areas where maize production was marginal due to a shorter growing season; it may also have been an issue in areas where people invested less in maize production for cultural and/or historical reasons.

Most of the previous isotopic studies were conducted with samples derived from sites in core areas of the American Southwest, places where maize would have been a relatively stable resource (Hayes and Caperton, 1981; Kohler et al., 2012). Because turkeys from sites in areas where the growing season was short and/or in which the material culture suggests a difference from these core areas have yet to be analyzed, it may be that we have underestimated the heterogeneity in prehistoric Southwestern turkey husbandry practices.

Environmentally marginal locations in the Southwest include high-elevation sites such as Tijeras Pueblo (Fig. 1; 2,150 m). Maize typically requires 120 frost-free days for good production (Mackey, 1985), but Tijeras is located in a pass in the Sandia Mountains (elevation range: 1,800–3,255 m), and the number of frost-free days at this site is often closer to 100 (Cordell, 1980b; Cordell et al., 1984; Julyan, 2006; Julyan and Stuever, 2005). Dendroarchaeological records suggests climate was particularly variable between 1300 and 1425 A.D., when Tijeras Pueblo was occupied (Cordell, 1980a; Van West and Cordell, 2013).

Despite this, the inhabitants of Tijeras Pueblo were, like other Ancestral Puebloan peoples, maize farmers (Cordell, 1980b), and the archaeofaunal remains from this site are rich in turkey (Young, 1980). Previous interpretations have assumed turkeys were husbanded here in ways similar to elsewhere in the Southwest region. Given the challenges inherent in growing maize in the Sandia Mountains coupled with the suitability of the local habitat for wild turkeys, however, it may be that the prehistoric inhabitants of Tijeras Pueblo exploited wild turkeys, which are common in this area today (Julyan and Stuever, 2005), rather than investing in domestic turkeys. Alternatively, if they did keep domestic turkeys, these turkeys may have been allowed to free-range for wild plants and insects, a strategy documented ethnographically among Eastern Puebloan peoples (Lang and Harris, 1984).

In this paper, we explore this question using stable isotope ($\delta^{13}C$ and $\delta^{15}N$) and aDNA data from the turkeys of Tijeras Pueblo. We compare our findings to isotope data from modern wild turkeys and from archaeological turkeys from two other eastern locations (the Albuquerque...
Basis and the Gallina region), as well as to the results of other studies that have examined these questions in other areas of the American Southwest (Conrad et al., this volume; Kellner et al., 2010; Lipe et al., 2016; McCaffery et al., 2014; Rawlings and Driver, 2010).

2. Background

2.1. The Sandias and Tijeras Pueblo

Tijeras Pueblo could be considered a marginal location for a maize agriculture-dependent settlement, as the relatively short growing season and higher climatic variability would make a subsistence strategy focused on maize challenging (Anderson and Oakes, 1980). Despite this, this site is a multi-story roomblock similar to other Pueblo IV period habitations (Cordell, 1980b). The bulk of its occupation occurred between A.D. 1300 and 1425, and multiple lines of evidence, including macrobotanical and geoarchaeological data, suggest maize was the basis of the diet for humans at this site, just as it was in other southwestern sites during this period (Cordell, 1980a; Garber, 1980).

Archaeological excavations at Tijeras Pueblo conducted in the 1970s resulted in a rich faunal assemblage (Jones and Gabe, 2015; Young, 1980), including a substantial number of turkey specimens (NISP = 151, or 12% of total vertebrate NISP). While turkey pens were not identified at Tijeras, other lines of evidence – including a concentration of turkey dung in several rooms and significant recovery of eggshell (Judy Vredenburg, personal communication) – suggest turkeys were a significant part of life at this site.

The Tijeras turkeys thus represent an ideal assemblage with which to test for heterogeneity in prehistoric turkey husbandry—one on the fringe of the Southwest core area but where turkeys were nonetheless maintained as a significant resource. We sampled 31 turkey specimens from Tijeras Pueblo recovered from a variety of contexts and spanning the full occupation of the site; detailed contextual information is available in the supplemental data.

