# THE ROLE OF GRASS SEED IN SOUTHWESTERN ARCHAIC SUBSISTENCE

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## ABSTRACT

*Archaeological reconstructions of prehistoric subsistence systems in the western United States often include wild-grass-seed harvesting, storage, and consumption. Biochemical data suggest that grass seed must be cooked before consumption for the starches within to be digestible. Cooking grass seeds can be accomplished in several ways. However, grass-seed use might have been relatively limited prior to the introduction of ceramic cooking vessels. Grass seeds are also good sources of vitamin E. Vitamin E has been shown to prevent some anemias in human infants. Furthermore, vitamin E may have increased the fecundity of populations consuming large amounts of grass seed. This increased fecundity may have acted as a selection factor for prehistoric groups exploiting storable grass seeds.*

## INTRODUCTION

Understanding the role of grass-seed use in Archaic subsistence is important because archaeological reconstructions of settlement patterns, tool use, and site and artifact function often hinge upon inferences of intensive exploitation of grass seed by hunter-gatherers. I address the role of wild-grass-seed use as it pertains to the introduction of agriculture in the Southwest. Some researchers assert that the introduction was abrupt, that it completely replaced existing subsistence systems, and that it marked the beginning of certain other traits in the archaeological record, such as structures. Minnis (1985:337) suggests that the introduction of cultigens into the Southwestern Archaic had little immediate adaptational impact because the cultigens were analogous to wild resources already in use: "Maize kernels are after all grass seeds."

Matson (1991) argues that Archaic grass-seed exploitation set the stage for later agricultural adaptations. Matson (1991:238) uses an ethnographic Papago model with a summer lowland village from which grass was gathered to describe the settlement pattern during the Archaic to horticulture transition.

> This modified settlement/subsistence pattern model also indicates how agriculture may have been integrated into the Basin and Range Archaic economy. . . . the only addition to turn it into the 'two village' Papago model is the introduction of maize horticulture to the already important late summer lowland base camps (Matson 1991:241).

I believe the introduction of agriculture was gradual, that it was integrated into existing subsistence systems, and that structures as well as other traits of so-called sedentary populations occurred long before the practice

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of agriculture. I do question the antiquity of intensive grass-seed collection, storage, and use predating farming. Most archaeological evidence concerning prehistoric grass-seed use is open to question. The coprolite data, however, are secure. Coprolite data from sites in the western United States are presented and their implications are considered.

Many assumptions about prehistoric use of wild-grass seed have derived from ethnographic descriptions of historic hunter-gatherer subsistence methods. For example, archaeologists working in the western United States based their interpretations of prehistoric hunter-gatherer sites and artifacts on observations of wild-grass-seed harvesting and use by Indians in that area (Irwin-Williams 1979:40; Matson 1991; Woodbury and Zubrow 1979:43; Wills 1988). Examples of such ethnographic observations are given in the section that addresses archaeological interpretation of grass use.

I suggest that although large expanses of grass offered plentiful food resources, preceramic populations were limited in their ability to exploit them. Because a major component of grass seed is starch, much of the nutritional value of such seed is unavailable unless specific processing methods are used. The biochemical structure of starch dictates that particular processing methods must be used if it is to be rendered digestible. I describe the structure of starch, and the processing methods necessary to its breakdown.

Additionally, vitamin E in grass seeds and its effect on human populations is discussed. Deficiencies of vitamin E can lead to certain types of anemia, especially in infants, and diets high in fat can cause increased need of vitamin E. Large amounts of grass seed may have provided enough vitamin E to have increased the fertility of some populations.

## STARCH

Starch naturally occurs in plant cells in the form of small granules that are water-insoluble at room temperature (Arons and Paschall 1975:85). The size and shape of these granules are consistent within and particular to each plant species (Sweetman and MacKellar 1954:518). Domesticated grasses may contain up to 75 percent starch by weight.

Starch granules consist of two polymer structures, amylose and amylopectin. Amylose is a linear chain of glucose units, while amylopectin is a highly branched chain of glucose units. Within a starch granule, the amylose and amylopectin are combined in a semi-crystalline form in ratios specific to each species (Banks et al. 1973:177-185). Because a starch is a complex series of molecules of a simple sugar (glucose) joined in repetition, it is termed a polysaccharide (Arons and Paschall 1975:85).

