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Beans, Baskets, and Basketmakers Testing the Assumption that Ceramics were Necessary for the Adoption of Bean Cultivation on the Prehistoric Colorado Plateau

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Abstract

Paleodietary investigations attest to heavy reliance on maize among Basket maker II groups living in the Colorado Plateau region by at least 400 BC. Maize is notably deficient in two essential amino acids, lysine and tryptophan, making it a poor protein source on its own. Early Mesoamerican farmers mitigated this shortfall by supplementing with beans, but most archaeologists don't place beans in the Basket maker region until around 500 AD. Researchers have long assumed that the late arrival of beans is contingent upon the need for ceramic cooking vessels for long-term boiling, and have advanced numerous hypotheses to account for attendant nutritional implications. To test this assumption, a series of experiments was designed to examine the feasibility of cooking beans in waterproofed baskets using hot-rock boiling. Results of these tests offer clues about subsistence strategies and diet breadth among pre-ceramic Southwestern populations.

Keywords: beans, Basketmaker, hot-rock boiling, Colorado Plateau, prehistory, basketry

1. Introduction

The adoption and spread of agriculture into the American Southwest from Mesoamerica has received considerable attention from archaeologists for over a century (Kidder 1924, McGregor 1982). Following domestication in southern Mexico by about 8,000 years ago (Piperno et al. 2009) maize (*Zea mays* s.s.), the dominant cultivar in the Americas, first appeared in the Southwest sometime just before 2,000 BC (Diehl and Waters 2006), delineating the Early Agricultural Period in the Tucson Basin of southernmost Arizona.

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Paleodietery reconstruction indicates reliance on maize agriculture by Basketmaker II (BMII) peoples of the Colorado Plateau by about 400 BC (Coltrain et al. 2007). From there, maize agriculture spread north to the Colorado Plateau over about the next 1500 years [Fig. 1].

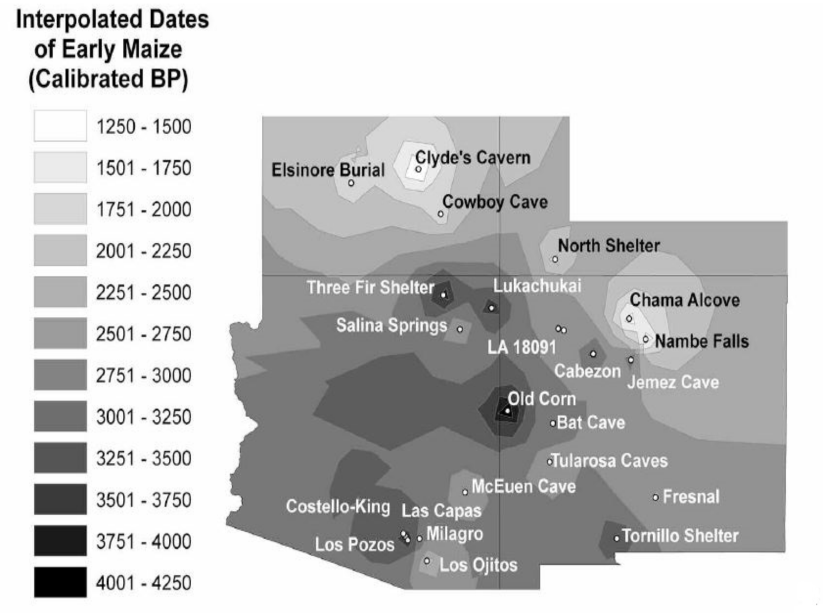

Figure 1: Earliest Dates of Maize Adoption (from Kohler et al. 2008)

However, maize is notably deficient in two essential amino acids: lysine and tryptophan (Mertz et al. 1964). Adverse health effects associated with consuming too little lysine include an increase in serotonin in the amygdala, characterized by pathological anxiety (Smriga et al. 2002). Adverse health effects associated with consuming too little tryptophan include pellagra, a protein deficiency syndrome characterized by dermatosis, anemia, neuropathy, and sometimes death (Bates 2005). The process of *nixtimalization* – processing maize with lime – increases the bioavailability of these amino acids and is known to have been conscientiously practiced in parts of Mesoamerica, particularly among the Aztecs from whom the word derives (Gomez et al. 2006). Experiments with hot-stone boiling using limestone cobbles have demonstrated that this may have occurred to some extent on the prehistoric Colorado Plateau (Ellwood et al. 2013).