2.2. Comparative samples

We hypothesize that turkeys from marginal locations should be more likely to have been procured in ways different than the typical southwestern pattern (Kellner et al., 2010; McCaffery et al., 2014; Rawlings and Driver, 2010; see δ13C and δ15N data in Fig. 2). This might include (1) eschewing domestic turkeys altogether and using wild turkeys in their place; (2) a husbandry practice in which domestic turkeys were allowed to free-range; or (3) using a combination of wild, domestic, and/or free-ranged turkeys. Testing these hypotheses requires data on the isotopic signature of wild turkeys. For this reason, we analyzed bone collagen δ13C and δ15N and bone apatite δ13C collected from the wild in relatively high-elevation locations in New Mexico and Texas that are archived at the UNM Museum of Southwest Biology (Table 1).

In addition, we analyzed prehistoric turkey samples from two other areas (Fig. 1): the Gallina region (n = 1 from Rattlesnake Ridge, LA 35648 at 2317 m; n = 2 from Cuchillo, LA 22861 at 2091 m; and four unprovenienced specimens that are likely from Cuchillo) and the Albuquerque Basin (n = 11 from Chamisal Pueblo, LA 22765 at 1518 m). The Gallina sites date to an earlier period (ca. A.D. 1100) than Tijeras Pueblo but may represent locations that are both culturally and environmentally marginal. Gallina sites have a distinct archaeological record (for example, pointed-bottom pots and architecture featuring masonry towers) and are widely assumed to represent a different cultural adaptation than contemporaneous southwestern sites (Ellis, 1988). In addition, like Tijeras Pueblo, the Gallina region is high elevation (both sites sampled here are at elevations over 2000 m) and could be considered marginal for maize production. The median number of frost-free days in the Gallina region is less than 98 (Constan, 2011), well short of the optimal 120. As at Tijeras, there is strong evidence for turkey husbandry in the Gallina sites, with abundant turkey remains and documented turkey pens (Constan, 2011).

While the Albuquerque Basin is more climatically favorable for maize agriculture than high-elevation Tijeras or the Gallina region, this region has an archaeological record suggesting that it was likely culturally distinct from many other parts of the Southwest. Analyses of prehistoric social networks based on architecture and ceramics indicate a different pattern than that seen elsewhere (e.g., Cordell and McBrinn, 2012; Eckert and Cordell, 2004; Schaffasma, 2007). Puebloan settlement appears to have been relatively sparse in this area prior to A.D. 1200, with population growth occurring later than it did in the Four Corners region (Eckert and Cordell, 2004; Marshall and Walt, 1984). The earliest known turkey pens in the Albuquerque Basin date to the Late Developmental/Early Pueblo I period (e.g., Cordero and Dicks, 2010), at least 500 years after they are documented in the Four Corners (Rawlings and Driver, 2010). If cultural difference, rather than environmental marginality, is driving heterogeneity in turkey husbandry, we might expect to see a different pattern of turkey management in the Albuquerque Basin. Chamisal Pueblo, from which we drew our turkey sample, dates between A.D. 1300 and 1600, making it roughly contemporaneous with Tijeras Pueblo.

3. Methods

We measured turkey bone collagen δ13C and δ15N values from the samples described above and compared them to previously published data from Shields Pueblo (SMT3807; Rawlings and Driver, 2010), the Tommy Site (LA 126581; McCaffery et al., 2014), Salmon Pueblo (LA 8846; McCaffery et al., 2014), the Box B Site (LA 16660; McCaffery et al., 2014), Arroyo Hondo Pueblo (LA 12; Conrad et al., this volume), and Gran Quivira (LA 120; Kellner et al., 2010) (Fig. 1), as well as to wild turkey collagen isotope data reported by Lipe et al. (2016). In addition, we measured bone apatite δ13C from the Tijeras turkeys and the comparative wild turkeys, and we calculated the spacing in δ13C values between bone apatite and collagen (Δ13Capatite-collagen).

Finally, 13 turkey specimens from Tijeras Pueblo underwent genetic analysis. Our goal in this was to identify whether turkeys exploited at Tijeras were wild Merriam’s turkeys, Southwestern domesticate turkeys, or members of some other genetic lineage(s).