The formation of starch in the developing grass seed is a complicated process. Some researchers have noted patterns of starch formation and disintegration followed by a second buildup of starch granules during the fertilization and ripening of seed (Kerr 1950:6). After the seed ripens, the starch granules become relatively stable. While still green, grass seed carries undeveloped starch granules, which yield their nutrients to humans more easily. Asdiscussed below, the process of granule development in grain affects the way humans harvest and process it.

### Starch Digestion

The mammalian intestine will not absorb polysaccharides (Barnett 1973:219); it will absorb only the monosaccharide components, or individual glucose molecules. For their nutrients to be available to humans, the granular structure of starch polysaccharides must be disrupted and glucose formed by the time the starch reaches the intestines.

Amylase is the only enzyme in the human digestive system that can react with a polysaccharide. This enzyme is secreted by the mouth and pancreas and will reduce amylose to a monosaccharide (Barnett 1973:213). Amylopectin is reduced to short strands of amylose when hydrolyzed by acid (Southgate 1976:58). However, the intact, stable starch granules in ripe grain are resistant to both enzyme and acid actions because of a waxy coat, possibly made of a lipoprotein (Southgate 1976:48). Kerr (1959:158) found that after starch granules were subjected to several months of leaching in dilute sulfuric acid, only fifty percent of the granules had been dissolved and the structural characteristics of the remainder were intact.

Researchers have conducted experiments with simulated human digestive systems and human subjects to determine the actual digestibility of raw starches. The *in vitro* experiments showed that the simulated digestion of raw starch never exceeded 7.6 percent of that of boiled starch receiving the same chemical treatment (Beazell et al. 1939:80). *In vivo* experiments with starch demonstrated that most raw starch granules pass through the human system without being digested (Langworthy and Deuel 1920, 1922; Beazell et al. 1939). While some raw starch was not recovered after passing through the volunteers' digestive systems (average starch losses for two of the studies were 21.8 and 26.0 percent), Beazell et al. (1939:82-83) concluded that this missing starch was lost mainly to bacterial fermentation and provided no nutritional benefits to the human subjects.

Starch digestion can be initiated by fragmenting the coats of starch granules prior to ingestion. Mechanical techniques such as pounding and grinding do not rupture starch granules in seed or grain. In the absence of sophisticated modern chemical techniques, cooking is the most efficient method of disrupting starch structure and rendering it digestible.

### Cooking Starch

Cooking alters the polymer structure of raw starch so that digestion may occur. Dry-heat cooking includes baking or parching; moist-heat cooking methods include boiling. Cooking by popping (for example, heating popcorn) is a dry-heat method; however, several aspects of popping justify a separate discussion.

#### *Dry Heat Cooking*

Dry-heat cooking can disrupt the granular structure of starch, but it can also break down its constituents. Breaking down the constituents—specifically amylose—means that potential nutritional value is lost. Too much heating produces dextrin (Southgate 1976:48); dextrin production results in oxidation, manifesting indigestible gums or gasses and carbons. Many modern baked products contain the entire range of degraded and unaltered starch (Southgate 1976:48).

Baking of starchy food such as bread can efficiently break the polymer structure of starch. However, successful breadmaking is in part due to the kind of starch in the flour used (which varies by source species) as well as to the use of an appropriate leavening agent (this includes sourdough). Some flours cannot be baked as bread. (See Banks et al. 1973 for a discussion of variable results of baking with different flours).

Baked items such as tortillas can be made with unleavened flours (e.g., masa—boiled corn meal/flour). Also, Stevenson (1915:75) described the baking of "sweetened" corn meal by the Zuni. In this instance, boiled corn meal was held in the mouth to "sweeten" it. Later the sweetened meal was mixed with other boiled meal and baked. This produced flat, unraised cakes of cooked meal. This is not technically a bread, but a boiled mush that is then baked.