The most common and reliable method for ameliorating this nutritional shortfall is via supplementation with other foodstuffs, i.e., pairing maize with beans and squash, as in the *milpa* (from the Nahuatl; see Zizumbo-Villareal and Colunga-GarcíaMarín 2010) or "Three Sisters" (Hart 2008) gardening and dietary strategy common among modern Native Americans. Beans are a complete protein source and nitrogen fixer, and squash deters erosion while providing both food and, when dried, handy vegetal vessels (Hart 2008, Landon 2008). Molecular evidence indicates that maize, beans, and squash were utilized simultaneously in Mesoamerica long before radiating outward to other regions (Bitocchi et al. 2012, Piperno et al. 2009, Piperno and Smith 2012), with some research indicating that squash was domesticated first (Landon 2008). More specifically, Phaseolus bean species appear to have been fully domesticated and implemented into local practices by at least 4,000 BP and probably before (Pickersgill and Debouck 2005, Zizumbo-Villareal and Colunga-GarcíaMarín 2010).

However, not all three of them were adopted uniformly in all places. In Peru, for example, dependence on maize agriculture appears somewhat rapidly, with local varieties of domesticated squash and beans lingering afterward (Dillehay et al. 2007, Piperno and Smith 2012). In the American Southwest, the earliest maize appears in Three Fir Shelter, Arizona and Bat Cave, New Mexico about 2,000-2,300 BC; squash appears in Bat Cave and Sheep Camp Shelter, New Mexico, by about 1,200 BC; and the earliest beans appear in Tularosa Cave and Bat Cave, New Mexico, between about 900 and 4 BC (Wills 1995:218; Merrill et al. 2009; see Fig. 1 for locations). On the Colorado Plateau, temporal spacing of maize and squash is approximately the same but most researchers don't associate beans with local farmers until about AD 500 (Geib and Spurr 2000, Matson 2006).

To account for this disparity, most authors have endorsed the long-standing assumption that "the cultivation and consumption of beans, beginning in the early [AD] 500s, required a container more durable than the tarred/pitched baskets used to cook previously." (Reed 2000: 8; see also Wormington 1961, Kaplan 1965, Cordell 1984, Wills 1995, Tagg 1996) Owing to the logic and persistence of this assumption, modern researchers continue to insist that, for example, "by the A.D. 600s… people had acquired beans *and the ceramic technology necessary to cook them*." (Allison et al. 2012: 40, my italics) This is an implicit rather than explicit assumption, however, and is based largely on analogy with modern circumstances.

Modern beans require extensive soaking and boiling times, but modern beans are also selected more for shipping and storing capability than for cooking capability – this may not have been the case with ancestral varieties. Furthermore, as Geib and Spurr (2000) point out, "If there was a functional relationship between pottery and beans, we would expect beans to first appear… at the approximate same time as ceramics. So far this is not the case." (197)

It is therefore likely that this assumption may be flawed, and material investigations are warranted. To that end, a series of experiments was designed to test whether or not it is possible to cook an ancestral variety of bean in a waterproofed basket using hot-rock boiling.

