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Paleodiet of Turkeys (*Meleagris gallopavo*) in the Early Pueblo Period of the Northern Southwest

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Turkey domestication in the northern Southwest is not clearly defined, in part because wild turkeys are difficult to differentiate from domestic turkeys based on skeletal morphology. Stable isotope analysis is a method that researchers have used extensively to help build a picture of how turkey populations were managed by humans. Earlier evidence for C_4 plant consumption by turkeys is limited to a small number of published studies. Using a stable isotope mixing model with a sample of 19 turkey bones from five early Pueblo habitation sites in northwestern New Mexico and southwestern Colorado, we estimated that the turkey diet consisted of 60–89% C_4 plants, with the remainder consisting of C_3 plants and invertebrates. This contributes to the existing body of data on turkey diet in the northern Southwest during the Basketmaker III and Pueblo I periods and shows that a mixing model can be useful for turkey paleodietary analysis.

La domesticación de pavos en el norte del suroeste no está claramente definida, en parte porque los pavos salvajes son difíciles de diferenciar de los pavos domésticos basándose en la morfología esquelética. El análisis de isótopos estables es un método que los investigadores han utilizado ampliamente para ayudar a construir una imagen de cómo los humanos manejaban las poblaciones de pavos. la evidencia anterior del consumo de plantas C_4 por parte de los pavos se limita a una pequeña cantidad de estudios publicados. Usando un modelo de mezcla de isótopos estables con una muestra de 19 huesos de pavo de cinco sitios de habitación de los primeros Pueblo en el noroeste de Nuevo México y el suroeste de Colorado, estimamos que la dieta del pavo consistía en 60 a 89% de plantas C_4, y el resto consistía en plantas C_3 y invertebrados. Esto contribuye al conjunto de datos existentes

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sobre la dieta del pavo en el suroeste del norte durante los períodos Basketmaker III y Pueblo I y muestra que un modelo de mezcla puede ser útil para el análisis paleodietario del pavo.

KEYWORDS Turkey (Meleagris gallopavo), domestication, isotope analysis-mixing model Basketmaker III, Pueblo I, C_4 plants, northern Southwest

Introduction

The use and domestication of the turkey in the American Southwest has recently been a topic of substantial archaeological interest. A proliferation of scientific information about the birds' economic and ritual role in early Pueblo societies, as well as their genetic origins, has led to a clearer picture of the lifeways and cultural evolution of the ancient people of the Southwest. However, the timing of turkey domestication in the northern Southwest is not well understood because wild turkeys are difficult to differentiate from domestic turkeys based on skeletal morphology (Speller 2009).

Stable isotope analysis is a method that researchers have used extensively to try to understand turkey domestication and management. A C_4-based diet (consisting of maize or amaranth) has been interpreted as an indicator of close proximity to humans for at least the last year of a turkey's life (Hard, Mauldin, and Raymond 1996; Lipe et al. 2016; Matson and Chisholm 1991; McCaffery et al. 2014; Rawlings and Driver 2010), although such a diet is neither necessary nor sufficient to infer domestication (Jones et al. 2016; Lipe et al. 2016). This paper presents the results of stable isotope analysis on a sample of turkey remains from five early Pueblo habitation sites in the northern Southwest (northwestern New Mexico and southwestern Colorado).

The chronological periods represented by the samples in this study, referred to in this paper as the early Pueblo period, range from Basketmaker III to Pueblo II (A.D. 500–1050) as defined in the Pecos Classification or Late Archaic and Developmental in the Northern Rio Grande Classification, as well as other regional chronologies (Gumerman and Olson 1968; Kearns 2007; Kidder 1927; Wendorf 1954; Wendorf and Reed 1955). Most of the samples date to the early part of the Pueblo II period or earlier periods. Additional components are represented on some of the sites in the sample (i.e. later Pueblo II/III and Navajo components), but we practiced careful consideration of context to confirm we did not test turkey remains from these later periods. These later components are not discussed in the Study Area and Sample section below.

Previous stable isotope (Lipe et al. 2016; McCaffery et al. 2014; Rawlings and Driver 2010) and coprolite (Nott 2010) studies indicated that turkeys consumed primarily C_4 over a long period (Basketmaker II through Pueblo III) and in many locations. However, while there is an abundance of data associated with later (post A.D. 700) periods, the earlier evidence for C_4 consumption by turkeys is limited to a small sample. The purpose of this study is to increase the sample size of paleodietary information from turkeys deposited at early Pueblo habitation sites in the northern Southwest. This will expand the available paleodietary data from early periods to include sites around the San Juan Basin and Northern Rio Grande, to help describe the nature of turkey use in these communities.

Background

The early Pueblo period in the northern southwestern U.S. brought significant increases in social complexity comparable to the Neolithic revolution in the Old World (Kohler et al. 2008). By roughly the sixth century A.D., residents of the northern Southwest began living an increasingly sedentary lifestyle and becoming more reliant on agriculture as their primary subsistence strategy. New tools and crops were introduced to the northern Southwest including trough metates and beans (Reed 2000). Small amounts of turkey remains are also found in the faunal assemblages of habitation sites during this period (Aasen 1984; Kearns 2007; Miller 2016; Munro 1994; Nickens and Hull 1982; Potter 2010; Reed 2000; Young and Herr 2012).

In cases where early Pueblo settlements were established near turkeys' natural range in mountainous, well-watered areas (Schorger 1966:177–178; Spicer 1959:24), it is conceivable that wild turkeys would have wandered near the villages to feed. In modern times, wild turkey encroachment, and even aggression, is common, particularly in suburban neighborhoods (Arnold 2006). Therefore, wild turkeys probably would not have been shy about feeding on food sources near human settlements in ancient times, including maize, perhaps in the form of refuse – Greene et al. (2010) showed that modern turkeys in Illinois consumed waste grain but not living maize plants. Thus, in the early Pueblo period, a rudimentary form of domestication in which turkeys benefited from humans without humans benefiting from turkeys (commensalism) could have developed. Fully domesticated turkey (i.e. supported by and kept within the household) would have been established only after humans intentionally kept and exploited the animals (Vigne 2011; Zeder 2006).