#### *Moist Heat Cooking*

Another efficient means of destroying the granular structure of starch is accomplished with moist heat. At room temperature, starch granules remain insoluble in water. Upon heating, the granules absorb water and expand. With continued heating, the granules rupture and the component molecules separate (Arons and Paschall 1975:85). Swelling in heated water to the digestible stage is known as gelatinization. Complete gelatinization is a result of critical level of temperature, amount of time, and amount of water used (Sweetman and MacKellar 1954:510). Five-percent concentrations of corn starch are completely gelatinized after boiling for one or two minutes. At a temperature of 95° C, five minutes is required for gelatinization of a five-percent solution (Sweetman and MacKellar 1954:510). More heat is required when the concentration of starch is increased above a five-percent solution.

The most efficient way of boiling starches is to use a metal or ceramic container. Stone-boiling can be used to boil mush, but the process is so difficult and inefficient as to make it nearly useless. In attempts to stone-boil corn meal, I ascertained that most of the corn meal rendered was indigestible. What was not left raw by the process was hard, scorched, and adulterated; only a minimal amount was gelatinized, making its nutrients available.

#### *Popping*

Popping grass seed is a specialized method of dry-heat cooking. Iodine reactions (Banks et al. 1973:180-185) indicate that popping corn alters the chemical structure of the starch within the kernel and disrupts the starch granules. During popping, the highly branched structure of amylopectin is fragmented into the linear amylose.

In nontechnical literature such as cookbooks, the process of popping corn is often described as expansion of moisture trapped inside the kernel, causing the tightly constricting hull to explode, but crushed popcorn kernels also pop, showing that this explanation is inaccurate. Some have suggested that popping corn results from a combination of gelatinized starch and steam pressure inside the kernel (McGee 1984:242). However, such complete gelatinization requires more water (Sweetman and MacKellar 1954:510) than popcorn's 10-15 percent content. So, while the starch structure within popcorn is altered to a digestible form by popping, the popping process has not been explained and apparently is not well understood.

With no adequate understanding of how popping works, it is difficult to predict which seeds and grains will be suitably processed with this particular dry-heat method. While flour-corn kernels expand upon heating, they apparently do not undergo complete structural change as popcorn kernels do. These differences in popping efficiency might be due in part to differences between the chemical composition of their respective starches.

I have attempted to pop the seeds of several species of wild grasses, but failed to discover any wild seeds that will pop as consistently as modern popcorn. Indian ricegrass (*Oryzopsis hymenoides*), a wild grass, was collected during the summer of 1986 in Albuquerque, New Mexico, and during the summers of 1991 and 1992 in the area surrounding Gunnison, Colorado. Portions of the 1986 collection were stored in a Mason jar and portions were subjected to dry heating. Unfortunately, amounts of the popped and unpopped grains were not quantified, so estimates are given. The first application of dry heat caused 60 percent of the grains to pop. Several months later, some of the stored ricegrass was subjected to dry heat, and about 20 percent popped. Still later—approximately ten months after collection—more of the stored grains were subjected to heat, and only 2-3 percent popped. None of the ricegrass kernels from the Gunnison area popped. I do not know whether this failure to pop is due to a geographical difference in grass populations or to some other factor. Further collections and popping research is planned.

### Vitamin E

While the action and function of vitamin E in mammals is poorly understood, deficiency possibly causes habitual abortion, male sterility, and reabsorption of the fetus (Mason and Horwitt 1972a, 1972b; Scott 1969). It has been suggested that high-fat diets increase the need for vitamin E (Ames 1972:313). Unsaturated fats, especially linoleic acid, decrease absorption of vitamin E in the intestine and increase the metabolism of vitamin E, thus depleting the stores of vitamin E within the body (Brubacher and Wiss 1972:258). Linoleic acids are found in high concentrations in nuts, refined vegetable oils, and lard (Watt and Merrill 1975:Table 3).

Clinical studies have demonstrated the results of vitamin E deficiency in humans (Farrell et al. 1977; Gibson 1990; Sokal et al. 1985). Disease can cause malabsorption leading to Vitamin E deficiency (Farrell et al. 1977:233-

234). Deficiency symptoms include shortened lifespan of red blood cells and hemolytic anemia in premature infants. Anemia is also common among infants fed diets high in polyunsaturated fats and iron (Zapsalis and Beck 1985:281). Administration of vitamin E supplements or fortified formula counteracts these conditions.