3.1. Bone collagen preparation

For bone collagen analysis, 50–100 mg of bone was sub-sampled from each element. Bone samples were demineralized in 0.5 N hydrochloric acid at −5 °C for 24 h. Samples were then rinsed to neutrality in deionized water. We extracted lipids from both modern and ancient
bone collagen samples; while lipid extraction is typically not needed for ancient samples, we chose to treat modern and ancient samples in a similar fashion prior to isotope analysis. Lipids were extracted via three sequential 24 h soaks in a 2:1 chloroform:methanol solvent solution; samples were then rinsed to neutrality in deionized water before being lyophilized. Approximately 0.5–0.6 mg of dried sample was weighed into tin capsules. δ13C and δ15N values were measured on a Costech 4010 elemental analyzer (Valencia, CA) coupled to a Thermo Scientific Delta V isotope ratio mass spectrometer (Bremen, Germany) at the University of New Mexico Center for Stable Isotopes (UNM–CSI, Albuquerque, NM). Isotope values are reported in delta (δ) notation: [(Rsample/Rstandard) − 1] × 1000, where Rsample and Rstandard are the 13C/12C or 15N/14N ratios of the unknown samples and standard, respectively. The internationally accepted standards for δ13C and δ15N are Vienna Pee Dee Belemnite (V-PDB) and atmospheric N2, respectively. The units for δ13C and δ15N values are parts per thousand (‰) or per mil. We also measured the weight percent carbon and nitrogen concentrations of all turkey bone collagen samples, which ranged between 2.7 and 2.9 indicative of intact collagen containing minimal amounts of contaminants (Ambrose, 1990; see supplemental data). Within-run analytical precision (SD) was ≤0.2‰ for both δ13C and δ15N values.

To directly compare modern and ancient turkey isotope data, we accounted for the historic decrease in the δ13C value of atmospheric CO2 (i.e., Suess effect) by applying a correction value of −0.005%/year for turkeys between 1930 and 1960 and −0.022%/year for turkeys collected since 1960 (Francey et al., 1999; Indermuehle et al., 1999; Leuenberger et al., 1992).

3.2. Apatite preparation

To prepare bone apatite, ~50–100 mg of bone was drilled from each bone element to produce a homogenized powder. Each sample was placed into a bath of 3% hydrogen peroxide for 24 h to remove all organic contaminants and rinsed three times to neutrality and air-dried under a fume hood for 24 h. Approximately 0.5–0.6 mg of apatite was weighed into glass Exeterial vials and reacted with phosphoric acid at 50 °C for 6 h. The CO2 produced from this reaction was measured on a Thermo Scientific GasBench (Bremen, Germany) coupled to a Delta V isotope ratio mass spectrometer at UNM–CSI. Delta values and units are reported as described above for δ13C measurement of bone collagen samples (Section 3.1). Within-run analytical precision was 0.1‰ for apatite δ13C.

McAffery et al. (2014) predict that apatite δ13C values for 100 percent maize-fed turkeys will fall between −2.7‰ and +4.0‰, while values for turkeys with a wholly C3 diet should be between −21.0‰ and −7.8‰ and for those turkeys with a mixed diet will range between −7.8‰ and −2.8‰. We use these values to guide our interpretations of apatite δ13C.

3.3. Apatite-collagen δ13C spacing

Bone apatite δ13C values represent bulk diet, which for largely herbivorous species such as turkeys is dominated by carbohydrates, while bone collagen δ13C values largely represent dietary protein (Ambrose and Norr, 1992; Kellner and Schoeninger, 2007). The spacing in δ13C values between bone apatite and collagen (Δ13Capatite-collagen) can be used to assess trophic level (e.g., herbivore, omnivore, or carnivore) and differentiate between dietary sources of carbohydrates and protein for both modern and ancient animals (Lee-Thorp et al., 1989). Kellner and Schoeninger (2007; also see McAffery et al., 2014) used Δ13Capatite-collagen to model diets, finding that animals that ate C3-based protein fit the line y = 1.74x + 21.4 (r2 = 0.95), while those eating C4-based protein best fit the line y = 1.71x + 10.6 (r2 = 0.80). We use these protein regression lines to identify the δ13C of dietary protein consumed by archaeological and modern turkeys (Fig. 4) and to interpret whether the turkeys in our sample had predominately C4, predominately C3, or mixed diets.