Some aspects of southwestern turkey use have been brought to light by archaeological studies particularly in the last few years. These include a number of stable isotope, ancient DNA, coprolite, and faunal bone analyses on turkey remains recovered from dozens of archaeological sites. As a result, there is now a corpus of evidence pointing to several characteristics of turkey use by early Pueblo people. These characteristics include: that southwestern turkeys likely derived from native North American turkey populations (Speller et al. 2010), genetically separate from the turkeys in Mesoamerica that were domesticated ca. A.D. 100 (Aurelie et al. 2018; Thornton et al. 2012); that their eggs were incubated and hatched *in situ* in some cases, but consumed or broken without hatching in others (Beacham and Durand 2007; Conrad et al. 2016); that many of the turkeys were eaten, but others were used for their feathers (Fothergill 2016; Lipe et al. 2020; Munro 1994; Webster 2008); that they became an increasingly important source of dietary protein, replacing artiodactyls in the northern Southwest in the 12th and 13th centuries (Badenhorst and Driver 2009); and that they fed on maize (Jones et al. 2016; Lipe et al. 2016; McCaffery et al. 2014; Rawlings and Driver 2010).

Mitochondrial DNA (mtDNA) analysis has proved useful for understanding the genetic origins of southwestern turkeys used by Pueblo people. In an analysis of turkeys from 38 archaeological sites across the Southwest, Speller et al. (2010) identified two haplogroups based on single nucleotide polymorphisms in mtDNA: one that had undergone a genetic bottleneck that was part of a maternal lineage distinct from any wild turkey populations (H1), and one that was more closely related to the local Merriam's wild turkey (H2). Kemp et al. (2017) further validated the existence of these haplogroups, obtaining mtDNA results from 127 samples of turkey from the Central Mesa Verde (CMV) and Northern Rio Grande (NRG) regions, and identifying the same maternal lineages as those identified by Speller et al. (2010). The Kemp study also provided evidence for the migration of early Pueblo people from the CMV to the NRG based on the distribution of turkey haplogroups in each region before and after the abandonment of the CMV ca. A.D. 1280. Importantly, they demonstrated a method by which ancient turkeys can be used as a proxy for the activities of human groups when it may be difficult to obtain permission for destructive analysis of human bone. One of the turkeys in our study (LA265 FS 1016) was included in the 2017 DNA analysis and was placed within the H1 haplogroup.

The apparent relationship of the H2 haplogroup to local wild turkeys, and the genetic bottlenecking of the H1 haplogroup, seem to suggest two populations of turkeys: a "wild" and "domestic," both of which are found in the archaeological record in many temporal and geographic contexts. However, Lipe et al. (2016) conducted a joint stable isotope/mtDNA analysis of turkeys from the Mesa Verde region, showing both haplogroups to have similar maize-based diets, and that both were found in "ritual" contexts such as interments. They suggested, therefore, that understanding H1 and H2 to be domestic and wild groups (respectively), would be an oversimplification. Moreover, Jones et al. (2016) found examples of C_3–fed turkeys that were in the H1 haplogroup. Therefore, neither paleodietary information nor haplogroups can identify turkeys that are wild or domesticated. To build the picture of turkey management and evolution over time, it is important to use multiple types of data.

Currently, the data on early Pueblo period turkey diet are limited to a small sample. To our knowledge, the only evidence of turkeys predominately consuming C_4 plants (maize or amaranth) before the Basketmaker III period (before A.D. 500) is coprolites from Basketmaker II contexts at the Turkey Pen Site (42SA3714) in southeastern Utah. These turkey droppings were found to contain a similar amount of maize pollen to what was found in human coprolites from the same site, as well as pollen from several other plant species (Nott 2010). Currently the only evidence of turkeys consuming maize in the Basketmaker III period (A.D. 500–700) outside of this study is a stable isotope analysis of turkeys from the Croom Site (42SA3701), located 8 km from the Turkey Pen Site. This analysis indicated a highly maize-based diet in five specimens (Lipe et al. 2016).

Study Area and Sample

Turkey skeletal remains analyzed in the study were recovered from early Pueblo contexts from five habitation sites/locales in northwestern New Mexico

(LA4487, NM-Q-14-278/LA168938 and NM-Q-14-302/LA174838, LA4169, and LA265) and southwestern Colorado (LA4195). The sample of 19 turkey specimens were recovered from a variety of contexts during compliance excavations for a reservoir, water pipeline, state highway, and interstate from six archaeological sites representing five early Pueblo habitation locales: Sambrito Village (LA4195), Oven Site (LA4169), Tohlakai Hamlet (NM-Q-14-278/LA168938 and NM-Q-14-302/LA174838), Bi'Chilly Village (LA4487), and LA265 (see Figure 1). We intentionally selected bones that represented different individuals. Their frequencies from each site are presented in Table 1. The sites and features included in this study date to the early Pueblo period, which is defined in this study as dating to approximately A.D. 500–1050; the dating of these features is discussed in the methods section below. These sites represent several distinct cultural regions (as defined by archaeologists) that include the San Juan Basin (Stuart and Gauthier 1988), Upper San Juan (Piedra District) (Eininger et al. 1982), and Northern Rio Grande (Crown, Orcutt, and Kohler 1996). The sites are currently on Navajo Nation, Pueblo of Cochiti, and Bureau of Reclamation lands.