2. Hot-Rock Boiling Historical Overview

The practice of using heated stones to boil liquids and cook foods is known to have occurred in many traditional societies, in some cases up to the present day (Williams 2003). The process involves heating stones in a fire until they've reached an optimal temperature and then transferring them into a water-tight vessel, container, or pit containing the liquid. To maintain cooking temperatures, stones would have to be "rotated" – i.e., cooled stones removed from the liquid and switched with stones taken freshly from the fire – until the food was fully cooked. As with modern cooking methods, the duration of this process would vary considerably between food item types. Boiling eggs in water or preparing soups with simple, non-starchy contents would likely take scarcely more than a quarter-hour, while more elaborate processes like preparing bone grease could take up to three days (Guernsey 1984). The labor involved in this process is simple, if time-consuming, although the fuel consumption is potentially tremendous.

This practice extended throughout the prehistoric world. Preparing foods in this manner in small, pitch- or bark-lined pits dug into the ground is known from antiquity in the Americas (Thoms 2009). Organic containers, constructed from animal hides or vegetal fibers, could be employed for this purpose without having to apply direct heat; although it is pertinent to note that direct-heat cooking in ceramic vessels, which could be left to stand in or on a fire without further tending for a considerable length of time, did not fully replace hot-rock cooking when ceramic technology was adopted (Sassaman 1993).

This may be due to economic or cultural factors – or both – but for whatever reason hot-rock boiling remained widely popular even amidst seemingly more efficient technologies.

Archaeological evidence of hot-rock boiling can be tricky to detect, and often the only diagnostic residue is fire-cracked rock (FCR) that appears to fit the logistical criteria (Petraglia 2002; Thoms 2008, 2009). From ethno archaeological observations, Binford (1978: 159) asserted that “if a stone boiling strategy has been employed, there are large quantities of fired rock, generally separated into at least two piles,” one consisting of rocks that broke apart during the cooking process and the other consisting of intact rocks intended for further use. Cavallo (1987) identified FCR features from the Late Archaic and Early Woodland periods in eastern North America, based largely on these criteria. Further, Cavallo discerned between large aggregations associated with large-scale cooking processes (231) and smaller FCR clusters likely associated with stone-boiling residue from single containers (183).

While the latter were taken to be associated with long-term, larger-scale processes like rendering fish or nuts for oil extraction, the latter represent household-scale cooking more akin to the sort under investigation in this study.

It should be noted that this method is not the most efficient of possible means available to BMII individuals for cooking beans. John Speth, in investigating Neanderthal cooking strategies, argues that direct-heat boiling, even in flammable vessels, is easier and far less fuel-intensive than hot-rock boiling, and he draws attention to a rich literature on direct-heat methods utilizing animal skins, plastic, and even leaves (from 2014 Society for American Archaeology conference lecture, summarized inVergano 2014; see also Driver and Massey 1957). Furthermore, as Paleoindian scholar Leland Bement has pointed out (personal communication), much greater heat retention can be utilized in boiling pits dug into the ground than in baskets or even ceramics (see also Thoms 2008). The purpose of this series of experiments is to establish an upper limit to potential bean preparation procedures available to BMII peoples, i.e., if it works in baskets, it would certainly work in either of the abovementioned alternatives.

3. Experimental Design and Materials

In setting up this investigation, a considerable amount of time was spent investigating and listing any and all relevant parameters so as not to skip any pertinent details. This was done with extensive assistance from Professors Joan Brenner-Coltrain and Brian F. Codding of the University of Utah Anthropology Department.

A final list consists of the following:

- What sort of beans would they have cooked?
- What type of baskets would they have used?
- What sort of stones?
  - How many stones?
  - How big?
  - How many rotations?
  - How hot can / should they be?
- How long and at what temperature do the beans need to cook?
- Can the baskets withstand the heat?
- Can the baskets *retain* the heat?
- How does one objectively tell when a bean is fully cooked?

