Title
Prehistoric Puebloan yucca (Yucca) quids with wild tobacco (Nicotiana) contents: Molecular and morphological evidence from Antelope Cave, northwestern Arizona

Journal
Journal of Field Archaeology, 40(3)

ISSN
0093-4690

Authors
Adams, Karen R
Johnson, Keith L
Murphy, Terence M

Publication Date
2015-06-01

DOI
10.1179/2042458214y.0000000006

Peer reviewed

Prehistoric Puebloan yucca (*Yucca*) quids with wild tobacco (*Nicotiana*) contents: molecular and morphological evidence from Antelope Cave, northwestern Arizona

Karen R. Adams[1], Keith L Johnson[2], Terence M. Murphy[3]

[1]Crow Canyon Archaeological Center, Cortez, Colorado, [2]California State University, Chico, California, [3]University of California, Davis, California

Correspondence to**:** Karen R. Adams, 2837 E. Beverly Dr., Tucson, AZ 85716, Email: agave@dakotacom.net

Abstract

Unburned yucca (*Yucca*) quids with wild tobacco (*Nicotiana*) contents have been preserved within Antelope Cave in northwestern Arizona. Although the cave was visited during the Archaic, Southern Paiute, and Euro-American periods, material culture remains and radiocarbon dates indicate heaviest use by the Virgin Anasazi (A.D. 1 - 1000). Quids are wads of fiber twisted or knotted into a ball for insertion into the mouth. Ten of the quids examined were clearly made from the fibers of *Yucca* plants, based on 6-7 base pairs identified via analysis of DNA sequences near the *trnL* gene of chloroplastic DNA. Twenty-seven of thirty quids examined were wrapped around a range of wild tobacco (*Nicotiana*) plant parts (capsule, seed, calyx, pedicel, main stem, leaf). Quids have been interpreted as serving various needs (food, ceremonial/ritual, other). The inclusion of tobacco and the diverse recovery contexts suggest the Antelope Cave quids provided occupants with a personal stimulant experience.

Key Words: Antelope Cave, Virgin Anasazi, quids, *Yucca* DNA, *Nicotiana* contents

Introduction

Quids are small, round to oval, and often compressed wads of fiber that have been chewed and/or sucked by prehistoric Native American peoples and then discarded. They are ubiquitous in uncharred condition in sheltered archaeological sites in the Southwestern United States, the Great Basin, Texas, and northern Mexico. Researchers who have studied quids in detail are few (LeBlanc *et al.* 2007; Reed 1978; Turner 1967; Zauderer 1975), producing examples of the kinds of studies advocated long ago by Taylor in *A Study of Archaeology* (1948). Uncharred quids have been called cuds or chews by early archaeologists (Loud and Harrington 1929; Harrington 1933; Fulton 1941). They average 3-5 cm in length, 2 cm in width and thickness, and weigh 2-3 g each, and sometimes display tooth impressions (Jones and Morris 1960: 116; LeBlanc *et al.* 2007: 163-164). Some researchers report that quids moistened by saliva when intentionally sucked can be utilized, along with cheek cells, to extract mitochondrial DNA to characterize ancient populations (LeBlanc *et al.* 2007: 163-164). The plant parts reported for quid manufacture commonly include yucca (*Yucca*) leaves, although other plants and their parts including agave (*Agave*) leaves, maize (*Zea mays*) leaves, husks, and stems (stalks), and common bean (*Phaseolus vulgaris*) stems are also cited (LeBlanc *et al.* 2007: 164; Zauderer 1975: 65). Publications generally do not report the details of quid fiber identification, particularly the difficulty in distinguishing yucca from agave fibers or tissue, with rare exceptions (Sobolik 1992).

Native American uses of wild tobacco (*Nicotiana*), on the other hand, have occupied the attention of many scholars (see Adams 1990: Table 4; Castetter 1943; Dunavan and Jones 2011; Kroeber 1941; Winter, ed. 2000). Ethnographic accounts report that a wide range of groups managed tobacco species by various means, among them: throwing the seeds in ashes of a burned mesquite tree (Spier 1928: 105); scattering seeds on a favorable spot (Whiting 1966: 16, 90); planting them in desert washes (Castetter and Bell 1942: 211); burning ground prior to planting (Setchell 1921: 411); and taking advantage of natural burns to harvest tobacco the following year (Anderson 2005; Castetter 1943: 322; Winter, ed. 2000). Archaeologists have focused on recognizing tobacco in sites and defining its cultural significance to prehistoric peoples. Previous researchers (Adams and Toll 2000:152-168; Switzer 1969) have published inventories of Southwestern sites that have yielded charred wild tobacco remains from sites occupied from the Archaic through Puebloan periods. Few reports, however, have included anatomical and morphological identification criteria, for example of *Nicotiana* plant stem fragments packed inside reedgrass (*Phragmites*) stem cigarettes (Adams 1990: 130-133). This report on Antelope Cave in far northwestern Arizona adds to that short list. A review of 24 Great Basin archaeological site publications found tobacco present in two Utah locations: (a) Radford Roost (Janetski *et al.* 2000: 188); and (b) uncharred tobacco and other plant parts from Five Finger Ridge sites in Clear Creek Canyon which researchers said might be intrusive (Talbot *et al.* 2000: 523, 557). A few sites in this sample also yielded stone or bone pipes that might have contained tobacco (eg., Aikens 1970; Heizer and Krieger 1956), but there is no clear evidence that they did.

Despite the fact that tobacco in Southwestern U. S. archaeological sites is well known, previous reports of tobacco wrapped inside *Yucca* fiber quids are very rare. Quids reported from several Basketmaker III caves in extreme northeastern Arizona contained minced up tobacco flowering stems, and in one case were associated with a ceramic jar full of tobacco parts (Jones and Morris 1960; Morris 1980).

The present study, based on specimens recovered from Antelope Cave, presents evidence of the prehistoric raw materials used to construct quids, and of the varied tobacco parts that were imbedded within them. DNA analysis confirms yucca plants as the major fiber source employed in quid production. Morphological traits indicate the majority of fragmented plant parts encased in the quids are *Nicotiana* capsules, seeds, and other parts associated with flowering stems.

Antelope Cave

Antelope Cave sheltered Ancestral Puebloan (Virgin Anasazi) groups and their predecessors many centuries ago. Located on the remote Arizona Strip at the north end of Mojave County, in the state of Arizona (FIG. 1), the site is an underground cavern on the edge of a limestone sink (FIG. 2). It is hidden under the semiarid, undulating landscape of low hills and dry washes on the Uinkaret Plateau, about 1420 m (4660 ft) above sea level. The Bureau of Land Management administers this area that today supports cattle ranching, as it has for decades. Historic overgrazing effectively changed the flora around the cave to the extent that the quantity and diversity of plant resources in prehistoric times no longer exists (Helen Fairley and Phil Geib, personal communication 1989). However, rabbits still are relatively abundant in the area and were the primary source of meat for the Virgin Anasazi who inhabited Antelope Cave.

Water availability was an important concern of the prehistoric peoples who lived on the Arizona Strip. It was especially crucial to those at Antelope Cave because the site was not close to any fresh water source. No permanent streams existed in the area, although nearby Clayhole Wash would hold water temporarily after a significant storm. The closest springs with potable water lay several km from the site.

Excavation

The interior surface of Antelope Cave (FIG. 3) is about 1700 sq m, but the eastern half is covered by huge, heavy chunks of limestone rock fall. The culture bearing deposit, between 5-184 cm thick, blankets the western half of the site including a steep sided depression or “secondary sink”, the bottom of which is about 23 m below the cave entrance (FIG. 4). While the cave has long been assaulted by vandals and looters, serious professional excavations by archaeologists from the Museum of Northern Arizona (MNA), the University of California Los Angeles (UCLA) and Brigham Young University (BYU) took place intermittently between 1953 and 1986 (see Fisher *et al.* 2013: 140-162).