Bi'chilly Village. Bi'Chilly Village (LA4487) consists of several roomblocks and well over a dozen associated pit houses representing a Pueblo I village situated on a butte at the head of Manuelito Canyon in the Puerco River Valley. The site was initially identified in 1957 and a portion of the site was excavated in 1961

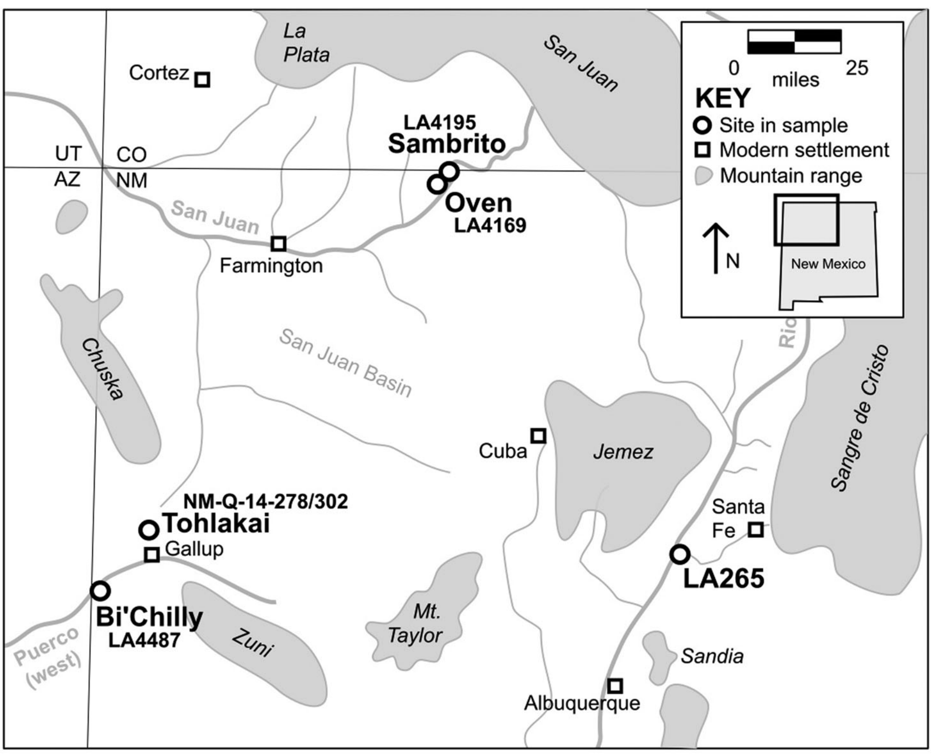

FIGURE 1. Map showing excavated sites that yielded the study sample.

to mitigate impacts from the construction of Interstate 40 (I-40) (Sciscenti 1962). A total of eleven pit houses and fifteen surface rooms were identified (all but one pit house was excavated) that comprise one locus of the larger village. This village comprises one of the largest, if not the largest, villages in the Puerco Valley during this time (Throgmorton 2012). The two turkey samples tested in this study were recovered from the fill of two residential pit houses.

Tree ring dates recovered from the Feature 1 pit house during the 1961 excavations suggest this locus of the site (including the Feature 4 pit house that exhibited similar architecture and contained similar ceramics, primarily Lino Gray, White Mound, and Woodruff Smudged) dates to the first half of the ninth century (White Mound phase), approximately A.D. 816-840s (Bannister, Robinson, and Warren 1970). The turkey remains were recovered from the general pit house fill of both Features 1 and 4.

Tohlakai Hamlet. Tohlakai Hamlet (NM-Q-18-278/LA168938 and NM-Q-18-302/LA174838) consists of a late Basketmaker III hamlet situated on the southern edge of the Chuska Valley, located just north of and below Tohlakai Hill (Miller 2016). The site occupies a bench and terrace above an unnamed wash that drains northeastward into Dye Brush Wash. The site consists of at least three residential pit houses with associated extramural storage structures and pits that represents a small hamlet within the larger Tohlakai community. A portion of this site was excavated in 2012–2013 as part of the Navajo-Gallup Water Supply Project (NGWSP). Recovered bones that comprised the sample in this study included one sample from NM-Q-18-302/LA174838 on the floor of a residential pit house (articulated turkey remains intentionally placed on the floor prior to abandonment) and four samples from NM-Q-18-278/LA168938 (two from the floor of a residential pit house [disarticulated remains that appeared to represent casual discard, not a formal placement of articulated remains], one from the upper fill of a storage pit structure, and one from the upper fill of a residential pit house).

None of the wood beams recovered from the pit houses submitted for dendrochronological analysis yielded dates. Ceramics were the primary means of relative dating the Basketmaker III occupation of Tohlakai Hamlet based on the ceramics recovered from the pit house floors, floor fill, and upper fill. Over six thousand sherds were

TABLE 1.

TURKEY BONE FREQUENCIES AND CONTEXT

Site Name	Site No.	Frequency	Date	Region
Bi'Chilly Village	LA4487	2	AD 816-840s	San Juan Basin (NM)
Tohlakai Hamlet	NM-Q-18-278/LA168938 NM-Q-18-302/LA174838	5	AD 600–725	San Juan Basin (NM)
Sambrito Village	LA4195	6	AD 700–1050	Upper San Juan (NM)
Oven Site	LA4169	4	AD 500–750	Upper San Juan (CO)
N/A	LA265	2	AD 700–900	N Rio Grande (NM)
Total		**19**	**AD 500–1050**	**Northern Southwest**

recovered, mostly representing Basketmaker III plain wares. The consistent presence of La Plata Black-on-white, the lesser amounts of brown wares and early polished gray ware (Obelisk Gray), and the absence of Tohatchi Red-on-brown indicated a Tohatchi phase occupation (A.D. 600-725). There are well-dated assemblages that have been recovered from similar contexts elsewhere in the Chuska Valley (Goetze and Mills 1993; Reed and Hensler 1998; Wilson 1989; Windes 1977). Though a small Pueblo II roomblock is just west of the pit houses where the turkey remains were recovered, the context of the turkey remains submitted for analysis as part of this study are evidently associated with the Basketmaker III (pre-A.D. 725) occupation, based on the association of Tohatchi-phase sherds found in the same levels as the turkey remains. This Tohatchi-phase occupation consisted of a small hamlet/homestead likely associated with farming along the drainage immediately east.

Sambrito Village. Sambrito Village (LA4195) consists of a Basketmaker III – Pueblo II (Sambrito to Arboles phase [late Pueblo I/early Pueblo II], primary occupation in the Piedra phase) aggregate of residential pit houses situated on the west bank of the San Juan River in the Navajo Reservoir District. The site occupies a bench above the floodplain at the junction of Sambrito Creek and the San Juan River. The site was excavated in 1960–1963 as part of the Navajo Reservoir Project (Eddy 1966) and consists of 38 pit houses, 25 surface structures, 28 exterior pits, 13 dog burials, and 25 inhumations. Six turkey samples were tested for this study that were recovered from the fill, bench fill, and ventilator from several pit houses. Pit houses that contained the turkey remains used in this study were dated to approximately A.D. 700–1050, with most of the features indicating association with the Piedra phase (Table 2; Dean Wilson, personal communication). No ceramics from Feature 8 were available for analysis.