To address the first parameter, investigations were conducted to establish what type of bean ancestral peoples of the Southwest would have used, and whether or not they are currently available. Of the 50 species of bean (*Phaseolus*) distributed among the Americas, four of them contain cultigens: *vulgaris*, *lunatus*, *acutifolius*, and *coccineus*. *P. vulgaris*, or the "common bean," is the one most often associated with the earliest legume farming in North America (Kaplan 1956). Native Seed Search, a popular and reliable purveyor of heirloom cultivars, provided clues that the simplest and easiest form to obtain would be "Anasazi Beans" produced and marketed by Red Mill Farms. In structure and appearance they closely resemble the earliest *P. vulgaris* beans recovered in the Southwest (Fig. 2; see Kaplan 1956 for complete morphological data).Not surprisingly, given the storability-vs-cookability dichotomy proposed above, Red Mill Farms' Anasazi beans turned out to be substantially easier to cook than modern, store-bought dried beans: approximately one hour of simmering following an initial boil, with no pre-soaking required.

Figure 2: (from left) Common *vulgaris* beans of the type recovered at Wupatki Pueblo, Point of Pines, and Murder House in Arizona (Kaplan 1956: Table VII and Plate 1); and close-up of Red Mill Farms' Anasazi Beans

For the second parameter, early Colorado Plateau peoples used single-rod coiled basketry in most cases (Adovasio 1977, Whiteford 1989), and single-rod coiled baskets of sufficient size and depth were obtained from native African artisans via Altamont Trading Company. The initial purchase included three large-size baskets, as well as three smaller-sized ones for preliminary testing to mitigate damages. Baskets were chosen that exhibited a sitting conical shape with a much wider mouth than base, as this is the best design for heat dispersal in hot-rock boiling (Nelson 2010).

Regarding the cooking stones, recent experimental investigations on hot-rock boiling of maize kernels and associated archaeological research indicates that limestone was a likely favorite for Colorado Plateau peoples (Ellwood et al. 2013). This is based on both the occurrence of limestone river cobbles in BMII pithouses and to the possibility that nixtamalization could have occurred as an intentional or unintentional result. However, broader investigations of hot-rock boiling by other authors and experimenters (e.g., Thoms 2008, 2009) suggest that basalt is the best choice for heat retention/transfer and reduced likelihood of fracturing, with limestone coming in a distant second. Given the appearance of limestone cobbles in BMII settings, it is likely that they were using limestone rather than basalt, but since the subject under investigation is bean rather than maize preparation it was decided to procure and test specimens of both types of rock.

Ethnographic accounts suggest that medium – i.e., roughly softball-sized – stones are best, and that about 8-10 of them are required for any long-term cooking so that fresh rocks rotated into the vessel are as hot as possible (Guernsey 1984, Custer and Silber 1995). To determine optimal rotation intervals given the rocks' maximal heat retention, it was decided that one round of experimentation would consist solely of heating and exchanging rocks in clear water.

The time and temperatures required to cook the beans were suggested by the instructions provided on their packaging, as noted above. Given that these instructions are intended for cooking in metal pans on stovetop ranges with regulated heating coils, tests were conducted to see how much flexibility the cooking directions would allow in the case of heat loss and fluctuations in the baskets. It was assumed that, if anything, a significantly longer simmering time would be required.

Whether or not the baskets could withstand the heat and, if so, to what extent heat would be lost through the outside wall proved to be a tricky problem. Ethnographic evidence from the Mono tribe in California (Codding, personal communication) suggests that thick-walled, well-constructed watertight or pitch-lined baskets can indeed withstand boiling temperatures but should definitely not be held in the hands or lap – and, furthermore, that the rocks need to be kept in constant motion by rolling so they don't sit too long against the basket wall. While the second condition was simple enough to facilitate, it was deemed essential to test the first by bringing water inside the baskets to a boil using a submersion heater to ensure their integrity.