Our primary focus here is on the UCLA collection of cultural materials from eight pits (FIG. 3, 4) excavated between 1956 and 1960. Because the cave is mostly dry, perishable artifacts have been preserved in excellent condition after resting safely in the soft, dusty gray midden for thousands of years. The collection consists of thousands of objects. Artifacts include arrows, sandals, basketry, nets, twine and rope, feather ornaments, gourd and ceramic vessels, quids, etc. In addition, animal bones and macrobotanical specimens, including thousands of corncobs, round out the collection. All the excavated specimens were catalogued under accession numbers 153 and 244 and are curated at the UCLA Fowler Museum of Cultural History.

Each of the eight units was dug by trowel and shovel employing, for the most part, arbitrary 6-inch (15 cm) levels. The usual methods of identifying and bagging specimens inside the cave were altered in the 1959 field season. The midden excavated in 1959 from units AC59-1 through -5 was placed in cloth level sacks and carried to a wooden box near the cave entrance. The sacks were loaded into the box and a manual operated rope pulley lifted the filled box 7.6 m up the solid limestone cave wall to a gasoline powered screen outside the cave (see Fisher *et al.* 2013: fig. 4). Here the midden was sifted through stacked ½ in and ¼ in mesh screens. This process greatly improved the recovery of cultural materials by eliminating the vision difficulties caused by the dim light and hovering, thick dust inside the cave.

Chronology

Thirteen radiocarbon dates from Antelope Cave (Fisher *et al.* 2013: Table 3) extend across 4000 years of time and help establish the sequence of four societies (Archaic, Virgin Anasazi, Southern Paiute and Euro-American) that are represented at the site. Archaic Period hunter/gatherers were the first to visit the cave around 2000 B.C. (2128-1773 CAL B.C.). Artifact evidence of their presence is skimpy and largely restricted to a few diagnostic projectile points (Pinto, Gypsum and Elko corner-notched). A date of CAL A.D. 26-331 marks the presence in Basketmaker II times of the Virgin Anasazi farmers who replaced the Archaic foragers and who occupied the cave seasonally for more than 950 years throughout Basketmaker II, Basketmaker III and Pueblo I periods. In addition to growing crops such as maize and squash, these earliest Ancestral Puebloans (Virgin Anasazi) wore square-toed fiber sandals, made string from human hair and fashioned rabbit fur blankets. By CAL A.D. 680-890 Basketmaker III traits appear in the cave deposits. These include domesticated beans, undecorated ceramics and bows and arrows. Basketmaker materials tend to cluster in the lower levels of the site. The upper levels, dated CAL A.D. 710-960, yield Pueblo I artifacts mixed with Basketmaker. Pueblo I is recognized in the cave by the appearance of black-on-gray painted pottery and round- or pointed-toed fiber sandals. A few corrugated ceramic sherds from the midden signal the beginning of the Pueblo II Period around A. D. 1000.

Soon after that date, the Virgin Anasazi abandoned Antelope Cave and joined the slow withdrawal of all Ancestral Puebloans from the Arizona Strip.

Several hundred years later (CAL A.D. 1650-1950), Southern Paiutes may have occasionally visited the cave leaving one twined water basket behind. Sometime after A.D. 1860 Euro-Americans began to explore Antelope Cave searching for Native American relics. Many potholes punched into the midden reflect their illicit activities over several decades. Today, in an effort to discourage vandalism and looting by unauthorized visitors, the Bureau of Land Management has gated the entrances to the cave. Sealing off the cave in this manner not only helps protect the significant archaeological deposits inside the cavern but also keeps people safely away from the site that is geologically unstable.

It is noteworthy that two of Antelope Cave's ^{14}C dates come from quids. They date CAL A.D. 680-890 and CAL A.D. 710-960 and represent the Virgin Anasazi occupation.

Previous research results

Here we briefly highlight the major published results from the various excavations at Antelope Cave. To place this research in a broader context, Lyneis (1995) offers an excellent, although somewhat outdated, overview of the Virgin Anasazi.

Hugh Cutler analyzed the corn from the UCLA and MNA collections. The row numbers of all the cobs (*n*=1022) from MNA pit D ranged between 8 and 16 with 12- and 14-row cobs making up 71% of the specimens (Cutler and Meyer 1965: Tables 5, 6). In terms of row count percentages, the Antelope Cave corncobs are similar to those recovered from Mesa Verde sites dating to Basketmaker and Pueblo I, II times. Cutler (1966: 16) found considerable quantities of dent corn kernels at Antelope Cave that led him to conclude that the earliest dent corn favored by the Fremont people in Utah may have reached them via the Virgin Anasazi.

Janetski and his colleagues (Janetski and Wilde 1989; Janetski et al. 2013) report on their test excavations in 1983 and 1986 as well as on the MNA investigations in 1954. At the base of the cave deposits they obtained three radiocarbon dates that confirmed the presence of Archaic Period hunter/gatherers. The bulk of the archaeological collections, however, represent the Virgin Anasazi. They suggest the site probably functioned as a seasonal hunting camp throughout all occupation periods and also served as a place to cache sandals and other items, including food. Prehistoric travelers used the cave as a stop off point as they moved along Clayhole Wash between Mount Trumball to the south and as far north as the more permanent villages along the Virgin River.

Pueblo style sandals from the BYU and MNA excavations are described by Yoder (2010, 2013). He analyzed 75 pointed/round-toed yucca sandals and sandal fragments from Antelope Cave. Four of these sandals were radiocarbon dated and fit nicely into the Pueblo I Period. In general, the pointed/round-toe sandals from Antelope Cave are morphologically similar to those found at other Anasazi sites in the Arizona Strip, but differ slightly from those in the Kayenta and Mesa Verde areas to the east.

Coprolites from the UCLA excavations numbered 190. Twenty-five of these feces, both human and canid, were analyzed by Reinhard and others (2012) to discover prehistoric parasites and reconstruct the diet of the Virgin Anasazi. The researchers were surprised to find that the Puebloans consumed ticks that potentially could have infected them with Rocky Mountain spotted fever and tularemia (Johnson *et al.* 2008). In addition to ticks and termites, Fugassa *et al.* (2011) report the discovery of pinworms and acanothocephalans (thorny-headed worms) in the human coprolite sample and *Trichuris vulpis* in the dog feces. Of special interest is their conclusion that the high percentage of pinworms and the occurrence of *T. vulpis* indicate that the Antelope Cave dwellers and their dogs spent part of each year in larger, more populated villages, probably to the northwest and northeast of the cave. Reinhard *et al.* (2012: Supplement A, Table A1; Supplement C) define the dietary habits of the Antelope Cave Puebloans. Small mammal meat and splintered bones (probably rabbit) were a significant finding in 70% of the 20 human coprolites studied. Wild seeds were major ingredients in 45% of the meals, followed by prickly pear pads (35%), and maize (25%). The botanical evidence indicates the cave was a seasonal habitation site occupied by the Virgin Anasazi in the late summer months through the early fall of each year.

The recovery and subsequent identification of tens of thousands of leporid bones from the cave excavations led Fisher *et al.* (2013) to conclude that prehistoric Puebloan families traveled seasonally to the site primarily to hunt rabbits for food and fur. They organized communal drives and stretched out nets to capture the animals. The hides from these little creatures were cut into strips and woven into warm rabbit fur robes and blankets, although no evidence of the completed articles have been found in the cave. Corn, grown and harvested at the site, along with a wide variety of wild plant foods supplemented the primary meat diet of the Antelope Cave Puebloans (Fisher *et al.* 2013).

Quids within Antelope Cave

UCLA archaeologists recovered 345 quids scattered throughout the excavations (TABLE 1). No significant clustering was observed and their distribution in the excavation units and levels in the cave demonstrates their use in all time periods throughout the Native American occupation of the site. The recovery of only one quid from pit AC 60 suggests that these small, sucked wads of fiber were characteristically discarded along with other trash in the midden and not spit out on living surfaces or house floors. Neither were they purposely disposed of in fire hearths as only 6 quids in the collection were partially burned. All the rest were unburned.