3.4. Ancient DNA

Thirteen turkey specimens from Tijeras Pueblo were sent to the Laboratory of Molecular Anthropology and Ancient DNA at Washington State University (WSU) for genetic analysis. Approximately 38–55 mg of bone (Table 2) was sub-sampled from the whole specimens and submerged in 6% sodium hypochlorite for 4 min to remove possible surface contamination (Barta et al., 2013). The bleach was poured off and the samples were rinsed twice by submersion in DNA-free water. DNA was extracted following the WSU method described by Cui et al. (2013) (this method is referred to as extraction method 1 in Table 2). The DNA extracts were first tested for the presence of PCR inhibitors and treated accordingly with repeat silica extractions, following Kemp et al. (2014). Attempts were made to sequence nucleotide positions (nps) 15554–16013 of the mitochondrial genome (relative to GenBank accession number EF153719) in 3 or 4 amplicons following the WSU methods described by Speller et al. (2010). Note that in Table S5 of Speller et al. (2010) there is a mistake in the description of their forward primer for the D-Loop 1 and 1A (primer T15533F), which actually spans nps 15533–15553. Larger portions of the two samples (sample 14: 112 mg, sample 21: 166 mg) that failed to yield analyzable DNA using these methods were decontaminated as described above and extracted according to the modified Kemp et al. (2007) method described by Moss et al. (2014) (this method is referred to as extraction method 2 in Table 2). Portions of the mitochondrial genome were sequenced as just described. Sequences were aligned to a turkey mtDNA reference (GenBank accession number EF153719) in Sequencer (version 4.8). Any novel mutations observed over those previously recorded by Speller et al. (2010) were confirmed by sequencing multiple independent amplicons.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Species Element Side Sex Provenience</th>
<th>δ13Ccollagen</th>
<th>Seuss corr.</th>
<th>δ15N</th>
<th>C:N</th>
<th>δ13Capatite</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSB:Bird:11007</td>
<td>Meleagris gallopavo</td>
<td>Femur R unk. Unknown</td>
<td>−20.4</td>
<td>−20.4</td>
<td>6.1</td>
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<tr>
<td>MSB:Bird:11006</td>
<td>Meleagris gallopavo</td>
<td>Femur R F Colorado</td>
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<td>−19.9</td>
<td>5.6</td>
<td>2.8</td>
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<tr>
<td>MSB:Bird:39002</td>
<td>Meleagris gallopavo</td>
<td>Femur R F Ft. Stockton, TX</td>
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<td>−20.5</td>
<td>7.1</td>
<td>2.9</td>
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<tr>
<td>MSB:Bird:39001</td>
<td>Meleagris gallopavo</td>
<td>Femur R F Ft. Stockton, TX</td>
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<td>−16.7</td>
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<tr>
<td>MSB:Bird:36001</td>
<td>Meleagris gallopavo</td>
<td>Femur R F Pueblon, NM</td>
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<td>2.8</td>
</tr>
<tr>
<td>MSB:Bird:36002</td>
<td>Meleagris gallopavo</td>
<td>Femur R M Mt. Taylor, NM</td>
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<td>2.8</td>
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<td>−20.9</td>
<td>3.9</td>
<td>2.8</td>
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</tbody>
</table>
in order to guard against recording “mutations” that, in fact, represent nucleotides that have been damaged post-mortem (Winters et al., 2011).

4. Results

4.1. Bone collagen

Tijeras turkey bone collagen $\delta^{13}C$ and $\delta^{15}N$ values produced a pattern (Fig. 3a) distinct from that seen elsewhere in the Southwest (Fig. 2). While approximately half ($n = 17$) of the Tijeras sample showed $\delta^{13}C$ values consistent with a C4-rich diet, the other half ($n = 14$) suggest a diet dominated by C3 resources (Tables 3 and 4). The difference between these groups is statistically significant (Welch’s t-test: $t_{\text{welch}} = -26.14, p < 0.01$). The $\delta^{15}N$ values also show a less-marked but still clear trend: turkeys with $\delta^{13}C$ values indicative of C4-based diets have lower $\delta^{15}N$ than do those with $\delta^{13}C$ values indicative of C4-based ones ($t_{\text{welch}} = -5.85, p < 0.01$).