Finally, as any restaurant chef can attest, whether or not something is "cooked" is largely a subjective measure. To mitigate potential bias on the part of project participants, a number of methods were suggested to objectively demonstrate whether or not the beans were fully cooked. The process of cooking breaks down cell membranes within the beans, such that fully-cooked beans are ubiquitously described as *tender* or easily mashed. Thus the proposed method was to test them by applying pressure with a fork. A separate sample of beans would be cooked in the conventional stovetop way, their "forkability" then compared with that of beans cooked using hot-rock boiling in the baskets.

4. Methods and Procedures

Tools and materials were procured through various outlets, mostly through online vendors. They consisted of:

- Three large-sized single-rod and coil baskets (7x12”)
- Three small-sized single-rod and coil baskets (2x5”)
- Three limestone cobbles (average weight 1lb)
- Nine basalt cobbles (average weight 1lb 15oz)
- One pair metal tongs
- OXO digital scale
- Extech 421501 submersion thermometer
- Norpro food thermometer
- DT-8750 laser point infrared thermometer
- Norpro household immersion heater

A sample of beans was cooked by conventional stovetop methods, accompanied by the immersion thermometer [Fig. 3]. One cup of beans was submerged in two liters of room-temperature water and brought to full cook. The process was repeated five times, at varying times and temperatures, to establish temporal and thermal flexibility. It was determined that an initial boil was indeed necessary, but that it didn’t matter how much time it took to reach. After the initial boil, a simmering temperature of between 170 and 190 degrees F sustained over between 45 and 105 minutes (higher sustained temperatures necessitated shorter steeping times) resulted in their being fully cooked.

Figure 3: Establishing Cook Time and Temperature Parameters

Cooking stones [Fig. 4] were heated using direct contact with a heating coil (approximately 1600 degrees F, about 200 degrees F lower than the average interior temperature of a medium-sized campfire) to determine heat retention and fracturing rates. As expected, basalt performed much better than limestone, having higher average heat retention and zero fracturing during testing. Given that limestone was already demonstrated to be an effective hot-rock cooking material by Ellwood et al. (2013), it was decided to use basalt stones gathered in northern Arizona to facilitate experimental methods while minimizing risk of explosions.

Figure 4: Basalt Stones Used in Experimental Cooking

To waterproof the baskets, various methods of pitch-lining were proposed and attempted. These trials were conducted on the smaller baskets to avoid damage to the larger, more expensive cooking baskets. Traditional methods call for piñon pitch in quantity, but this proved nearly impossible given time and budget limitations. Following consultation with the advising professors noted above, it was decided that a comparable alternative to piñon pitch would be acceptable, given that the variable under investigation was whether or not baskets can adequately stand up to the heat of extended hot-rock boiling rather than whether or not they would remain waterproof. An assemblage of plastic-based resins was tested, but all of them cracked apart as they dried. Instead, a two-part epoxy resin was recommended, which proved to provide both a waterproofing and elasticity comparable to that of cured piñon pitch. All three large-sized baskets were given one interior coat [Fig. 5].

Figure 5: Pitch-Lined Interior of one of the Baskets

To examine whether or not the material integrity of the baskets could withstand being gradually brought to boiling temperatures, a pair of tests were conducted. First, water was raised to a rapid boil on a stovetop and then poured into them – this did not result in any adverse issues. Next, room-temperature water was brought to a gradual boil inside the baskets themselves using the immersion heater [Fig. 6]. Although the baskets held up to the heated and boiling water, one was irreparably damaged when the heater was allowed to rest against the bottom. This served to underscore an observation from the ethnography noted above: that the heat-radiating object must be kept in constant motion.

Figure 6: Testing Baskets' Ability to Withstand Increasing Temperatures

Having established that the baskets could withstand both short- and long-term boiling conditions, the next examination was to see how easily – if at all – water could be brought to a boil inside them using heated rocks [Fig. 7]. Nine rocks were used in rotation, thus allowing each one to reach maximal temperature before being submerged again; times and temperatures were carefully monitored and noted. Overall the baskets fared quite well, but exterior temperatures, determined by the laser thermometer, indicated a lot of heat loss through the basket wall. While a not-insurmountable obstacle, this is definitely likely to be less of a problem with ceramic vessels.