All the UCLA quids were apparently made of fibers from yucca leaves (see below), although the species is not confirmed. Quid sizes average 5.0 cm long (range, 2.5-9.3 cm), 3.8 cm wide (range, 1.6-6.2 cm), and 1.7 cm thick (range, 0.5-2.8 cm). The lengths of compressed fiber strands in two quids were measured. One strand from specimen 244-2385 is 9.5 cm long. The second specimen (244-4389) was too compacted to easily remove individual strands, so it was soaked in water for a day to loosen the fibers. Four strands from this quid gave lengths of 58.3 cm, 67.6 cm, 75.6 cm, and 76.3 cm. It is not clear whether the measured strands are fragmentary or complete. All of the fiber lengths, however, compare well with those of a living *Yucca baccata* plant whose longest spine-tipped leaves range in length from 60 cm to 95 cm. Osborne (1965: 48), Zauderer (1975: 66-67) and Reed (1978: 12) describe the various methods that may have been used to produce yucca leaf quids.

Tiny fragments of plants were found inside 268 (78%) of the 345 quids in the UCLA collection. The group of Antelope Cave specimens that contain these small plant fragments fits into Reed’s Type 2 Yucca Quids category that is characterized, in part, by the inclusion of intrusive materials in the fiber wads (Reed 1978: 15). Reed’s study of seventy-four Type 2 yucca quids from Hoy House and Antelope House in Southwestern Colorado (Early Pueblo III sites dating to the mid-1100s and early 1200s) was unable to identify intrusive materials. Identification of the plant particles wrapped in the Antelope

Cave quids was the primary goal of this research, followed by use of a molecular approach to confirm the identity of the quid fibers.

Seventy-seven (22%) UCLA quids appeared to lack plant inclusions. Some of these fiber bundles were too compact to easily determine the interior presence of intrusive materials without potentially harming the artifacts. Others were composed of looser, less compact, fibers and a few may not be quids at all.

Quid sample analyzed

An arbitrary sample of 30 quids that appeared to contain plant parts was selected and examined for this study. The sample was chosen to obtain maximum coverage across the site and at all vertical levels below the midden surface. Thus, quids were picked out from seven different excavation units at depths ranging from 0-6 inches to 66-72 inches below the surface (TABLE 2). The 30 quids vary in shape and dimensions. Most are round or oval (FIG. 5A) and they range between 3.8-9.3 cm in length, 2.9-5.1 cm in width, and 1.0-2.8 cm in thickness (TABLE 2). The quids appear to have been wound around and sometimes lapped over to form a partial knot (FIG. 5B).

Quid fiber identification

MORPHOLOGICAL EVIDENCE

The quid “fibers” (a common term) are technically Monocotyledon fibro-vascular bundles that have been intentionally separated from plant leaves and possibly from stems. Monocotyledons comprise a large and diverse group of flowering plants that in Arizona include grasses, sedges, rushes, and large plants such as yuccas (*Yucca*), agaves (*Agave*), beargrass (*Nolina*), and sotol (*Dasylirion*). The major Southwestern U.S. crop plant, domesticated maize (*Zea mays* L.), is also a monocotyledon.

Each fibro-vascular bundle includes groups of closely packed thick-walled fibers that provide support and strength for adjacent regions of vascular conducting tissues such as xylem and phloem. Xylem conducts water and provides support, and phloem is the principal food-conducting tissue (Arms and Camp 1979). Other cell types, such as living parenchyma cells, are often included within the fibro-vascular bundle (Esau 1977:317; 519). This distinctive Monocotyledon anatomy is easily recognized in transverse (cross-section) views of leaves, stems, and storage tissue, and because these fibro-vascular bundles align themselves in parallel fashion they can be recognized in longitudinal view on stems and leaves by their parallel vein patterning.

All 30 quids were constructed of long and flexible Monocotyledon fibro-vascular bundles that had been worked free from leaves. At least two quids (244-1118 and 244-2385) contained fibro-vascular bundles in their original parallel alignment (FIG. 5C) emerging from fragments of leaf tissue (FIG. 5D). The long leaves of *Agave* (agave), *Yucca* (yucca), and *Nolina* (beargrass) plants were all considered as potential sources of the Antelope Cave quid fiber materials, as species within these genera grow in the Arizona Strip country where Antelope Cave is located. According to Gentry (1982: 253, 257-262) and the USDA PLANTS Database (http://plants.usda.gov/), these include: *Agave utahensis* Engelm. ssp. *kaibabensis* (McKelvey) Gentry, *Agave utahensis* Engelm. ssp. *utahensis*, *Yucca angustissima* Engelm. Ex Trel., *Yucca baccata* Torr. var. *baccata*, *Yucca baccata* Torr. var. *brevifolia*, *Yucca jaegeriana* (McKelvey) L.W. Lenz, *Yucca schidigera* Roezi ex Ortgies, *Yucca utahensis* McKelvey, *Yucca kanabensis* McKelvey, *Nolina bigelovii* (Torr.). S. Watson, and *Nolina microcarpa* S. Watson. Although maize (*Zea mays*) remains were commonly recovered in the cave deposits, maize leaf fibro-vascular bundles were considered unlikely candidates for quid manufacture, as they are not nearly as robust, break easily, and cannot be easily removed from relatively thin maize leaves.

Distinguishing among *Agave, Yucca*, and *Nolina* is easily accomplished if entire leaves are present. Leaf cross- (transverse) sections are particularly diagnostic. Under microscopic magnification, the locations and arrangements of fibers and associated xylem and phloem cells within each bundle clearly differ for these genera (Bell and King 1944:152-156). In addition, diagnostic traits of the numerous individual fibers within a fibro-vascular bundle include average fiber width, average fiber wall width, average lumen width, and whether they are straight or curved when soaked in water or dilute potassium hydroxide (Bell and King 1944: 156-159). Other analyses of Monocotyledon specimens from archaeological contexts in Arizona have included consideration of various traits (Bohrer 1987: 71-73): (a) the presence of calcium oxalate crystals; (b) the appearance of their fibro-vascular bundles when they burn and come apart; (c) traits of fibro-vascular bundles in secondary stem tissue; and (d) the nature of both apical leaf spines and marginal teeth along leaf edges. Researchers have also utilized microscopic epidermal features to clearly distinguish *Agave* from *Yucca* (Sobolik 1992).

Efforts to identify the Antelope Cave quid fibro-vascular bundles using criteria cited above produced no reliable results, in part because of the degraded condition of the individual bundles and leaf tissue fragments. Efforts then turned to determining if a molecular approach could be used to distinguish major Monocotyledon plants when specimens were ancient and degraded, but not charred. This new approach precisely targets which plant genus was preferred for quid-making by Antelope Cave occupants. The relatively low cost and fast turn-around of molecular analyses, coupled with the ever-growing body of molecular signatures of Southwestern US plants, suggests that the future is bright for DNA studies. Plants chosen for making quids could vary among ancient groups, reflecting long-standing cultural habits, and add one more cultural trait to understanding the past.

DNA ANALYSIS

Of the 30 quids examined, ten were further selected for DNA analysis. Samples of fibro-vascular bundles ranging in weight from less than 10 mg to 40 mg, some with small amounts of attached leaf tissue, were ground in 1.5-ml microcentrifuge tubes using acid-washed plastic pestles. The grinding was performed in two stages: first as samples were moistened with buffer (2% cetyltrimethyammonium bromide, 1.4 M NaCl, 0.1 M trishydroxyaminomethane (Tris)-Cl, 20 mM ethylenedinitrilotetraacetic acid, pH 8) and then again after the addition of 300 µl of the same buffer. Samples were then incubated at 64ºC for at least 2 h. Additional buffer was added to assure the availability of supernatant. Samples were agitated strongly with 300 µl of $CHCl_3$, centrifuged, and the aqueous supernatant (ca. 250 µl) mixed with 300 µl of isopropanol. The precipitate was collected by centrifugation, washed with 500 µl of cold 80% ethanol, and dried. All samples had small, visible pellets, which were dissolved in 50 µl of water.