The Tijeras turkeys with a C4-based diet also differ significantly in $\delta^{15}N$ values from modern wild specimens. Bone collagen from the modern wild turkeys sampled as part of this study (Tables 1 and 4; also see supplemental data) and from those sampled by Lipe et al. (2016) have lower $\delta^{13}C$ values than do the Tijeras turkeys with a C4-based diet ($t_{\text{welch}} = -4.58, p < 0.01$), although $\delta^{15}N$ values are similar between these two groups ($t_{\text{welch}} = -0.10, p = 0.92$). In addition, modern turkey $\delta^{13}C$ and $\delta^{15}N$ values differ significantly from those of the Tijeras birds with C4-based diets ($\delta^{13}C$: $t_{\text{welch}} = -21.32, p = 0.00$; $\delta^{15}N$: $t_{\text{welch}} = -6.26, p = 0.00$).

The Albuquerque Basin and Gallina samples produced divergent results (Table 4). The 11 Chamisal turkeys all suggest a C4 diet (Fig. 3b) and are statistically indistinguishable from the Tijeras turkeys with a C4-based diet ($t_{\text{welch}} = -0.99, p = 0.33$); the Chamisal turkeys also have $\delta^{13}C$ values similar to those analyzed in previous studies (Fig. 2). Chamisal turkey $\delta^{15}N$ values are similar to those with C4-based diets in the Tijeras sample ($t_{\text{welch}} = -0.37, p = 0.71$; Table 4).

By contrast, the majority of Gallina samples ($n = 5$) suggest a C3-based diet (Fig. 3b). While two of these specimens did have a $\delta^{13}C$ values indicative of C3-based diets, these two specimens may represent a single individual (see supplemental data). In addition, $\delta^{15}N$ values from these turkeys are similar to modern wild turkeys ($t_{\text{welch}} = -0.46, p = 0.66$) and to the Tijeras turkeys with C3-based diets ($t_{\text{welch}} = -1.38, p = 0.21$; Table 4).

4.2. Bone apatite

Bone apatite $\delta^{13}C$ results from the Tijeras turkeys concur with the collagen results (Tables 3 and 4), with apatite $\delta^{13}C$ values again
separating into two clear groups (\( t_{\text{welch}} = 12.61, p = 0.00 \)). The specimens identified as having \( C_4 \)-based diets from bone collagen had lower apatite \( \delta^{13}C \) values than the others; the majority (\( n = 9 \)) fell between \(-21.0\%\) and \(-7.9\%\), that is, within the range predicted by McCaffery et al. for turkeys with a \( C_2 \)-based diet (2014). The remaining five specimens identified as having \( C_2 \)-based diets from bone collagen had apatite \( \delta^{13}C \) values between \(-7.0\%\) and \(-5.3\%\), placing them in McCaffery et al.’s “mixed” diet group. Apatite \( \delta^{13}C \) values of the modern wild turkeys ranged between \(-12.9\%\) and \(-11.1\%\), suggesting a \( C_2 \)-based diet for all specimens (Tables 1 and 4). Although the modern and Tijeras \( C_3 \) turkeys with a \( C_2 \)-based diet clearly are closer to each other than either is to the Tijeras turkeys with a \( C_4 \)-based diet, these two groups also differ from each other (Fig. 4): apatite \( \delta^{13}C \) values are lower for the modern wild turkeys than the Tijeras \( C_3 \) group (\( t_{\text{welch}} = -7.31, p = 0.00 \)).

### 4.3. Apatite-collagen spacing

\( \Delta^{13}C_{\text{apatite-collagen}} \) values support the hypothesis that at least some of the Tijeras turkeys with \( \delta^{13}C \) values indicating a \( C_4 \)-based diet had a mixed diet with inputs from both wild resources and from maize (Fig. 4). Not only do the Tijeras turkeys with collagen \( \delta^{13}C \) values indicative of a \( C_3 \)-based diet have higher mean \( \Delta^{13}C_{\text{apatite-collagen}} \) than either the \( C_3 \) group or the modern wild specimens (Welch’s F-test: \( F = 11.55, p = 0.004 \)), there is also significantly more variation in \( \Delta^{13}C_{\text{apatite-collagen}} \) values in this group (Table 4).