The Oven Site. The Oven Site (LA4169) consists of a Basketmaker III and late Pueblo I/early Pueblo II (Sambrito and Piedra phases) hamlet situated on the east bench of the San Juan River in the Navajo Reservoir District. The site is located

TABLE 2.
OBSERVED CERAMICS FROM SAMBRITO VILLAGE (LA4195)

Feature No.	Phase	Date Range	Ceramic assemblage
6	Rosa/ Arboles	AD 700–1050	Abundant Arboles, Piedra B/w, Piedra and Rosa Gray, Red Mesa, Abajo (few)
8	–	–	–
11	Piedra	AD 800–950	Abundant Piedra B/w and Gray, few Abajo and Arboles Gray
17	Piedra	AD 800–950	Piedra Gray and Piedra B/w, <10% Arboles Gray and Arboles Neckbanded
40	Piedra/Rosa	AD 700–950	Abundant Piedra Gray, Piedra and Rosa B/w, <20% Arboles Neckbanded
71	Piedra	AD 800–950	Abundant Piedra and Rosa Gray, Piedra B/w, few Rosa Neckbanded and Arboles Gray

on the crest and north flank on an east–west trending ridge of a bench along the river. The site was originally excavated in 1962–1963 as part of the Navajo Reservoir Project (Eddy 1966). This excavation revealed five pit houses, a surface structure, 45 exterior pits, 22 dog burials, and 12 inhumations. Later excavations occurred on the Peccary Pit Locus of the site in the late twentieth century (Mabry 2000), but samples included in our study were not recovered from this fieldwork.

Turkey remains tested for this study consisted of four samples from a pit houses (n=1) and extramural pits (n=3). These features were dated to the Sambrito period (A.D. 500–700), possibly in the late Sambrito period (post-A.D. 600). The ceramic assemblage from Feature 32 consisted of 16 Chapin-Rosa Gray sherds with one piece of Chapin Black-on-white. Feature 34 yielded five Rosa-Chapin Gray sherds (Dean Wilson, personal communication).

LA265. LA265 is a large Early Developmental (A.D. 600–900) habitation locale situated on a Pleistocene terrace just south of the confluence of the Santa Fe River and Rio Grande. New Mexico Office of Archaeological Studies (OAS) excavated the site to mitigate effects associated with the expansion of New Mexico State Route 22 (Chapman and Sheppard 2012). The excavations revealed three residential pit houses, two pocket pit structures, two seasonal workspaces or pit houses, and numerous other extramural features. Turkey remains analyzed as part of this project were recovered from the upper fill of Structure 1 (SU1) and a turkey burial in an extramural pit (Feature 15/19, SU3).

Archaeomagnetic, radiocarbon, and ceramic analyses of assemblages associated with these contexts suggest an early Developmental period occupation (AD 600–900). Feature 1 yielded an archaeomagnetic date around A.D. 820–900, 2-sigma calibrated radiocarbon date ranges of A.D. 530–890 and AD 690–1240, and a ceramic assemblage primarily consisting of Middle Rio Grande plain ware. The adjacent pit house to Feature 15/19 yielded an archaeomagnetic date range of AD 780–825 and the ceramics we also primarily Middle Rio Grande plain ware. Corn pollen was recovered from the stomach area of the turkey burial in Feature 15/19 (Chapman and Sheppard 2012, 69–70).

The turkey burial in the extramural pit (LA265 FS 1016) was subjected to mtDNA analysis during a previous study of turkey genetics (Kemp et al. 2017). That analysis yielded a partial mtDNA sequence that placed this turkey in the "aHap1" haplotype or lineage. However, due to the incompleteness of the mtDNA sample, that turkey could also belong to one or more derived lineages.

Methods

The maize plant uses C_4 carbon fixation instead of C_3 carbon fixation, resulting in an elevated level of stable isotope ^{13}C relative to many plants native to temperate climates (Tykot 2020). Thus, enriched $\delta^{13}C$ in ancient bone collagen is interpreted as a signal for prehistoric maize consumption by humans and animals in the temperate parts of North America (Hard and Anne Katzenberg 2011; van der Merwe and Vogel 1978; Watts, White, and Longstaffe 2011) and the Southwest (Coltrain, Janetski, and Carlyle 2007; Spielmann, Schoeninger, and Moore

1990). In the Southwest there are, in addition to maize, indigenous plants with enriched $\delta^{13}C$ levels. Amaranth, which is indigenous to the Southwest and was also cultivated prehistorically (Cordell 1997), is a C_4 plant. There are also indigenous geophytes such as agave, prickly pear, and yucca that were consumed by humans prehistorically (Cordell 1997:31). These plants (CAM plants) use Crassulacean Acid Metabolism and have $\delta^{13}C$ values intermediate between those of C_3 and C_4 plants (Tykot 2006:132–133). The C_4 signatures observed in ancient Pueblo people and turkeys of the Southwest are likely driven by maize consumption given the importance of maize in farming communities in the early Pueblo Southwest, but could also be caused by amaranth and geophyte consumption. In this paper we refer to a C_4 diet component as C_4, maize/ C_4, or maize and/or amaranth.

The ratio of ^{13}C to ^{12}C is expressed using δ notation to indicate deviation in per mil (‰) from the Vienna Pee Dee Belemnite (VPDB) fossil. The standard used for $^{15}N/^{14}N$ ratios is atmospheric nitrogen (AIR) (van der Merwe 1982:598). Bone collagen $\delta^{15}N$ is influenced by many dietary factors including meat/vegetable ratio, consumption of nitrogen-fixing plants such as legumes, marine vs. terrestrial food sources (Schoeninger and DeNiro 1984), and non-dietary factors including heat stress (Ambrose 1991:299). The concentration $\delta^{15}N$ is useful in dietary reconstruction because, like $\delta^{13}C$, it is enriched as nitrogen is transferred up the food chain, and varies among species and environments. Global averages place plants at the lowest end of the range, followed by herbivores and then carnivores, increasing by about 3–4‰ with each trophic step (Ambrose 1991:297).