Polymerase chain reactions (PCRs) amplified segments of chloroplast DNA in the sample extracts. Primers were designed to select a 250-base section near the *trnL* gene (*trnL*AYF1: GCTAAGTGGTAACTTCCAAATTCAGA; *trnL*AYR1: TTGATATGCCAGTATGTATACGTACG). Each reaction mixture of 20 µl contained 12.1 µl of water, 4 µl of Green GoTaq buffer (Promega Corporation, Madison, WI, USA), 1.6 µl of dNTPs (2.5 mM of each dNTP), 0.125 µl of Taq DNA polymerase

(GoTaq, 5 u/µl, Promega), 0.6 µl of each primer solution (20 µM) and 1 µl of template DNA. Initial PCR conditions were 96ºC for 2 min; 35 cycles of 94ºC for 30 s, 59ºC for 30 s, and 72ºC for 1 min; 72ºC for 5 min; 4ºC hold. Mixtures were separated on 1.5% agarose gels. Bands at 250 bp were cut from the gel and extracted and purified by adsorption and elution from glass filters (Promega Wizard PCR purification system). Re-amplification of DNA purified from bands used a similar PCR protocol, except the template DNA was diluted (generally 1/100) and only 25 cycles were used for amplification.

The sequences of the DNA purified from agarose gels were determined (UC Davis Sequencing Center) using each primer described above. The sequencing chromatograms were very clear, showing no ambiguities (except, as is normal, at the very ends). The sequences were compared to those from GenBank for species of agave (*A. angustifolia*, *A. deserti*) and yucca (*Y. baccata*, *Y. brevifolia*, *Y. glauca*). They were also compared to GenBank sequences for wild coyote tobacco (*Nicotiana attenuata*) and a species of beargrass (*Nolina microcarpa*) to rule out possible tobacco contamination or the use of beargrass fibers. In the section of DNA that we amplified, there were clear differences among the genera, although not between the two species of agave and not between *Y. baccata* and *Y. glauca*. There were 6-7 base sequence differences between the agaves and the two yuccas (FIG. 6), and even greater differences distinguishing agaves and yuccas from tobacco and beargrass (not shown). The sequences from the archeological samples were all the same. The results showed a clear match between DNA from the archeological samples and yuccas (specifically, *Y. baccata* and/or *Y. glauca*) (FIG. 7).

Quid content identification

The interior contents of the quids were barely visible to the naked eye (FIG. 8A). When these fragments were removed from the quids and spread out on a plate, it became clear that a variety of plant parts were present (FIG. 8B). Based on comparisons to reproductive parts of pressed plant specimens in the University of Arizona Herbarium, the fragmented quid contents appear to represent tobacco (*Nicotiana*) flowering stems on the basis of numerous plant parts identifiable via morphological traits. These included: (a) both immature (deflated) and mature *Nicotiana* seeds; (b) the broken triangular lobes of smooth *Nicotiana* capsules that once contained the seeds; (c) fragments of very thin ribbed and veined *Nicotiana* calyx tissue that tightly adhered to the capsules; (d) some relatively short flower/fruit pedicel (supporting stem) segments; (e) longer fragments of main plant stems; and (f) ragged leaf fragments still attached to their central vein. Twenty-seven of the 30 quids contained from two to seven of these tobacco parts inside them (TABLE 3). Two quids contained unidentified leaf fragments and one was devoid of interior contents.

Two species of wild tobacco have been reported from the Arizona Strip country, according to the USDA Plant Database (http://plants.usda.gov/java/) and *The Arizona Flora* (Kearney and Peebles 1960: 760-761). These are: wild coyote tobacco (*Nicotiana attenuata* Torr. ex S. Watson), and wild desert tobacco (*Nicotiana obtusifolia* M. Martens & Galeotti var. *obtusifolia*, synonym = *N. trigonophylla* Dunal).

SEEDS

The seeds inside the UCLA quids compare very well to modern *Nicotiana* seeds (FIG. 8C), which range from 0.4-1.3 mm in longest dimension, and are oval, elliptic, spherical, reniform, or angularly several-sided (Goodspeed 1954: 89). Being packed against other seeds within a capsule likely contributes to shape variability even within a single species. Tobacco seeds have a particular "wavy-walled" appearance that is quite distinct (Gunn and Gaffney 1974: 8).

Of the two species that grow in the region of Antelope Cave, *Nicotiana attenuata* seeds have a slightly larger mean length of 0.7 mm compared to the 0.5 mm mean length of *N. obtusifolia (as N. trigonophylla*), and the two species vary slightly in overall shape (Adams and Toll 2000: 145-149). However, overlap in populations makes it difficult to confidently identify seeds when they are few in number or immature in condition. Many of the tobacco seeds within the UCLA quids appeared shrunken and immature. This is reasonable for a wild plant that flowers and fruits over many weeks during the growing season. On any given day during the growing season, a wild tobacco plant can sport flower buds, flowers, ripening seeds inside closed capsules, and open capsules that have already released their mature seeds.

CAPSULE FRAGMENTS

Tobacco capsules are thick-walled and smooth, with no evidence of trichomes (hair or hair-like extensions of an epidermal cell) or glands. They naturally split into four triangular lobes at the apex to release their seeds. Broken fragments of these triangular lobes are present in the UCLA quids (FIG. 8D).

CALYX FRAGMENTS

In the UCLA samples, ripe capsules often retained their thin and papery calyx, essentially the outer floral envelope of a flower. These calyx fragments display obvious ribs and veins, and at times visible glands (FIG. 8E). Like the capsules, they also split into triangular lobes toward the top. When detached from the capsule, the thin calyx fragments are still recognizable. The calyx of modern *N. obtusifolia* specimens generally extends all the way to the top of the capsule, in contrast to the calyx of modern *N. attenuata* specimens, which does not (Cronquist *et al.* 1984; Kearney and Peebles 1960: 761). The lack of capsules that still retain a complete calyx in the Antelope Cave quids prevents a determination of this relationship. Some calyx specimens of modern *N. attenuata* are covered with glands, appearing as orange-yellow spots; glands are less evident on modern *N. obtusifolia* calyx specimens. Some of the calyx fragments of the Antelope Cave materials appear to have at least a few glands present.

PEDICELS

Small stems that attach a flower to a flowering stalk are called pedicels. These are often shorter than main stems. They can naturally dehisce (release) from the plant, leaving smooth and even scars. Numerous pedicels attached to calyx and/or capsule fragments were found mixed in with the quid contents from Antelope Cave (FIG. 8F).

MAIN STEM FRAGMENTS

Tobacco main stem fragments are generally longer and more robust than pedicels (FIG. 9A). Their generally round shape is often somewhat irregular via flattening or via natural depressions running their length. Numerous main stem fragments were present in the quid contents.

LEAF FRAGMENTS

Leaf fragments can have a visible central vein with ragged leaf tissue still attached (FIG. 9B). Trichomes (hairs) can be present on these veins and on leaf edges and also on the leaf surfaces. Trichomes on *Nicotiana* parts are useful in recognizing different wild species (Cronquist *et al.* 1984: 72; Goodspeed 1954: 72-74). Those on *Nicotiana attenuata* are generally simple and sometimes gland-tipped, in contrast to those that are forked or dendritically branched on *N. obtusifolia*. Although time and circumstances have likely worn away some of the trichomes on the Antelope Cave materials, the few trichomes still visible on the leaves appear to be the simple type, suggesting *Nicotiana attentuata* was the tobacco picked for use. No forked or branched trichomes were observed. Leaves can also have a limited number of resin glands on their surfaces. White crystal/powder spots notable on some leaf fragments (244-3463) do not react to vinegar, suggesting they are not composed of calcium carbonate ($CaCO_3$). Nor do they appear to have the distinctive shapes (needle-like raphides, rod-like styloids, or irregular druses) of calcium oxalate (CaO) crystals found in a wide range of plant families (McNair 1932). Possibly they represent glands whose resin has dried to a white powder with age.