### 4.4. Ancient DNA

Of the 15 extractions performed on the 13 samples, five required a repeat silica extraction to sufficiently remove inhibitors (Kemp et al., 2014; Table 2). Eight of the 13 samples (specimen numbers 11, 12, 16, 18, 20, 21, 22, and 23) yielded “complete” mtDNA sequences spanning

### Table 3

Tijeras Pueblo turkey isotope and aDNA results; n.d. indicates context is undated. C:N ratios are weight percent.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Context</th>
<th>Occupation</th>
<th>( \delta^{13}C_{\text{collagen}} )</th>
<th>( \delta^{15}N )</th>
<th>C:N ratio</th>
<th>( \delta^{13}C_{\text{apatite}} )</th>
<th>Haplotype</th>
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<td>7.5</td>
<td>2.7</td>
<td>-0.8</td>
<td>aHap1</td>
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<tr>
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<td>Room 139</td>
<td>n.d.</td>
<td>-7.7</td>
<td>7.2</td>
<td>2.7</td>
<td>-0.5</td>
<td>aHap1</td>
</tr>
<tr>
<td>13</td>
<td>Room 40</td>
<td>Late</td>
<td>-16.9</td>
<td>4.0</td>
<td>2.7</td>
<td>-6.6</td>
<td>aHap27</td>
</tr>
<tr>
<td>14</td>
<td>Midden 1</td>
<td>n.d.</td>
<td>-15.8</td>
<td>7.3</td>
<td>2.8</td>
<td>-5.5</td>
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<tr>
<td>15</td>
<td>Midden 2</td>
<td>n.d.</td>
<td>-18.1</td>
<td>5.3</td>
<td>2.8</td>
<td>-7.0</td>
<td>aHap1</td>
</tr>
<tr>
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<td>Room 116</td>
<td>Early</td>
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<td>7.7</td>
<td>2.7</td>
<td>0.0</td>
<td>aHap1</td>
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<td>Room 116</td>
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<td>-9.1</td>
<td>-</td>
</tr>
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<td>-10.2</td>
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### Table 4

Means and standard deviations (SD) of bone collagen and apatite stable isotope values for the turkeys discussed in this study.

<table>
<thead>
<tr>
<th>Gallina Sites</th>
<th>Chamil Pueblo</th>
<th>Arroyo Pueblo</th>
<th>Tujierras Pueblo C2 diet</th>
<th>C3 diet</th>
<th>Modern</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta^{15}N ) Mean</td>
<td>6.8</td>
<td>7.7</td>
<td>9.0</td>
<td>5.7</td>
<td>7.6</td>
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<tr>
<td>SD</td>
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<td>1.4</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>( \delta^{13}C_{\text{Collagen}} ) Mean</td>
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<td>-7.6</td>
<td>-8.2</td>
<td>-17.1</td>
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<tr>
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<td>1.8</td>
<td>1.0</td>
<td>0.9</td>
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<tr>
<td>( \delta^{13}C_{\text{Apatite}} ) Mean</td>
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<td>-8.1</td>
<td>-1.0</td>
<td>-13.0</td>
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<tr>
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<td>1.7</td>
<td>1.8</td>
<td>1.1</td>
<td>1.3</td>
<td></td>
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<tr>
<td>( \Delta^{13}C_{\text{Apatite-collagen}} )</td>
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<td>5.0</td>
<td>7.0</td>
<td>6.0</td>
<td>0.8</td>
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</table>

Fig. 4. Collagen and apatite \( \delta^{13}C \) of the Tijeras Pueblo and modern wild turkeys (this study), with \( C_3 \) and \( C_4 \) protein lines following Kellner and Schoeninger (2007) and McCaffery et al. (2014); \( C_3 \) protein: \( y = 1.74x + 21.4 \) (dotted line); \( C_4 \) protein: \( y = 1.71x + 10.6 \) (solid line).
In the archaeological record, the complete sequence of specimen number 13 reveals a unique form of turkey mitochondrial DNA, one that is derived by an A→G transition at nucleotide position (np) 15791 from the aHap2 haplotype (Speller et al., 2010). A BLAST search of GenBank (conducted on August 25, 2015) revealed no complete matches to this haplotype, confirming its uniqueness—it has yet to be observed in any other modern or ancient turkey. The mutation (15791G) that makes this lineage unique was confirmed by sequencing from two independent amplifications. Repeated observations of an identical sequence effectively rules out these results as having been influenced by post-mortem nucleotide damage (Winters et al., 2011). Specimen number 14 yielded no analyzable DNA using the methods employed in this study.