We conducted stable isotope analysis on 19 turkey specimens from five prehistoric habitation locales in northwestern New Mexico and southwestern Colorado. The turkey samples tested for this study are curated with the Museum of Indian Arts and Culture (MIAC) at the Center for New Mexico Archaeology (CNMA) Archaeological Research Collections (ARC) in Santa Fe, New Mexico and at PaleoWest Archaeology's Farmington, New Mexico laboratory. The turkey remains from PaleoWest's laboratory have since been reburied at the direction of the Navajo Nation Heritage and Historic Preservation Department (NNHHPD). Permits and permissions for the destructive analysis of our sample were obtained from the NNHHPD, Pueblo of Cochiti, the United States Department of the Interior Bureau of Reclamation, and the MIAC Collections Committee. The samples were analyzed by Dr. Robert H. Tykot at the Laboratory for Archaeological Science at the Department of Anthropology, University of South Florida (USF), Tampa, Florida. Funding was obtained from the PaleoWest Foundation.

Only collagen (not bone apatite) was analyzed for this study. Given limited funding, it was necessary to analyze only one bone component to maximize the sample size of turkeys. The reason for choosing collagen instead of apatite is that collagen has been more commonly used in other studies when only one bone component was reported (Kemp et al. 2017; Lipe et al. 2016; Morris et al. 2016; Rawlings and Driver 2010). By examining only collagen, the analysis is focusing on the protein component of the turkey diet, rather than the overall diet which is reflected by isotope ratios in bone apatite (Ambrose and Norr 1993). Maize is not a particularly high-protein food source compared to wild turkeys' diets, so a strong C_4 signal in collagen could indicate direct management of the turkeys' diet by humans, as it would suggest that a high proportion of their dietary protein came from maize.

Collagen samples were prepared using well-established practices (Ambrose 1990; Tykot 2004, 2020). Bone samples of 1–2 grams were placed in 0.1 M NaOH for 24 hrs to remove humic acid contaminants. Samples then were demineralized with 2% HCl, replaced daily for 72 hrs. This was followed by a second 24 hr treatment of 0.1 M NaOH. Finally, the samples were treated with a 2:1:0.8 defatting mixture of CH_3OH, $CHCl_3$, and water to remove any lipids. Dried and weighed pseudomorph samples of 1 mg were analyzed for $\delta^{13}C_{co}$ and $\delta^{15}N$ with a CHN analyzer connected to a Finnigan MAT Delta Plus stable isotope mass spectrometer in the Paleolab facility at USF. Reliability of the isotope results was confirmed through visual assessment, measurement of collagen yields, and C:N ratios from the isotope analysis. All of the samples tested in this study had sufficient collagen yields, and C:N ratios between 3.2 and 3.5, well within the accepted range. The analytical precision is ± 0.1‰ for $\delta^{13}C_{co}$, reported with respect to the VPDB standard, and ± 0.2‰ for $\delta^{15}N$, reported with respect to AIR.

Most of the remains were recovered from the upper fill and floor fill of residential pit houses. Few remains were recovered from extramural pits and a storage structure. Because no radiocarbon or dendrochronological dates were recovered from most of the features included in this study, determining the chronology of the site and features proved difficult. Temporal affiliation of these features, and therefore the turkey remains recovered within them, was estimated through relative means via the ceramic assemblage. Three features where turkey remains were recovered were dated through dendrochronological, archaeomagnetic, and radiocarbon analysis (LA4487-1-1, LA265 FS 1011, and LA265 FS 1016) (Bannister, Robinson, and Warren 1970; Chapman and Sheppard 2012). The remainder of the features that were not dated by direct means were analyzed by Dean Wilson at the Center for New Mexico Archaeology (CNMA) in Santa Fe. Analysis of the ceramic assemblage recovered from NM-Q-18-278/LA168938 and NM-Q-18-302/LA174838 occurred at the Office of Archaeological Studies (OAS) as part of the Navajo-Gallup Water Supply Project (NGWSP) in 2013 (Miller 2016). Ceramic analysis of selected features from LA265, LA4169, LA4195, and LA4487 occurred at the Archaeological Research Collection (ARC) in 2018–2019 and its completion was directly related to this study (Dean Wilson 2019, personal communication).

Statistical Analysis

Estimating turkey diet using bone collagen stable isotope concentrations requires information about the isotopic concentrations of dietary components and the fractionation of those isotopes when they are consumed and incorporated into the collagen. Typically, the expected collagen isotopic signatures for C_3 and C_4 plants are based on their average $\delta^{13}C$ values of −26.5‰ and −12.5‰ (Tykot 2006). Some quantity for the diet-to-bone collagen fractionation is added, which for various species diets, and conditions, may range from +2.8 to +5.3‰ (DeNiro and Epstein 1981; van der Merwe and Vogel 1978). One study suggests fractionation may be lower for birds than mammals (Hobson and Clark 1992). In the Southwest, these estimates are used to broadly classify ancient humans and turkeys as C_3, C_4, or mixed feeders. However, the stable isotope concentrations in plant life and fractionation to bone collagen vary considerably; therefore, a more rigorous method for estimating the diet is desirable.

In order to estimate the actual proportion of maize/C_4 in ancient turkey diet, we took into account the uncertainty around $\delta^{13}C$ and $\delta^{15}N$ in turkey food sources, and their fractionation to bone collagen, using a Bayesian mixing model. We used R version 4.0.2 (R Core Team 2020) and the package *simmr* version 0.4.2 (Parnell 2020). This model uses Markov Chain Monte Carlo (MCMC) sampling to calculate the posterior distributions for the proportion of the diet that is composed of dietary components. This type of model is frequently used in the biological sciences, but its use in archaeology of the southwestern United States is limited to a small number of studies (Coltrain and Janetski 2013). To our knowledge, stable isotope mixing models have not been used in studies of ancient turkey diet in the Southwest.