NON-TOBACCO CONTENTS

A limited number of non-*Nicotiana* plant parts were also present within some quids. For example, quid 244-2279 contained four sunflower/golden eye (*Helianthus/Viguiera*) type achenes (FIG. 9C) and a ricegrass (*Achnatherum hymenoides*) grass floret (FIG. 9D). Quid 244-0395 also preserved a small juniper (*Juniperus*) twig fragment. These non-tobacco parts may have been intentionally added to the quids, or unintentionally included when the quids were constructed.

Discussion

These Antelope Cave quids are among the first to have had a molecular analysis applied to identification of their fibers, and to have identifying traits of interior tobacco contents presented in descriptive and image form. They provide seasonality perspective on the presence of ancient groups using the cave, and bring additional insight to a discussion of quid function(s).

Previous report on Yucca quids and Nicotiana contents

The archaeological literature of ancient *Yucca* quids with *Nicotiana* contents extends back to a report over fifty years ago by Jones and Morris (1960). They described a series of Basketmaker III period (tree-ring dates clustering between A.D. 621-630) cave sites in extreme northeastern Arizona as having around two dozen *Yucca* quids with *Nicotiana* and calcium carbonate ($CaCO_3$) contents. Some of the quids had teeth imprints, as if held in the mouth under pressure but not masticated vigorously. One of the sites also had a pottery vessel of Lino Gray ceramic type with a well-preserved sample of tobacco leaf portions, smaller stems, corollas, capsules, and seeds. This list of tobacco parts sounds remarkably similar to those described here from the Antelope Cave quids. Although Jones and Morris may be correct in their identifications, they provided no specific identifying criteria for the *Yucca* or the *Nicotiana*. They also pointed out that, although a survey of literature and museum collections revealed similar quids within Basketmaker caves, the nature of any interior contents had not been recognized or reported. Potentially, other collections of quids with *Nicotiana* and/or other contents are on museum shelves awaiting discovery.

Seasonality implications

The distribution of the Antelope Cave quids within different excavation units and at different depths makes it difficult to know if quids were prepared ahead of time and cached together, or were prepared individually on an “as needed” basis. The immature and mature seeds and associated flowering parts suggest that the tobacco was picked during summer or fall months, following the start of the monsoon rains which spur both growth and reproduction. This generally agrees with previous reports that the cave served as a seasonal habitation from late summer through early fall (see discussion above). Of course, these flowering parts could have been picked and stored for use in another season, as illustrated by the parts within the Lino Gray jar reported by Jones and Morris (1960: 115). Therefore, the season of tobacco acquisition might not correlate with the season of quid manufacture and usage. The availability of ricegrass (*Achnatherum hymenoides*) as a springtime resource complicates an effort to perceive when, during the calendar year, some of the quids may have been constructed and/or used.

Explanations for quid usage

Quids may have served more than one purpose for ancient groups. There are a number of possible reasons for making quids. Common conjectures are: as a food; for use in ritual/ceremony; for personal pleasure; or for other daily needs (see Reed 1978).

FOOD

The interpretation given most often for quids is that they represent the indigestible residue left over from food use. Because they often have teeth marks and can appear flattened and matted, they have been interpreted as plant tissues that were wadded up and sucked on and/or chewed and then expectorated, with no mention of other associated plant parts. Quids made from maize (*Zea mays*) husks, stalks, and leaves, such as those representing the Puebloan Period at Antelope House in Canyon de Chelley in northeastern Arizona, may have been chewed for nutriment (Zauderer 1975: 68-70). Experiments by Reed (1978: 7,8) demonstrated that corn leaf or husk quids are sweet and pleasant to chew and are also nutritious. Maize is a grass with a central main stalk, like sugarcane, and one of the first uses of teosinte, the wild ancestor of maize, could have been for the sugars in its stalks (Smalley and Blake 2003). Thus it is reasonable that ancient groups in the American Southwest may have sucked on different maize plant parts for sugars and then spit out indigestible fibers in the form of quids.

Yucca leaf quids were said to have been chewed for nutriment at Antelope House (Zauderer 1975: 65). At Bighorn Cave, another shelter site in Mohave County, Arizona, many quids measuring 3-6 cm in length and 1.5-2.5 cm in diameter exhibited distinct teeth marks and extensively crushed fibers, suggestive of chewing; these quids were thought to have been made from *Agave*, based in part on other evidence at the site for *Agave* consumption (Geib 2002: 152-153).

RITUAL OR CEREMONY

A primary ethnographic theme is that tobacco satisfied numerous ritual or ceremonial needs (Jones 1944: 455). At times, reedgrass cigarettes with tobacco contents are associated with sacred paraphernalia in archaeological sites (Gifford 1980:11), or have been used by historic groups to provide smoke to make a path for prayer to the gods or ensure the general good of the people (Bohrer 1962: 87). There is ample ethnographic evidence that historic indigenous groups clearly recognized a connection between woodland fires and the presence of wild tobacco plants the following year; active management to ensure future tobacco harvests has been commonly reported (Adams 1990).

PERSONAL PLEASURE

There is also the possibility that personal pleasure was a motivation for placing tobacco inside quids. We speculate that this practice would keep the tobacco plant parts from direct contact with cheek tissue, perhaps reducing irritation or obtaining too much nicotine too quickly. Linton (1924: 9) suggested that ancient reedgrass cigarettes with tobacco contents represented smoking for personal pleasure, and historically the Seri in Sonora, Mexico smoked native tobacco for personal satisfaction (Felger and Moser 1985: 165). Although many Native American individuals today revere tobacco as a sacred and powerful substance used only in ceremonies and prayers, others now also use commercial tobacco for recreational purposes (Winter 2000: 9-58).

OTHER USES

Other uses for tobacco have been reported. Indigenous groups in southern California mixed lime (calcium carbonate) with tobacco for use as a medicine, emetic, stimulant, and an aid in inducing visions. Lime, obtained by grinding calcined shell, was ingested in a semi-fluid state or formed into pellets which were then sucked or salivated along with tobacco (Kroeber 1941: 1). Presumably the addition of lime enhances the effects of nicotine and other alkaloids contained in tobacco. The report on *Yucca* quids with tobacco contents by Jones and Morris (1960: 116) mentioned above included the identification of calcium carbonate, which clearly differs from the current study which lacks evidence of this additive. Nicotine also suppresses appetite (Mineur *et al*. 2011), and people might have chewed quids with tobacco inside to suppress hunger when environmental stress resulted in food scarcity.

Additional functions for archaeological quids abound. *Yucca* fiber quids at Antelope House in northeastern Arizona were conjectured to be strainers, “tea bags”, dye bundles, and wash pads, although no details supporting these specific uses were presented (Zauderer 1975: 65). Abrasion marks on un-chewed corn husk quids from Tularosa Cave in New Mexico led to the conclusion that they may have served as pot scrubbers (Martin *et al.* 1952: 471). Kidder and Guernsey (1919: 113), Zauderer (1975: 66), Reed (1978: 12, 20) and others conclude that many yucca quids resulted from processing useable fiber for cordage.

Summary and Conclusions

Dry caves and rock-shelters have preserved thousands of uncharred quids, essentially folded over wads of fibers, in archaeological contexts in the American west. Quids often appear to have been placed in the mouth and chewed or sucked, evidenced by compression, human tooth indentations, and matting due to saliva, suggesting extraction of substances to quench hunger. The identification of both the fibers gathered to construct quids and of any contents inside contributes to understanding of the range of possible reasons for making them. This research used morphological details to suggest that ancient Basketmaker/Puebloan occupants of Antelope Cave in northwestern Arizona made quids from regionally available large Monocotyledons (*Yucca*, *Agave*, or *Nolina*). Molecular analysis of quid fibers then confirmed that *Yucca* plants provided the fibers (as fibro-vascular bundles) for these quids.