Figure 7: Testing Baskets' Ability to Retain Enough Heat to Reach a Boil using Heated Rocks

The final stage was an attempt to cook the Anasazi beans in a basket using hot-rock boiling. Per previous tests, one cup of dried beans was submerged in two liters of room-temperature water and nine rocks were heated, submerged, and reheated in rotation. Water temperatures were monitored using the submersion heater [Fig. 8] and rock temperatures were monitored using the laser thermometer. While in the basket the rocks were kept in motion by rolling them around using the tongs with which they were transferred between the heat source and the water. Rock rotations were timed and recorded. A second sampleof beans was prepared using conventional stovetop methods for side-by-side comparison.

Figure 8: Cooked Beans (Photo Taken Just after the Simmering Phase)

5. Results

It took almost 60 minutes to reach an initial rolling boil inside a basket, owing to heat loss through the basket wall and to the beans themselves. Once the initial boil was reached, however, maintaining simmering temperatures was much easier (although still more difficult than with clear water).The results of the cooking process are summarized in the graph [Fig. 9] below.

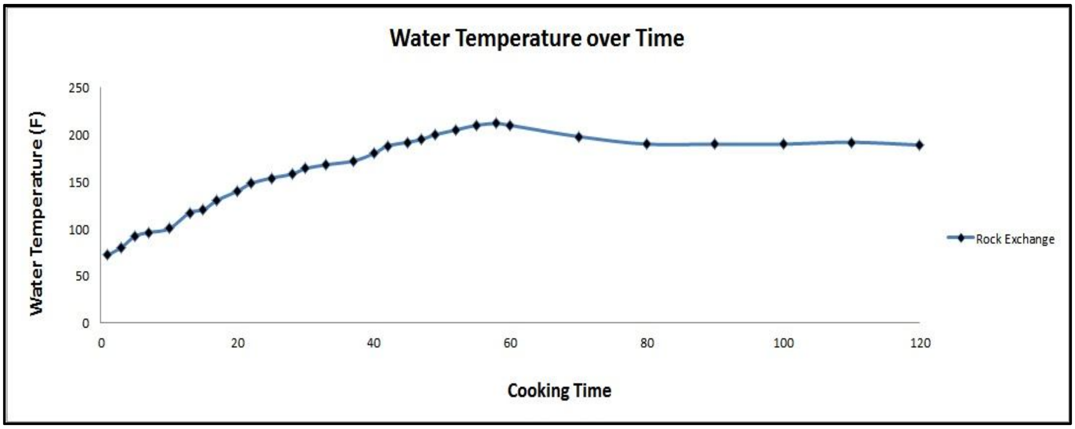

Figure 9: Temperature over Time, Measured at Each Rock Rotation

Once they were fully cooked, the cooking rock was removed and the beans were rinsed and allowed to cool. A "forkability" test was then administered, having first demonstrated the relative pressure necessary on conventionally cooked beans. The beans cooked using hot-rock boiling in the basket were found to mash as easilyas those from the stovetop method [Fig. 10], and were furthermore found by participants to be "edible."