A key assumption of a stable isotope mixing model is that some aspects of the animal's diet are known *a priori* (Phillips et al. 2014), so we were careful to postulate a plausible diet for ancient turkeys. Wild turkeys are known to feed on a wide variety of grasses, nuts, acorns, berries and seeds, invertebrates (insects, arachnids, and snails), and small reptiles (Munro 1994; Schorger 1966; Stearns 2010). Invertebrates play a key role in the diet, making up a majority of the diet for poults; as turkeys grow to adulthood they shift to eating primarily plant matter. Juvenile and adult wild turkeys have diets that are 73–85% plant matter with the remainder made up mostly of invertebrates, according to some studies (Hurst 1992). The archaeological turkeys of this study likely had access to different types of food, even if they were primarily maize feeders. A pollen analysis of turkey coprolites at the Turkey Pen Site concluded that maize, amaranth, indian rice grass, pinyon, chenopodium, and other plants, were likely dietary components (Nott 2010). Based on this information, it is likely that the turkeys in our sample had some combination of C_4 plants, C_3 plants, and invertebrates in their diets. The invertebrates themselves may have been either C_3 or C_4 feeders, which would have affected their isotope values.

We postulated a diet consisting of four components: C_4 (maize/amaranth); C_3 (grasses, nuts and seeds); C_4 invertebrates; and C_3 invertebrates (Table 3). We calculated means and standard deviations of the stable isotope concentrations for the plant components based on published concentrations of archaeological and modern plants. For uncorrected $\delta^{13}C$ from modern samples, we added +1.65‰ to account for global ^{13}C depletion caused by modern industrial activities (Yakir 2011). Invertebrates' isotopic signatures depend on their own diets (DeNiro and Epstein 1981; Fry, Joern, and Parker 1978). We could not find sufficient published data on invertebrate isotopic values that would be appropriate to the turkeys in our study area. So to estimate the invertebrate dietary components, we shifted the values of our C_3 and C_4 plant data by the average enrichment of herbivorous insects: +1.88‰ for $\delta^{15}N$ and −0.53‰ for $\delta^{13}C$ (Spence and Rosenheim 2005). We used published experimental data to estimate means and standard deviations for diet-to-collagen fractionation (see Table 3). It is likely that some CAM plants would have been consumed by turkeys; however, Nott (2010) found little evidence for prickly pear consumption in her coprolite analysis. Given that isotopic concentrations of CAM plants such as prickly pear are intermediate between C_4 and C_3, they are not included in this model to avoid overestimating their contribution to the diet,

TABLE 3.

ESTIMATED ISOTOPE VALUES OF TURKEY DIET AND FRACTIONATION

	$\delta^{13}C$ (mean ± SD)	$\delta^{15}N$ (mean ± SD)	Species	Sources
C_4 plants	−10.20 ± 0.62	6.17 ± 2.46	Maize (*Zea mays*), amaranth (*Amaranthus sp.*)	Coltrain and Leavitt (2002); Spielmann, Schoeninger, and Moore (1990); Warinner, Garcia, and Tuross (2013)
C_3 plants	−24.10 ± 2.78	1.38 ± 3.15	Acorn nut meat (*Quercus emoryi*), chenopodium seeds (*Chenopodium sp.*), indian rice grass (*Oryzopsis hymenoides*), pinyon (*Pinus monophyla*), sagebrush (*Acer grandidentatum*), sand dropseed (*Sporobolus cryptandrus*), winterfat (*Ceratoides lanata*)	Coltrain and Leavitt (2002); Spielmann, Schoeninger, and Moore 1990; Stearns (2010)
C_4 invertebrates	−10.70 ± 0.62	8.05 ± 2.46	Herbivorous insects	Spence and Rosenheim (2005) (fractionation data)
C_3 invertebrates	−24.60 ± 2.78	3.26 ± 3.15	Herbivorous insects	Spence and Rosenheim (2005) (fractionation data)
Diet to bone collagen fractionation	3.04 ± 1.10	2.40 ± 0.82	Chicken (*Gallus gallus*), gull (*Larus delawarensis*), mouse (*Mus musculus*), Japanese quail (*Coturnix japonica*)	DeNiro and Epstein (1978); DeNiro and Epstein (1981); Hobson and Clark (1992)

which is likely to have been small. We used the default prior distributions in the *simmr* package for the proportions of the four diet components.

Results

The collagen isotopic signatures from the sample of 19 turkey elements from the five early Pueblo habitation locales are presented in Table 4. The results of the isotopic analysis of turkey bones in our sample are similar to what has been found in other similar studies in the Southwest (Jones et al. 2016; Lipe et al. 2016; McCaffery et al. 2014; Rawlings and Driver 2010). The $\delta^{13}C$ range from −14.2 to −7.0‰ with a median of −8.7‰, a strong signal for C_4 in the diet of turkeys found at these early Pueblo residential sites. Notably, the $\delta^{13}C$ values in turkeys are a bit lower than what is typically observed in humans living in the Southwest around the same time (see results from Coltrain, Janetski, and Carlyle 2007; Lipe et al. 2016; McCaffery et al. 2014); this may be due to differences in fractionation as well as differences in diet. We note here that one specimen analyzed in a previous study with a relatively depleted $\delta^{13}C$ of −18.1‰ (specimen 1042.1 from Salmon Pueblo, McCaffery et al. 2014) was published before it was discovered to have been inaccurate, when it was retested yielding a $\delta^{13}C$ of −6.7‰. The sample was likely contaminated and therefore is not included in the figures presented in this paper.

Figure 2 presents the posterior probability distributions for the proportions of each dietary component using the sample of 19 turkeys. The model suggests a majority of maize and/or amaranth in the diet (median 80.0%, 95% CI: 59.8–88.5%), and a relatively low proportion of C_3 plants (median 7.3%, 95% CI: 1.6–14.4%). The proportion of C_4 invertebrates in the diet is also low, but with a wide credible interval (median 6.6%, 95% CI: 1.0–25.9%). The proportion of C_3 invertebrates is similar to that of C_3 plants (median 5.1%, 95% CI: 1.1–12.4%). Turkeys from all sites spanning the sixth through eleventh centuries in our sample exhibited a diet rich in C_4 plants.