The surprising discovery of fragmented plant contents inside 90% of this arbitrary sample of 30 quids led to identification of a diversity of parts associated with wild tobacco (*Nicotiana*) flowering stems. This is not meant to imply that 90% of the total 268 quids with inclusions all contained tobacco parts. Immature and mature seeds, capsule fragments and their surrounding calyx fragments, flowering stem pedicels, main plant stems, and fragmented leaves were all identified, along with a small number of non-tobacco specimens. Due to damage, it was not possible to say with certainty which of two wild tobacco species in the region, *Nicotiana attenuata* and *Nicotiana obtusifolia* (synonym = *N. trigonophylla*), or both, were placed inside the quids, although future molecular analysis might sort this out. A previous report over 50 years ago detailed a similar recovery in northeastern Arizona (Jones and Morris 1960; Morris 1980), but with no identification details.

Wild tobacco plants generally flower in the summer through fall months. They are especially spurred to reproduce by monsoonal precipitation, and will continue to flower and make seeds until the first fall frost. The presence of many immature tobacco seeds within the Antelope Cave quids suggests collection within the summer growing season; these parts could have been stored for future placement inside quids. Other limited plant parts associated with the quids include a spring-ripening ricegrass floret and fall ripening sunflower/goldeneye achenes, all possibly as incidental inclusions.

Because the Antelope Cave quids contain broken-up flowering stems of tobacco, it is reasonable to assume these particular quids were not intended as a food. Instead we speculate the quids were intended to be chewed and sucked in order to obtain the stimulant effect of the tobacco. Use of these tobacco-laced quids in ritual or ceremony, commonly credited for tobacco collection among historic groups, is a possible function. However, the fact that the quids were scattered throughout the Antelope Cave midden deposit and were not directly associated with any ritual artifacts or ceremonial features renders this possibility less likely. In fact, we know of no archaeological sites where quids, with or without tobacco inclusions, have been found in a ritual, ceremonial or burial context.

We believe that yucca leaf quids containing wild tobacco were sucked and/or chewed primarily for pleasure and the stimulant effect they brought to the individuals who inhabited Antelope Cave over hundreds of years. Just like smokeless tobacco (snuff, chews, plugs, etc.) in today's modern world, ancient tobacco sucked through quids could become addictive and may have been used regularly at Antelope Cave. This conclusion is supported by Reed (1978: 2). Of the 517 quids he analyzed from Hoy House and Lion House in southwestern Colorado, none were found on kiva floors and only two on living floors. The rest were discarded in the middens along with other trash.

It appears that wrapping tobacco parts inside *Yucca* quids is a cultural trait restricted to the Ancestral Puebloan peoples of the American Southwest. But that may change as more and more archaeologists see the research value in these little wads of yucca fiber. Use of molecular methods to identify the quid fibers, coupled with examination for interior contents, could reveal a range of cultural behaviors associated with these seemingly simple but intriguing artifacts.

Acknowledgments

We thank Wendy Teeter at the Fowler Museum of Cultural History at UCLA for loaning the quids examined in this study. Andrew Sais and Statistical Research, Inc. (Tucson, AZ) assisted with development of Figures 5, 8, and 9, and Grant Coffey of Crow Canyon Archaeological Center (Cortez, CO) provided assistance with producing the final versions of all figures. We also appreciate the comments provided by our three reviewers.

Author Biographies

Karen R. Adams (Ph.D. 1988, University of Arizona) is a Research Associate for Crow Canyon Archaeological Center in Cortez, CO. Research interests: pre-Hispanic plant use in the Southwest U.S. and northern Mexico.

Keith L Johnson (M.A. 1962, University of California, Los Angeles) is Professor Emeritus, California State University, Chico, CA. Research interests: archaeology of California and the Southwest U.S.; California Chinese temples.

Terence M. Murphy, (Ph.D. 1968, University of California, San Diego, CA) is Professor Emeritus, University of California, Davis, CA. Research interests: use of molecular methods of plant identification in forensics and archaeology.

References

Adams, K. R. 1990. “Prehistoric "Reedgrass" (*Phragmites*) "Cigarettes" with Tobacco (*Nicotiana*) Contents: A Case Study from Red Bow Cliff Dwelling, Arizona,” *Journal of Ethnobiology* 10(2): 123-139.

Adams, K. R. and M. S. Toll. 2000. “Tobacco Use, Ecology, and Manipulation in the Prehistoric and Historic Southwestern United States,” in J. C. Winter, ed., *Tobacco Use by Native North Americans: Sacred Smoke and Silent Killer.* Norman: University of Oklahoma, 143-170.

Aikens, C. M. 1970. *Hogup Cave. Anthropological Papers, University of Utah* 93. Salt Lake City: University of Utah.

Anderson, M. K. 2005. *Tending the Wild. Native American Knowledge and the Management of California’s Natural Resources*. Berkeley: University of California Press.

Arms, K. and P. S. Camp. 1979. *Biology*. New York: Holt, Rinehart and Winston.

Bell, W. H. and C. J. King. 1944. “Methods for the Identification of the Leaf Fibers of Mescal (*Agave*), Yucca (*Yucca*), Beargrass (*Nolina*) and Sotol (*Dasylirion*),” *American Antiquity* 10(2): 150-160.

Bohrer, V. L. 1962. "Nature and Interpretation of Ethnobotanical Materials from Tonto National Monument," in C. R. Steen, L. M. Pierson, V. L. Bohrer, and K. P. Kent, *Archaeological Studies at Tonto National Monument, Arizona*. Southwestern Monuments Association Technical Series 2, 75-114.

Bohrer, V. L. 1987. "The Plant Remains from La Ciudad, A Hohokam Site in Phoenix," in J. E. Kisselburg, G. E. Rice and B. L. Shears, eds., *Specialized Studies in the Economy, Environment and Culture of La Ciudad, Part III*. Tempe: Arizona State University Anthropological Field Studies 20, 67-202.

Castetter, E. F. 1943. "Early Tobacco Utilization and Cultivation in the American Southwest," *American Anthropologist*, New Series 45: 320-325.

Castetter, E. F. and W. H. Bell. 1942. *Pima and Papago Indian Agriculture*. Inter-Americana Studies I. Albuquerque: The University of New Mexico Press.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1984. *Intermountain Flora, Vascular Plants of the Intermountain West, U. S. A. Volume Four, Subclass Asteridae (except Asteraceae)*. New York: The New York Botanical Garden.

Cutler, H. C. 1966. *Corn, Cucurbits and Cotton from Glen Canyon. Anthropological Papers, University of Utah* 80. Salt Lake City: University of Utah.

Cutler, H. C. and W. Meyer. 1965. “Corn and Cucurbits from Wetherill Mesa,” in B. S. Katz (ed), *Contributions of the Wetherill Mesa Archaeological Project. Memoirs of the Society for American Archaeology* 19. Salt Lake City: University of Utah, 136-152.

Dunavan, S. L. and V. H. Jones. 2011. Tobacco and Smoking in North America. In B. D. Smith (ed), *The Subsistence Economies of Indigenous North American Societies, A Handbook*. Washington, D.C.: Smithsonian Institution Scholarly Press.

Esau, K. 1977. *Anatomy of Seed Plants*, 2nd Edition. New York: John Wiley and Sons.

Felger, R. S. and M. B. Moser. 1985. *People of the Desert and Sea. Ethnobotany of the Seri Indians*. Tucson: University of Arizona Press.

Fisher, J. L., J. C. Janetski, and K. L Johnson. 2013. “Variability in Far Western Puebloan Subsistence Strategies: The View from the Uinkaret Plateau, Northwest Arizona,” *Journal of Arizona Archaeology* 2:140-162.

Fugassa, M. H., K. J. Reinhard, K. L Johnson, S. L. Gardner, M. Vieira, and A. Araujo. 2011. “Parasitism of Prehistoric Humans and Animals from Antelope Cave, Mojave County, Northwest Arizona,” *Journal of Parasitology* 97: 862-867.

Fulton, W. S. 1941. *A Ceremonial Cave in the Winchester Mountains, Arizona. Amerind Foundation Publications* 2. Dragoon: The Amerind Foundation.