5. Discussion

The results presented here clearly support the hypothesis that there was variability in turkey husbandry in the prehistoric American Southwest. At Tijeras Pueblo, approximately half (n = 14) of the turkeys sampled had collagen δ¹³C values suggesting a diet intermediate between wild turkeys and domestic ones. The remaining Tijeras Pueblo turkeys (n = 17) produced collagen δ¹³C values suggesting a diet dominated by C₄ resources—in this case, likely maize (Rawlings and Driver, 2010). The aDNA δ¹³C data further support this finding. δ¹⁵N data suggest Tijeras turkeys with a C₃-based diet and modern turkeys occupied a similar trophic level—one different from the turkeys with a C₄-based diet. As discussed earlier, ethnographic data suggest that among Eastern Puebloan groups, domestic turkeys were sometimes “free-ranged” and/or brought to cornfields to assist in insect control (Lang and Harris, 1984). The Tijeras turkeys with a C₃-based diet may represent turkeys husbanded in this way.

Δ¹³Capatite-collagen patterns provide further support for a group of free-ranging turkeys at Tijeras. Mean Δ¹³Capatite-collagen for the Tijeras turkeys with a predominantly C₃ diet (+ 7.0 ± 1.1‰) is similar to that previously reported for turkeys from the Four Corners region that had C₄-based diets (+ 6.8 ± 2.3‰; McCaffery et al., 2014) and to our sample of modern turkeys (+ 6.0 ± 0.8‰) with a C₃-based diet. Smaller Δ¹³Capatite-collagen spacing suggests that both the carbohydrate and protein components of diet are derived from either C₃ or C₄ resources, but not a combination of the two. This appears to have been the case for both the modern wild turkeys and the Tijeras turkeys with a C₄-based diet.

In contrast, Tijeras turkeys with apatite and collagen δ¹³C values indicative of a diet rich in C₃ resources have significantly larger Δ¹³Capatite-collagen spacing (+9.0 ± 2.8‰), suggesting that the ultimate source of protein and carbohydrates for these birds included a combination of C₃ and C₄ resources. Such a pattern could arise if turkeys were used for insect control in agricultural fields where they had access to protein sources that were largely C₃-based while also being fed C₄ carbohydrates (i.e., maize). Comparison of our data with the protein regression lines developed by Kellner and Schoeninger (2007) supports this hypothesis. The C₃ Tijeras turkeys plot separately from the modern ones but largely cluster along the C₃ protein regression line (Fig. 4). Our data therefore suggest the Tijeras turkeys with a C₃-based diet may have been free-ranged—the first documentation of this ethnographically reported pattern in the archaeological record.

These data thus indicate two distinct turkey husbandry regimes at Tijeras Pueblo: one in which turkeys were likely fed maize and another in which turkeys were free-ranged. While fine-grained chronological data are not available for these samples, the relatively short occupation range of Tijeras (~125 years) suggests that temporal shifts in husbandry practice are not responsible for the variation in δ¹³C and δ¹⁵N patterns among these turkeys. What chronological data are available show no discernable temporal trend (Table 3).

The Tijeras turkeys therefore represent a departure from previously identified husbandry practice in the prehistoric Southwest in two ways: the practice of maintaining free-ranging birds, and the presence of two distinct husbandry patterns (Kellner et al., 2010; McCaffery et al., 2014; Rawlings and Driver, 2010). But why is Tijeras different? While we do not have sufficient evidence at this point to definitively answer this question, our comparative data (Fig. 2b) in combination with data from previous studies (Fig. 2) are suggestive.

Earlier, we suggested that turkeys from marginal locations—whether the marginality was due to environmentally posed challenges involved with maize production and/or to cultural differences—would be more likely to have been husbanded in variable ways. While our study did identify variability, we did not find evidence clearly supporting the marginality hypothesis. All of the Chamilas Pueblo turkeys (n = 11) indicated a C₄-dominated diet, while most (n = 5) of the Gallina samples produced values consistent with a C₃-based wild diet. While at first glance this might seem to support the environmental marginality hypothesis, as both the Gallina region and Tijeras are high-elevation while Chamilas is located along the Rio Grande, δ¹³C data from turkeys of Arroyo Hondo Pueblo (Fig. 3b; Conrad et al., this volume) suggest otherwise. Arroyo Hondo Pueblo is also located at a high elevation (2,161 m) and like Tijeras Pueblo and the Gallina sites would have been subject to variability in the length of the growing season (Lang and Harris, 1984; Wetterstrom et al., 1986). Despite this, δ¹³C values of Arroyo Hondo turkeys are consistent with a C₃-based diet. Environmental marginality may have played a role in why some of the Tijeras turkeys consumed a C₃-based diet, but it does not seem to be the only driver of this pattern.