The lowest $\delta^{13}C$ value of −14.2‰ suggests this individual could have had a mixed C_3 and C_4 diet. This specimen (265 FS 1011) is from the Northern Rio Grande. The other sample from the Rio Grande (267 FS 1016) yielded a $\delta^{13}C$ of −7.9‰, closer to the remainder of the sample. If Specimen 265 FS 1011 did belong to a different population of turkeys with a distinct diet, it would have been inappropriate to include it in the mixing model. As a sensitivity analysis, the model was rerun excluding this specimen. This produced similar diet component estimates (median (95% CI): 83.2% (55.3%, 89.0%) for C_4 plants; 5.4% (1.3%, 10.5%) for C_3 plants; 11.8% (1.6%, 35.0%) for C_4 invertebrates; and 4.3% (1.0%, 9.3%) for C_3 invertebrates). It did not change the distributions enough to alter the main conclusions about the turkey diet.

Figure 3 presents a scatter plot of ^{13}C and ^{15}N isotopic concentration with distributions of isotope concentrations for the four diet components. The sample of turkeys from Basketmaker III, Pueblo I and Early Pueblo II contexts (this study) is closely clustered with the sample from Pueblo II and Pueblo III contexts in the Middle San Juan Region from McCaffery et al. (2014). A sample of modern wild

TABLE 4.

TURKEY BONE STABLE ISOTOPE RESULTS

FS No.	Feature No.	Element	Site No.	Site Name	Feature Type	Provenience	Date Range	$\delta^{13}C$	$\delta^{15}N$	C:N
4169-4-2	4	tibiotarsus	LA4169	Oven Site	pit house	general fill	AD 600–750	−8.2	5.5	3.5
4169-32-10	32	huge tibiotarsus	LA4169	Oven Site	extramural pit	general fill	AD 600–750	−8.2	6.4	3.4
4169-34-7	34	radius and ulna	LA4169	Oven Site	extramural pit	general fill	AD 600–750	−8.7	5.5	3.4
4169-34-8	34	tibiotarsi	LA4169	Oven Site	extramural pit	general fill	AD 600–750	−8.2	5.3	3.4
4195–6	6	tibiotarsus	LA4195	Sambrito Village	pit house	ventilator	AD 700–1050	−8.3	7.1	3.4
4195–8	8	tibiotarsus	LA4195	Sambrito Village	pit house	general fill	AD 700–1050	−9.8	7.3	3.4
4195–11	11	tibiotarsus	LA4195	Sambrito Village	pit house	fill	AD 850–950	−7.0	7.9	3.4
4195–17	17	tibiotarsus	LA4195	Sambrito Village	pit house	fill above bench	AD 850–950	−9.1	7.2	3.4
4195–40	40	tibiotarsus	LA4195	Sambrito Village	pit house	fill	AD 700–950	−7.9	7.6	3.4
4195–71	71	tibiotarsus	LA4195	Sambrito Village	pit house	fill	AD 850–950	−8.3	7.6	3.4
4487-1-1	1	humerus	LA4487	Bi'Chilly Village	pit house	general fill	AD 816–840s	−9.2	10.3	3.4
4487-52-1	4	tibiotarsus	LA4487	Bi'Chilly Village	pit house	general fill	AD 816–840s	−9.0	10.2	3.4
265 FS 1011	1	humerus fragment	LA265	N/A	pit house	upper fill	AD 800–900	−14.2	3.2	3.4
265 FS 1016	15/19	tibiotarsus & femur	LA265	N/A	extramural pit	turkey burial in large pit	AD 700s–800s	−7.9	7.5	3.4
FS64	14	tibiotarsus	NM-Q-18-302/ LA174838	Tohlakai Hamlet	pit house	turkey remains on floor	AD 600–725	−8.9	7.2	3.4
FS555	14	humerus	NM-Q-18-278/ LA168938	Tohlakai Hamlet	pit house	floor	AD 600–725	−8.1	7.0	3.4
FS265	21	tibiotarsus	NM-Q-18-278/ LA168938	Tohlakai Hamlet	pit house	floor	AD 600–725	−9.9	5.7	3.2
FS587	18	tibiotarsus	NM-Q-18-278/ LA168938	Tohlakai Hamlet	storage structure	fill	AD 600–725	−7.6	6.0	3.3
FS220	1	tibiotarsus	NM-Q-18-278/ LA168938	Tohlakai Hamlet	pit house	fill	AD 600–725	−7.4	6.6	3.3

turkeys collected by Jones et al. (2016) is differentiated from the archaeological turkeys by their $\delta^{13}C$ and $\delta^{15}N$, which are reflective of the C_3 plants and C_3-fed invertebrates native to the Southwest rather than C_4 plants and C_4-fed invertebrates.

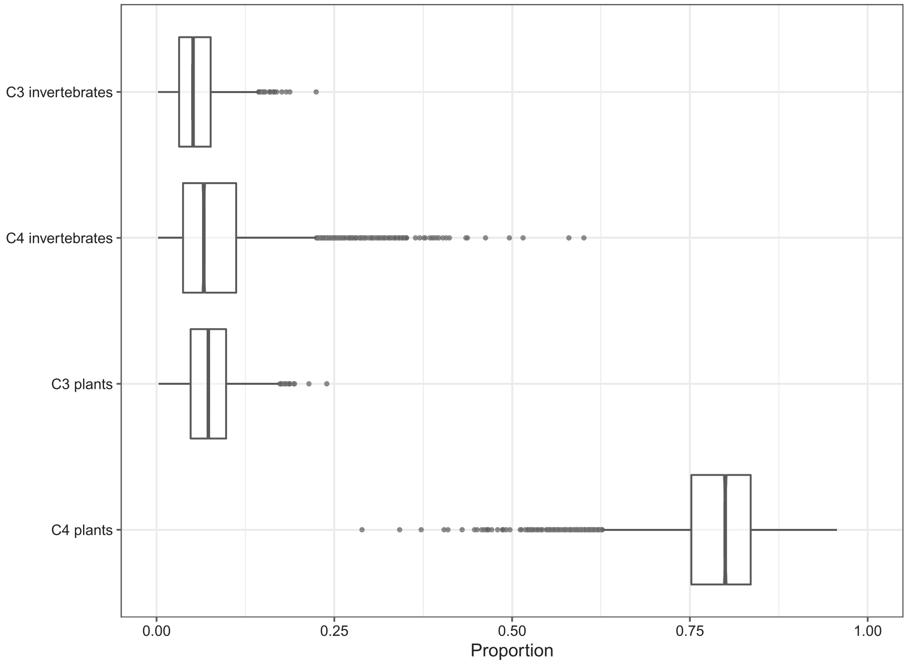

FIGURE 2. Posterior probability distributions for the proportions of each dietary component.