Geib, P. R. 2002. “Summary of Recovered Quids and Feces,” in P. R. Geib and D. R. Keller, eds., Bighorn Cave, Test Excavation of a Stratified Dry Shelter, Mohave County, Arizona. *Bilby Research Center Occasional Papers* No. 1, Flagstaff: Northern Arizona University, 152-153.

Gentry, H. S. 1982. *Agaves of Continental North America*. Tucson: The University of Arizona Press.

Gifford, J. C. 1980. Archaeological Explorations in Caves of the Point of Pines Region, Arizona. Tucson: *Anthropological Papers of the University of Arizona*, No. 36.

Goodspeed, T. H. 1954. “The Genus Nicotiana. Origins, Relationships, and Evolution of its Species in the Light of their Distribution, Morphology and Cytogenetics,” *Chronica Botanica* Vol. 16 (No’s. 1-6).

Gunn, C. R. and F. B. Gaffney. 1974. Seed Characteristics of 42 Economically Important Species of Solanaceae in the United States. *U.S.D.A. Agricultural Research Service, Technical Bulletin* No. 1471: 1-33.

Harrington, M. R. 1933. *Gypsum Cave, Nevada. Southwest Museum Papers* 8. Highland Park: Southwest Museum.

Heizer, R. F. and A. D. Krieger. 1956. *The Archaeology of Humboldt Cave, Churchill County, Nevada. University of California Publications in American Archaeology and Ethnology* 17. Berkeley: University of California, 1-190.

Janetski, J. C., R. K. Talbot, D.E. Newman, L. D. Richens, and J. D. Wilde. 2000. *Clear Creek Canyon Archaeological Project: Results and Synthesis. Museum of Peoples and Cultures Occasional Papers* 7. Provo: Brigham Young University.

Janetski, J. C., D. A. Newman, and J. D. Wilde. 2013. *A Report of Archaeological Excavations at Antelope Cave and Rock Canyon Shelter, Northwestern Arizona. Museum of Peoples and Cultures Occasional Paper* 19. Provo: Brigham Young University.

Janetski, J. C. and J. D. Wilde. 1989. "A Preliminary Report of Archaeological Excavations at Antelope Cave and Rock Canyon Shelter, Northwestern Arizona," *Utah Archaeology* 2: 88-106.

Johnson, K. L, K. J. Reinhard, L. Sianto, A. Araujo, S. L. Gardner, and J. Janovy, Jr. 2008. "A Tick from a Prehistoric Arizona Coprolite," *Journal of Parasitology* 94: 296-298.

Jones, V. H. 1944. "Was tobacco smoked in the Pueblo region in pre-Spanish times?" *American Antiquity* 9(4): 451-456.

Jones, V. H., and E. A. Morris. 1960. "A Seventh-Century Record of Tobacco Utilization in Arizona," *El Palacio* 67: 115-117.

Kearney, R. H. and R. H. Peebles. 1960. *Arizona Flora*. Berkeley: University of California Press.

Kidder, A. V. and S. J. Guernsey. 1919. *Archaeological Explorations in Northeastern Arizona. Bureau of American Ethnology, Bulletin* 65. Washington, D. C.

Kroeber, A. L. 1941. *Culture Element Distributions: XV Salt, Dogs, Tobacco. Anthropological Records* 6(1). Berkeley: University of California.

LeBlanc, S. A., L. S. Cobb Kreisman, B. M. Kemp, F. E. Smiley, S. W. Carlyle, A. N. Dhody, and T. Benjamin. 2007. "Quids and Aprons: Ancient DNA from Artifacts from the American Southwest," *Journal of Field Archaeology* 32: 161-175.

Linton, R. 1924. Use of Tobacco among North American Indians. Chicago: *Field Museum of Natural History Anthropology Leaflet* No. 15.

Loud, L. L., and M. R. Harrington. 1929. *Lovelock Cave. University of California Publications in American Archaeology and Ethnology* 25. Berkeley: University of California, 1-183.

Lyneis, M. M. 1995. “The Virgin Anasazi, Far Western Puebloans,” *Journal of World Prehistory* 9: 199-241.

Martin, P. S., J. D. Rinaldo, E. Bluhm, H. C. Cutler, and R. Grange, Jr. 1952. *Mogollon Continuity and Change: The Stratigraphic Analysis of Tularosa and Cordova Caves. Fieldiana: Anthropology* 40. Chicago: Chicago Natural History Museum.

McNair, J. B. 1932. “The Interrelation Between Substances in Plants: Essential Oils and Resins, Cyanogens and Oxalats,” *American Journal of Botany* 19: 255-271.

Mineur, Y. S., A. Abizaid, Y. Rao, R. Salas, R. J. DiLeone, D. Gündisch, S. De Biasi, T. L. Horvath, X.-Bing Gao, M. R. Picciotto. 2011. Nicotine Decreases Food Intake through Activation of POMC Neurons. *Science* 332: 1330-1332.

Morris, E. A. 1980. *Basketmaker Caves in the Prayer Rock District, Northeastern Arizona. Anthropological Papers, University of Arizona* 35. Tucson: University of Arizona.

Osborne, C. M. 1965. “The Preparation of Yucca Fibers: An Experimental Study,” in B. Katz, ed., *Contributions of the Wetherill Mesa Archaeological Project, Memoirs of the Society for American Archaeology* 19. Salt Lake City: University of Utah, 45-50.

Reed, A. D. 1978. “An Analysis of the Quids from Hoy House and Lion House,” *Southwestern Lore* 44: 1-22.

Reinhard, K. J., K. L Johnson, S. LeRoy-Toren, K. Wieseman, I. Teixeira-Santos, and M. Vieira. 2012. “Understanding the Pathoecological Relationship between Ancient Diet and Modern Diabetes through Coprolite Analysis. A Case Example from Antelope Cave, Mojave County, Arizona,” *Current Anthropology* 53: 506-512 and Supplements A, B, C.

Smalley, J. and M. Blake. 2003. “Sweet Beginnings: Stalk Sugar and the Domestication of Maize,” *Current Anthropology* 44: 675-703.

Sobolik, K. D. 1992. “Microscopic Epidermal Identification of *Yucca* and *Agave* for Archaeological Use,” *The Texas Journal of Science* 44: 187-199.

Setchell, W. A. 1921. Aboriginal Tobaccos. *American Anthropologist*, New Series 23(4): 397-413.

Spier, L. 1928. Havasupai Ethnography. *Anthropological Papers of the American Museum of Natural History*, Vol. XXIX, Part III. New York: The American Museum of Natural History.

Switzer, R. R. 1969. Tobacco, Pipes, and Cigarettes of the Prehistoric Southwest. *El Paso Archaeological Society Special Report* 8.

Talbot, R. K., L. D. Richens, J. D. Wilde, J. C. Janetski, D. E. Newman. 2000. *Excavations at Five Finger Ridge, Clear Creek Canyon, Central Utah. Museum of Peoples and Cultures Occasional Paper* 5. Provo: Brigham Young University.

Taylor, W. W. 1948. *A Study of Archaeology*. Carbondale: Southern Illinois University Press.

Turner, C. G. 1967. *Bite Marks in Tule Quids of Prehistoric Nevada Indians. Archaeological Survey Reports, University of California* 70. Berkeley: University of California, 117-122.

USDA, NRCS. 2014. The PLANTS Database (http://plants.usda.gov, 15 June 2013). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Whiting, A. F. 1966. *Ethnobotany of the Hopi*. Flagstaff: Northland Press. Originally published in 1939 as Bulletin No. 15, Museum of Northern Arizona.

Winter, J. C. 2000. "Traditional Uses of Tobacco by Native Americans," in J. C. Winter, ed., *Tobacco Use by Native North Americans, Sacred Smoke and Silent Killer*. Norman: University of Oklahoma Press, 9-58.

Winter, J. C., ed., 2000. *Tobacco Use by Native North Americans: Sacred Smoke and Silent Killer*. Norman: University of Oklahoma Press.

Yoder, D. T. 2010. “Plain-Weave Sandals from Antelope Cave, Arizona,” *Kiva* 75: 327-350.