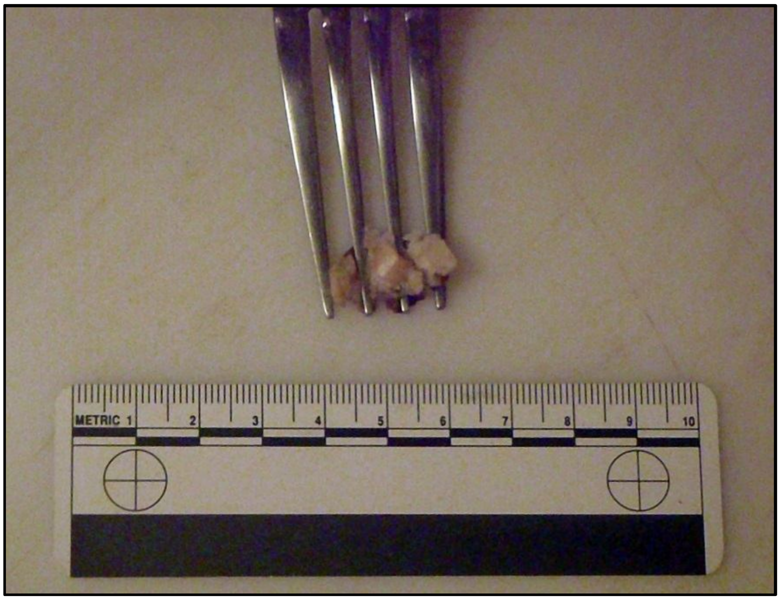

Figure 10: Objective Test of Masticability

6. Discussion

While time-consuming, cooking beans in baskets using hot-rock boiling is indeed possible, and it is therefore a certainty that cooking them with direct-heat boiling in skins and/or hot-rock boiling in shallow pits would be easier still – so why didn't beans come into Basketmater diets at the same time as maize and/or squash? Ultimately there are two answers to this question.

1. They actually did. Maize ears consist of soft kernels lining a tough ligneous or "woody" cob. The ligneous material on squashes is limited to the relatively smaller stem and the seeds, the latter of which are choice morsels for varmints; and although the dried husks preserve remarkably well they do not necessarily endure longer than maize cobs. Meanwhile beans have no ligneous material content whatsoever.

Owing to this, maize would last longest in the ground and thus preserve longest in the archaeological record, followed by squash, and, at a greater remove, beans – as in the conceptual model below [Fig. 11].

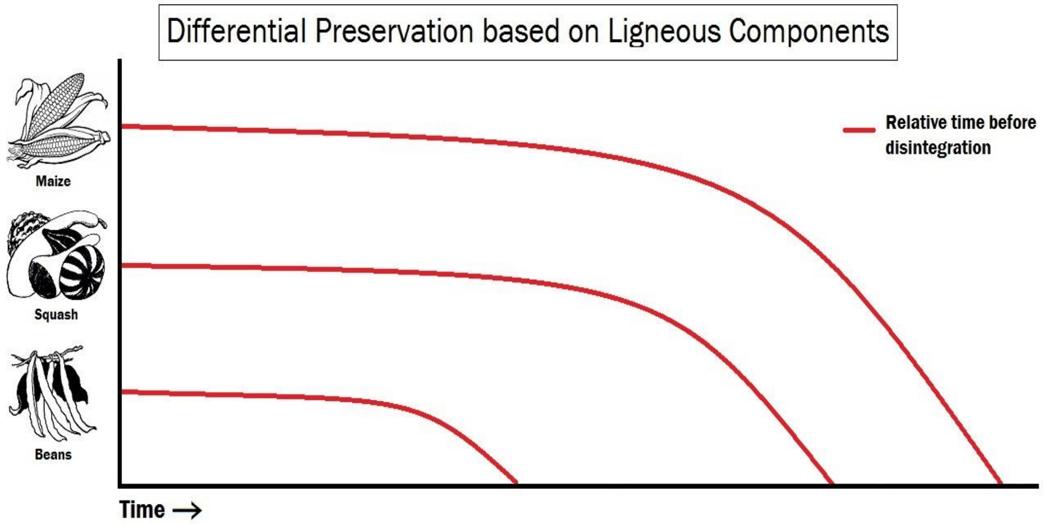

Figure 11: Conceptual Model of Relative Rates of Differential Preservation Based on Ligneous Material Content

However, as pointed out by Stephen Leblanc (personal communication), what we find at the chronological commencement of bean cultivation is not sporadic macrofossils but significant caches. This lends considerable support to the contention that beans appeared at about that time on the landscape itself, rather than suddenly appear in the archaeology out of a haze of preservation bias. Further investigations into [a] preservations rates between maize, squash, and beans; and [b] revised investigation of stable isotope ratios from BMII materials (as in Coltrain et al. 2013), with bean data included in the mixing models, would be needed to examine this possibility more thoroughly.