Mammal flesh is not a good source of vitamin E (Gibson 1990:398). Today's major sources of vitamin E are oils obtained from seeds such as corn and safflower. Domesticated grasses are good sources of vitamin E, but it is important to note that levels of vitamin E in wild grasses or in green-state seeds may not be equivalent to levels found in domesticated cereals. I have been unable to find reliable information on the vitamin E content of wild plants.

High levels of vitamin E in cereals may have been selected for during their domestication. The viability of grass seed during prolonged storage may be enhanced by vitamin E. Vitamin E levels decrease the longer grain is stored; for example, during storage at room temperature, ground corn loses up to 6 percent of its vitamin E per month. Possibly the high concentration of vitamin E contained within the plant embryo serves as a stabilizer during seed dormancy (Mason 1944:115).

### Summary of Grass Seeds and Implications for Human Consuption

Starch is a major nutritional component of grass seed, and the chemical makeup of each starch varies with the taxon. A fully ripened grass seed contains more nutrients "crystallized" in its starch granules than does a green grass seed; however, the more mature the granules, the more digestion-resistant they are. Both *in vitro* and *in vivo* evidence shows that raw starch is not digestible by humans. Cooking starchy foods changes the structure of starch, rendering it digestible. Moist-heat cooking has been shown to be an effective method of cooking starches. Also, some starches lend themselves to popping, a dry-heat method.

If the assessment of raw starch as a poor food for humans is correct, then several implications may be drawn. First, human use of wild-grass seed might have involved exploiting what nutrients are available during the "milk" stage of unripened seed. Allen (1974) and Tindale (1977) report firsthand accounts of the grass-seed culture of Australia. From these accounts it is obvious that Australians collected, stored, and consumed grass seeds. It is also clear that grass seeds were important to the aboriginal economy. Green seed was stored for future use in bags, mud-grass packets, and haymows. Allen's summary statement (1974:316-317) about the Australian grass-gathering system is pertinent to this discussion.

> There is no doubt that the wild millets gathered by the Bagundji were brittle-rachis grains (Flannery 1969a:295), which allowed rapid dispersal of seed once the grass was ripe. The Bagundji overcame this problem and avoided the necessity of genetically modifying the grasses in order to obtain tough-rachis grains, by gathering them before they were fully ripe.

Second, human use of wild-grass seed depends on some form of cooking if the seed is fully ripe. The most effective cooking method is boiling. Stone boiling mush is possible, but the low return of digestible food given the high amounts of effort and seed expended make extensive use of this process unlikely. However, boiling whole or ground seeds in ceramic containers is very efficient. The success of bread baking depends on the grass species exploited and on the use of leavening. Popping depends on the species of grass exploited, and perhaps on the length and conditions of storage prior to use.

Last, consumption of grass seed may positively influence the fecundity of human populations. Intake of domesticated cereal products (high in vitamin E) may, in part, be responsible for observed population increases among historic Eskimo groups (Binford and Chasko 1976). Such consumption may increase vitamin E intake and absorption, resulting in more pregnancies and/or less infant death.

## ARCHAEOLOGICAL INTERPRETATIONS OF GRASS USE

The suggestion that grass seed was an important part of the prehistoric hunter-gatherer diet (McGregor 1982:135; Wills 1988:93; Woodbury and Zubrow 1979:43) is largely based on ethnographic descriptions of historic populations. Firsthand observations by chroniclers illustrate that grass seed was collected, stored, and consumed by North American aboriginal populations. Two individuals unambiguously describe grass seed as an important resource. John Muir (1979:225-226) described the Mono Indians performing such a collection in 1864.

> The Indians I had met near the head of the canon had camped at the foot of it the night before they made the ascent, and I found their fire still smoking on the side of a small tributary stream near Moraine Lake; and on the edge of what is called the Mono Desert, four or five miles from the lake, I came to a patch of elymus, or wild rye, growing in magnificent waving clumps six or eight feet high, bearing heads six to eight inches long. The crop was ripe, and Indian women were gathering the grain in baskets by bending down large handfuls, beating out the seed, and fanning it in the wind. The grains are about five eighths of an inch long, dark-colored and sweet. I fancy the bread made from it must be as good as white bread.