Conclusions

We have presented additional evidence that turkeys used by Pueblo people of northwestern New Mexico were feeding primarily on C_4 plants (most likely including maize) and C_4-fed animals prior to the intensified exploitation of large quantities of turkeys by Pueblo groups in later periods (i.e. Pueblo II/III). This increases the sample of turkeys from this early period beyond what has been done (i.e. Lipe et al. 2016), and reinforces the current understanding. C_4 plant consumption does not equate to domestication, but does indicate an interaction between turkeys and another key component of human food system: maize.

This study also demonstrates that a Bayesian mixing model can be useful for inferring the composition of ancient turkey diet. The model is not intended as a complete reconstruction of the turkey diet, as this is not possible using stable isotopes alone. Rather, it is intended to provide a probability distribution for the proportion of the components of the diet given the data and the assumptions of the model. The assumptions are that the turkey diet was composed of a combination of C_4 and C_3 plants, and invertebrates that fed on them, and that it is a sample from a homogeneous population of turkeys with a specific diet. The result is a model of the turkey diet that incorporates both $\delta^{13}C$ and $\delta^{15}N$, known isotopic values of the dietary components, diet-to-bone collagen fractionation, and uncertainty around these values, that is more rigorous than just visually inspecting a range of values to draw conclusions about the diet. Inference about the diet is likely to be more accurate when we incorporate all this information into one model.

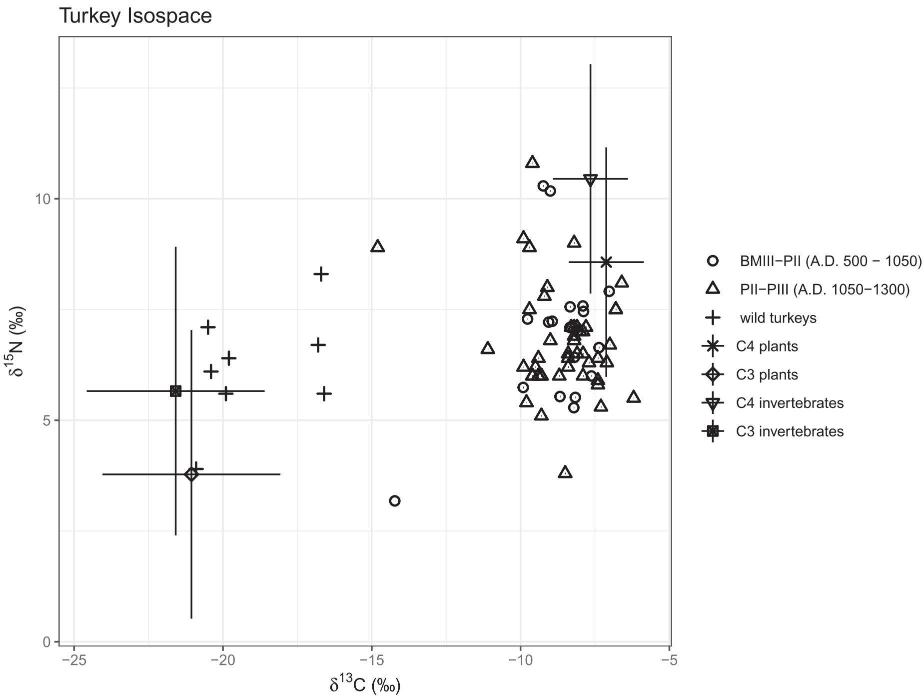

FIGURE 3. Scatter plot of ^{13}C and ^{15}N isotopic concentration with distributions of isotope concentrations.

This method also allowed us to include invertebrate animals in estimates of turkey diet. This is key for accurate turkey dietary reconstruction, but more research is needed to estimate isotopic values for these diet components. Due to the closeness of C_4 invertebrates and C_4 plant isotopic values in our model, and the somewhat small sample size, there is substantial uncertainty about the proportion of the diet made up of C_4 plants and C_4 invertebrates. It is possible that these components are difficult to tease apart using isotopic data alone. Coprolite analysis could prove useful for determining the amount of invertebrates in the turkey diet; in coprolite studies insect remains have been noted (Nott 2010) but the published analyses tend to focus on botanical elements (Lipe et al. 2016; Nott 2010).

The chronological placement of the samples in this study was imprecise. Most of the samples were dated via relative means (ceramic assemblage), with few of the samples associated with features that were dated with archaeomagnetic, radiocarbon, and dendrochronological samples. Incremental changes in C_4 consumption over time could not be explored during this study because of the relatively poor chronological control. However, most of the samples produced similar values indicating a diet primarily composed of C_4 plants and animals; therefore, tight chronological control was not necessary to define larger patterns of turkey use and management.

Future studies should examine the diets of even earlier turkeys (Basketmaker II or Archaic) to explore how turkeys were managed by humans, and whether the practices changed over time. A variety of types of data should be incorporated to understand turkey diet and biology. These can include stable isotope ratios from bone apatite as well as collagen, ancient DNA, skeletal morphology including analysis of turkey sex and age, and coprolite analysis. Leveraging this data with appropriate statistical methods, we can better describe the nature of early turkey use in multiple dimensions.

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Data Availability Statement

The data and R script used for this study are openly available at https://github.com/hmccaff/turkey and tdar.org/.

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