2. They didn't after all. Models for diet breadth (e.g., Hawkes and O'Connell 1992)and technology investment (e.g., Bettinger et al. 2006) both predict that people will not readily shift their diets and associated behaviors unless circumstances compel them, as when old practices are no longer available or when new ones offer significantly greater returns than what's already in place.

In the Southwest, supplementation with hunted game could have sufficed until increased population and concomitant resource depression (see Reynolds 2012) resulted in bean cultivation being a less expensive enterprise. In their study of the archaeology of Cedar Mesa, Matson et al. (1988: 255) note that the addition of beans in the Basket maker III (BMIII) "can be viewed as the adoption of a supplemental cultigen," i.e., adoption of bean agriculture was more likely the result of a push by nutritional needs rather than a pull by advancements in cooking technology (see also Lipe 1993). Furthermore, in Ellmore et al.'s 2013 experiments it was shown that hot-rock boiling with limestone could noticeably increase bioavailability of the amino acids in which maize is known to be deficient, an effect which may have helped buttress supplementation.

Intriguingly, one of the most commonly occurring wild plant items in prehistoric – and, indeed, a few modern – Southwestern diets is goosefoot (*Chenopodium album*), a protein-rich relative of quinoa (*Chenopodium quinoa*), both of which provide a full complement of essential amino acids (Pachauri et al. 2012). It is possible that intensive use of this plant item made supplementation with beans unnecessary, at least until population densities increased so much as to render it too expensive to process and acquire goosefoot relative to bean farming.

Notwithstanding whether or not beans were present in the diets of people on the prehistoric Colorado Plateau before they appear in the material record, this study's challenge that ceramic containers were not altogether necessary to prepare them does not diminish the fact that they appear in the archaeological record during approximately the same time period. Ceramics first appear in southernmost Arizona by about AD 1 and on the Colorado Plateau by about AD 200, preceding agriculture in some specific societies and postdating it in others (Crown and Wills 1995:173-174). As noted above, the earliest beans appear at Bat Cave and Tularosa Cave in New Mexico sometime between about 900 and 4 BC, and most authors don't associate them with prehistoric Colorado Plateau farmers until about 500 AD. Their *near*-contemporaneity suggests not that they were adaptations one to another, but were instead part of a suite of behaviors (see Reed and Geib 2013:104) that swept into and across the region during the Basket maker era.

7. Conclusion

The transition from gathering to production of food is among the most intriguing topics for scholars of prehistory (Janetski 1993). It has led to greater and more dramatic social, technological, economic, and biological changes than nearly other sociobehavioral innovation in human history (Smiley 1993, Larsen 1995) The dominant cultivar in the American Southwest is maize, and its adoption and spread has received considerable attention from archaeologists for over a century (Kidder 1924, McGregor 1982). Somewhat less considerable is the attention directed at the adoption and spread of other cultivars into the Southwest, in particular beans and squash, which none the less came to accompany maize with near ubiquity (Hart 2008).

As experimental procedures and results presented in this study demonstrate, ceramic vessels are not necessary for cooking beans, and thus the long-standing assumption that bean cultivation was not adopted in the Southwest alongside maize cultivation for reasons of cooking technology is invalid. Beans nonetheless do not consistently appear in BMII assemblages, and instead appear with significant consistency only during the subsequent BMIII period and beyond. Further investigations into local dietary options and differential preservation rates may help in solving the mystery of the chronological gap between adoption of these cultivars. For now, it is at least certain that adoption of bean cultivation on the Colorado Plateau did not require the presence ceramic cooking vessels.

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