Also during the 1860s, Dan DeQuille made observations of Paiute grass collection.

> Three squaws now hove in sight each with a huge basket of conical form suspended upon her back. They had been gathering the seeds of a species of water-dock, and of various grasses growing in the marshes near the mouth of the slough [DeQuille 1963:38]

> This valley was covered by a most luxurious growth of bunch grass and mountain red-top, with groves of nut-pine in groups about its borders; here and there we saw Indian women, with their conical baskets on

their heads, gathering the harvest of grass seed, while the children were playing near by in the shade of the pines [DeQuille 1963:83].

DeQuille further noted that the grass harvest was important to the Indian's subsistence. The band's leader, Juan, requested that the visitor's party camp away from the grass fields because DeQuille's horses were in competition with the Indians for the grass harvest.

> As soon as it began to grow dark on the mountains the squaws lashed the *endoowames* into the baskets, and suspending them on their backs by a strap passing over their foreheads, the men drew their rags about them, rose up and all departed for their dwellings in the sunny little valley a quarter of a mile below. This little lap of land, resting high up on the side of the mountain, was the one bright jewel set in this great rocky spur: here were groves of timber for shade or fuel, here was grass to furnish seeds for bread, and here were springs of delicious water. Captain Juan took care in giving us a camp to take us above and beyond this valley in which dwelt his subjects- he did not wish our animals to trample down and devour the grain fields of the villagers, and he was right [DeQuille 1963:105].

The descriptions above demonstrate that grasses were harvested for seed and that the seed was a valuable, not a casual, resource. It is not clear what the terms "villagers" and "dwellings" mean in terms of length of residence of the grass collectors. However, there is an indication that this was not a simple camp of only a few days' duration.

The European observers were undoubtedly influenced by the importance of bread in their own culture; they may have assumed the Indians were baking leavened bread. (For a description of this infatuation with bread see Muir 1979:75-85.) It is not known whether bread-baking is a European introduction, although Weatherwax (1954) has suggested that leavened bread was unknown in the New World prior to contact.

While it is possible that post-contact Indians might have been baking bread, it is also possible that they might have been making porridge or mush by boiling ground seeds in ceramic containers. The historic peoples of the Great Basin were manufacturing and using ceramic vessels at the time Muir and DeQuille observed them.

Researchers have assumed, based on such ethnographic descriptions, that grass seed was part of the wide range of plant and animal resources that contributed to Archaic hunter-gatherer subsistence in the western U.S. (Jennings 1964:150, Matson 1991:129). Others have concluded that throughout the Archaic, grass seed was stored for future use (Carmichael 1986:213; Irwin-Williams 1979; Stiger 1980; Woodbury and Zubrow 1979:43). It has been posited that certain prehistoric sites functioned as grass-gathering stations (Carmichael 1986; Matson 1991; Stiger 1980; Wills 1988). The concept of the Desert Culture (Jennings 1964) is based in large part on the ethnographic descriptions of hunter-gatherers living in the desert environment of the Great Basin at the time of European contact, and is central to much description of the Archaic manifestation in the Southwest (Beckett and

MacNeish 1987). Grass-seed collection and storage have been important to models of Archaic settlement pattern and land use (Irwin-Williams 1979; Stiger 1980; Thomas 1971:33), based on Steward's (1938) classic reconstruction of the aboriginal lifestyle.

Indeed, wild-grass seeds are sometimes recovered from Archaic archaeological deposits. It is possible, however, that these seeds may not be evidence of consumption as food. Grasses were used historically and prehistorically as pads, beds, tinder, and construction material for basketry and structures. Also, rodent activity (recent and prehistoric) is responsible for the presence of some grass stems and seeds in archaeological deposits. Rodents take up residence in structures even while people are present and after the humans depart, rodents often become plentiful. Rodents bring grasses as food and nesting material into human-built constructions and nesting spots may be made in abandoned firepits and storage features. Fire, a natural component of the ecosystem, consumes occupied and abandoned houses and carbonizes pads, beds, and construction material as well as rodents' food caches and nests. Natural processes (rodents and fire) may contribute concentrations of burned seeds to archaeological assemblages.