Yoder, D. T. 2013. “Antelope Cave Sandals,” in J. C. Janetski, D. A. Newman, and J. D. Wilde, *A Report of Archaeological Excavations at Antelope Cave and Rock Canyon Shelter, Northwestern Arizona. Museum of Peoples and Cultures Occasional Paper* 19. Provo: Brigham Young University, 103-120.

Zauderer, J. 1975. “A Survey of Typical Antelope House Quids,” *Kiva* 41: 65-70.

Table 1 Distribution of all quids at Antelope Cave.

Depth	Excavation Unit									
(inches)	59 -1	59 - 3	59 - 4	59- 2	59 - 5	60	B	E	NP	Total
0-6	4		1	3	11					19
6-12	6	1	5	14	12		5	7		50
12-18	1	1	2	11	17					32
18-24	7		1	20	11		4			43
24-30	2			14	27			3		46
30-36				10	31		2			43
36-42				4	21					25
42-48				4	21					25
48-54					8					8
54-60					7					7
60-66					15					15
66-72					6					6
NP			5			1			20	26
Total	20	2	14	80	187	1	11	10	20	345

NP (no provenience)

Table 2 Location and measurement data on 30 uncharred quids examined for this study.

Quid No.	Location			Measurements (cm)		
	Excavation Unit	Depth (inches)		Length	Width	Thickness
153-0022	E	24-30		4.3	4.2	1.2
153-0189	E	6-12		5.6	4.6	1.2
153-0263	B	18-24		5.7	3.0	2.1
153-0291	B	30-36		5.5	4.8	2.6
244-0395	59-1	0-6		4.5	4.3	1.5
244-0465	59-1	6-12		5.3	3.3	1.0
244-0556	59-1	18-24		4.5	4.3	2.0
244-0597	59-1	24-30		5.5	4.1	2.0
244-0892	59-2	6-12		4.6	2.9	2.1
244-1118	59-2	12-18		8.4	4.7	1.5
244-1334	59-2	18-24		3.8	3.1	2.8
244-1490	59-2	24-30		3.8	3.2	1.8
244-1628	59-2	30-36		5.8	5.1	2.3
244-1752	59-2	36-42		5.1	3.4	1.8
244-1818	59-2	42-48		5.8	2.9	1.4
244-2043	59-3	6-12		4.4	3.2	1.3
244-2098	59-3	12-18		4.8	3.6	1.5
244-2279	59-4	6-12		5.3	4.3	2.1
244-2345	59-4	12-18		6.3	4.1	2.2
244-2385	59-4	18-24		5.0	2.6	1.0
244-3162a	59-5	12-18		6.3	4.5	1.5
244-3463	59-5	18-24		4.8	3.6	2.2
244-3897	59-5	24-30		4.6	3.3	2.6
244-4389	59-5	30-36		5.1	4.7	2.2
244-4710	59-5	42-48		6.7	3.2	1.5
244-4751	59-5	54-60		4.5	3.9	2.1
244-4765	59-5	48-54		5.9	3.1	2.3
244-4822	59-5	60-66		4.3	3.8	1.7
244-4842	59-5	66-72		5.7	3.2	1.6
244-4850	59-5	36-42		9.3	3.0	1.4

Table 3 Uncharred *Nicotiana* contents within quids. x = present.

Quid No.	Seeds		Calyx fragments	Leaf fragments	Stem fragments	Smooth capsule fragments	Pedicel fragments	Notes
	immature	mature		w/glands				
153-0022						**x**	**x**	
153-0189			**x**	**x**		**x**	**x**	
153-0263	**x**		**x**	**x**		**x**	**x**	
153-0291		**x**	**x**	**x**		**x**	**x**	
244-0395			**x**				**x**	**Plus one *Juniperus* twig**
244-0465	**x**		**x**	**x**		**x**	**x**	
244-0556	**x**		**x**	**x**		**x**	**x**	
244-0597				**x**		**x**	**x**	
244-0892	**x**			**x**		**x**	**x**	
244-1118								**No *Nicotiana* parts present; interior contents are unidentified leaf fragments.**
244-1334	**x**		**x**	**x**		**x**	**x**	
244-1490				**x**		**x**	**x**	
244-1628			**x**	**x**		**x**	**x**	
244-1752	**x**		**x**	**x**		**x**	**x**	
244-1818				**x**		**x**	**x**	
244-2043	**x**		**x**	**x**		**x**	**x**	
244-2279	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**Plus *Helianthus/Viguiera* achenes and one *Achnatherum hymenoides* floret**
244-2098		**x**	**x**	**x**		**x**	**x**	
244-2345								**No *Nicotiana* parts present; quid is partially composed of *Juniperus* bark. Interior contents are uniden-tified thin leaf tissue fragments.**
244-2385								**No interior contents; some fibro-vascular bundles still embedded in leaf tissue.**
244-3162a				**x**		**x**	**x**	
244-3463	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
244-3897		**x**	**x**	**x**		**x**	**x**	
244-4389	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
244-4710		**x**		**x**		**x**	**x**	
244-4751		**x**	**x**	**x**		**x**	**x**	
244-4765			**x**	**x**			**x**	
244-4822	**x**		**x**	**x**		**x**	**x**	
244-4842			**x**	**x**		**x**	**x**	
244-4850	**x**		**x**	**x**		**x**	**x**	

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 1 Map of the Arizona Strip and location of Antelope Cave. Map by Judy Stolen.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 2 View northeast of Antelope Cave in summer 1962. Lost Spring Mountain rises in the background right. Photo by K. L Johnson.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 3 Map of the interior of Antelope Cave, surface features and excavation units: UCLA (University of California, Los Angeles), MNA (Museum of Northern Arizona), BYU (Brigham Young University). Map by Judy Stolen.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 4 View northeast of the culture bearing deposit, completed excavation unit AC59-2 and pit AC59-3 under excavation (June 1959). Note the cloth level sacks next to AC59-3. Photo by K. L Johnson.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 5 Quids. (A) Quid 244-3463 (left) and quid 244-2279 (right), with a cm scale; (B) knot visible on quid 244-2279; (C) parallel fibro-vascular bundles still attached to intact leaf tissue (D) of quid 244-1118. Photos by K. R. Adams.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 6 Comparison of *trnL* intron region DNA sequences from two *Agave* species and three *Yucca* species. Bases that are different between *Agave* and *Yucca* sequences are indicated in bold face. Sequences were taken from NCBI accessions: *A. angustifolia*, DQ50089.1; *A. deserti*, DQ500894.1; *Y. baccata*, EU09555.1; *Y. brevifolia*, EU585500.1, *Y. glauca*, EU092594.1.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 7 Comparison of segments of the *trnL* intron region amplified from ten numbered Antelope Cave (A. Cave) archaeological samples with the equivalent regions from *Y. baccata* (top) and *A. deserti* (bottom). Seven bases in the archeological samples differ from those in *A. deserti* and match the ones in *Y. baccata*. Relative to the start of N-terminal primer used to amplify the sequences, the differences occurred at bases 50, 51, 106, 158, 169, 176, and 180.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 8 Quid Contents. (A) Interior contents barely visible inside quid 244-4822; (B) diversity of parts present within quid 244-2279; (C) three seeds from quid 244-4389 on the left compared to three modern *Nicotiana attenuata* seeds (Crow Canyon #327) on the right; (D) broken triangular capsule fragments from quid 244-3463; (E) thin and papery calyx fragments with visible ribs from quid 244-4389, and with a few visible glands on the right specimen; (F) short flower pedicels from quid 244-3463, two with their calyx still attached. Photos by K. R. Adams

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 9 Quid Contents, continued. (A) Sturdy main stem segments from quid 244-3463; (B) leaf fragments from quid 244-3463, with central vein still visible; (C) two *Helianthus/Viguiera* achenes from quid 244-2279; (D) one ricegrass (*Achnatherum hymenoides*) floret from quid 244-2279 (left) compared to a modern floret (right). Photos by K. R. Adams.