However, the location of Tijeras Pueblo may still be important in understanding the turkey isotope data. Tijeras lies along a pass through a mountain range that divides the Eastern Pueblo cultural region from that of the Plains (Fig. 1), and thus along a travel route that may have been an important conduit of Plains–Pueblo exchange (e.g., Speth, 1991; Spielmann, 1991; Wilcox, 1991). Indeed, other aspects of the Tijeras assemblage, such as the presence of buffalo (Bison bison) and pronghorn (Antilocapra americana), provide evidence of such contact (Cordell, 1980b; Jones and Gabe, 2015). Perhaps the variability in turkey husbandry observed at Tijeras relates to its location on a cultural boundary—whether through the import of turkeys from other regions and/or different clan or family groups with distinct traditions of turkey husbandry. That we also identified turkeys with a C₃-based diet in the Gallina region provides some support for the cultural boundary interpretation, as Gallina peoples also inhabited a cultural boundary, albeit a very different one (e.g., Constan, 2011).

A final point of discussion concerns the combined isotope and aDNA results. Our δ¹³C data show two distinct groups with no overlap. Initially, we assumed that in such a situation, a turkey with a δ¹³C value indicative of a C₄-based diet would reliably identify a member of the southwest domesticate lineage, and conversely, turkeys with δ¹³C values suggesting a C₃-based diet would signify wild Merriam’s turkeys. The aDNA data presented here falsify this hypothesis. The majority of turkeys with a C₃-based diet sampled for aDNA (n = 4) were members of the most common southwest domesticate lineage (aHap1). While one sample had an aHap2 lineage, and thus is a member of the less frequently observed mitochondrial haplogroup H2, there is little reason to believe that these turkeys were wild based on DNA alone (Lipe et al., 2016). This specimen had δ¹⁵N values similar to the other Tijeras turkeys with a C₃-based diet.

The aDNA findings are significant in part because they suggest δ¹⁵N data cannot be used as a proxy for a turkey’s mitochondrial DNA lineage, at least not among Southwestern turkeys, without significant additional data. However, these data also open up larger questions: if the Tijeras turkeys that consumed a C₃-based diet but were genetically domestic
were “free-range,” why were only some turkeys raised in this way? Why has this practice only been recorded at Tijeras Pueblo? Does the variability in apatite $\delta^{13}C$ and $\delta^{15}C_{\text{apatite-coll}}$ in this sample indicate that some turkeys were free-ranging and others more feral? More research is required to understand variability in turkey husbandry practices in the prehistoric Southwest.

6. Conclusions

The data presented here demonstrate that there was heterogeneity in turkey husbandry practices in the prehistoric American Southwest. Our sample from Tijeras Pueblo produced two groups with distinct $\delta^{13}C$ values, and this pattern cannot be adequately explained by time. Neither is the pattern explained by membership in one or another mitochondrial DNA lineage: all but one of the specimens sampled for aDNA were identified as members of the most common southwestern domestic turkey lineage (aHap1, Speller et al., 2010). Our comparative samples from other potentially marginal locations add to this heterogeneity: turkeys from Chimalo Pueblo adhered to the previously established turkey husbandry pattern (i.e., Fig. 2) with all samples indicating a C$_2$-based diet, while the turkeys from the Gallina region had a C$_4$-based diet. Although our study does indicate heterogeneity in turkey husbandry, the factors driving this variability remain uncertain. Marginality may play some role, but this hypothesis is not well-supported by the data presented here and in Conrad et al. (this volume). Site location along cultural boundaries seems a more likely driver, but why this should be important remains unresolved. In short, more data are needed to fully answer the questions we have raised here. We can conclude with certainty, however, that turkey husbandry practices did vary in the prehistoric American Southwest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2016.05.051.

References