Fortunately, unambiguous information on human consumption of grass may be gained from coprolites (fossil human feces) recovered from archaeological deposits. Table 1 gives the frequencies of grass seeds in coprolites from sites in the northern Southwest and the Great Basin. The data from these two areas are given together because of the supposed similarities between the Desert Culture and the Southwestern Archaic and because Steward's (1938) Great Basin ethnographic description is often used to model the Southwestern Archaic.

The coprolite data given in Table 1 indicate grass consumption. Not only did the kinds of grass used vary, but the amounts consumed—and the relative role of grass seed in subsistence patterns—also vary greatly. Among Early Hunter-gatherer coprolites, only those from Dust Devil Cave (Van Ness 1986) show marked grass consumption. Seventy-nine of the 81 coprolites yielding grass seed contained dropseed (*Sporobolus cryptandrus*); two coprolites contained Indian ricegrass (*Oryzopsis hymenoides*). Many of the dropseed grains had apparently been consumed while green (Margaret Van Ness, 1992 personal communication). Of the grass seed found in coprolites from Early Agriculturalist-Preceramic contexts, the majority is Indian ricegrass (Matson and Chisholm 1991). Information on pre-consumption processing of seeds found in these coprolites is not available. Coprolites from times later than the Early Agriculturalist-Preceramic period contain seeds of a variety of grasses and starchy sedge seeds. With the data at hand, there is no way to tell whether these seeds were green when consumed, whether they were stored resources, or whether some of the seeds were ingested as a by-product of eating whole rodents or large-mammal organ contents.

A pattern of grass-seed use seems apparent. Early in the prehistoric record, grass seeds were consumed green (dropseed from Dust Devil Cave).

**TABLE 1. Wild Grass Seeds in Prehistoric Coprolites.**

| Location of Sample | Number of Samples | Number of Samples with Wild Grass Seeds (%) |
|---|---|---|
| | **Early Hunter-Gatherer** | |
| Danger Cave, all levels[a] | 46 | 0 (0) |
| Hogup Cave, ca. 9000-650 BC[a] | 51 | 2 (4) |
| Dust Devil Cave ca.6800-4800 BC[b] | 97 | 81 (84) |
| | **Late Hunter-Gatherer** | |
| Lovelock Cave, AD 740-1805[c] | 101 | 5 (5) |
| | **Early Agriculturist-Preceramic** | |
| Glen Canyon, Basketmaker II[a] | 3 | 1 (33) |
| Cedar Mesa, Basketmaker II[d] | 28 | 9 (32) |
| | **Early Agriculturist-Ceramic** | |
| Southwest, Basketmaker III[e] | 20 | 2 (10) |
| | **Agriculturist-Ceramic** | |
| Hogup Cave, Fremont levels[a] | 6 | 3 (50) |
| Pueblo III sites in Southwest[e] | 139 | 37 (27) |
| Glen Canyon site Pueblo II-III[f] | 4 | 0 (0) |
| | **Post-Agriculturist** | |
| Glen Canyon site post-Pueblo[f] | 9 | 6 (67) |
| Hogup Cave, Shosoni levels[a] | 3 | 2 (67) |

[a] Fry 1976
[b] Cowan 1967; Roust 1967
[c] Van Ness 1986
[d] Matson and Chisholm 1991
[e] Stiger 1977a
[f] Stiger 1977b

Later, poppable wild grasses were exploited (ricegrass from Early Agricul-turalist-Preceramic deposits). Ceramic-using peoples exploited a wide variety of grass seed. It should be noted that the coprolites from post-agriculturist proveniences reflect the dietary importance, and the species variety, of exploited grasses as reported by Steward (1938); this is not true of coprolites from earlier hunter-gatherer proveniences. Other archaeologists (Bettinger and Baumhoff 1982; Euler 1964; Schroeder 1963) have suggested that the appearance of post-Fremont ceramic material with seed processing equipment in the Great Basin may represent an immigration of new hunter-gatherer peoples. These new technologies may indicate exploitation and processing of grass seed with ceramic vessels in a subsistence system unlike that used by earlier hunter-gatherer peoples.

## DISCUSSION

I have suggested that ripened grass seed, when raw, is a poor source of human nutrition because of the structure of their starch granules. For its nutrients to be available to humans, grass seed must be consumed either green or cooked. Ripe-seed collection and storage imply that cooking preceded consumption. Both bread-making and popping, two alternative cooking methods in the absence of ceramics for boiling, can be done only with a few specific taxa.

As demonstrated by the coprolite data, preceramic grass-seed consumption in the American Southwest was probably limited. The sequence of changing use of grass seed corresponds to the use of ceramics. Early agriculturists in the Southwest used popcorn, a domesticated grass whose nutritional components are accessible to humans without ceramics. Later, during times associated with ceramic vessels, flour corn was grown. In the post-agricultural period, wild grasses were gathered and ceramic vessels were used to cook the wild-grass seed. This sequence suggests that archaeological models of the Archaic subsistence system that are based on the ethnographic hunter-gatherers may incorrectly incorporate extensive grass use.

Use of green seeds and fully ripened seeds probably were integrated into prehistoric subsistence systems in very different ways. Most likely, levels of storage and processing technology played important parts in determining how seeds were prepared for consumption. The different ways of using grass seed are logical responses in light of the biochemical data and ethnographic observations described above. It should be suspected that preceramic grass gathering was primarily a foraging adaptation (Binford 1980) with consumption of green grass and with limited bulk procurement and storage. Some short-term storage might have been practiced if a poppable grass, such as Indian ricegrass, was exploited; the storage period might have been limited to the few months after collection that ricegrass remains poppable.

Given that grass-seed use without concomitant use of ceramics was probably limited, it is interesting to note that corn was cultivated prior to the use of ceramics. Dick (1954) long ago pointed out that early corn in the Southwest was a popcorn. Early corn has been found in deposits as popped kernels (Hurst 1942). After the introduction of ceramics, corn grown by Southwestern agriculturists did include popcorn and other varieties of corn, but was predominantly non-popcorn flour corn.

### Explaining the Introduction of Corn

Many researchers working to understand the introduction of farming into the American Southwest make two assumptions. The first assumption, accepted by most researchers, is that corn was first domesticated in Mexico, then brought into the Southwest.

> If one expects agriculture to develop in a general south to north trend—which we know is the case on a larger North American scale—one would expect maize horticulture to develop first in the southern Southwest, as that area is both closer—and more similar to—Mexico (Matson 1991:207).

A second assumption is that sedentism and the importance of stored food followed the increasing importance of corn in subsistence. Evidence given for this assumption is the appearance of houses and storage features in the far south regions of the Southwest (i.e., the Milagro Site in the Tucson Basin) before their appearance in the northern Southwest.

> In Anasazi territory sedentary village life did not occur until the Christian era, with the Black Mesa Basketmaker II Lolomai Phase

being the earliest contender for this status. The Milagro site indicates that at least some pithouse villages oriented around floodwater maize farming existed by 2800 B.P. (Matson 1991:194).

The Milagro Site near Tucson produced small shallow pithouses, storage pits, and 86 fragments of corn (Matson 1991:191-194).

> The meaning of this site is indisputable. By 850 B.C. San Pedro people were relying on floodwater maize farming and living for at least large parts of the year in sedentary, pithouse villages (Matson 1991:193).

After evaluating the dating of early corn remains and of habitations in the Southwest, Berry (1982, 1985) concludes that early structures are found shortly after the appearance of corn. He argues that the Southwestern transition from hunting-gathering to agriculture is abrupt. Similarly, LeBlanc (1982) includes a few additional cultural traits in his search of the literature on early agricultural sites, asserts that these traits follow the appearance of corn in the record, and argues for a short transition to agriculture. Matson (1991), Wills (1988), LeBlanc (1982), and Berry (1982) all believe that the use of pithouses and storage accompany or follow shortly behind the spread of corn farming into the Southwest.

> Documented pithouses dating to the Late Archaic seem to occur in a geographic belt extending from southeastern Arizona through eastern Arizona and into the Black Mesa region of northeastern Arizona (Gummerman 1966; Wendorf 1953). . . . Many of these pithouses produced evidence of maize cultivation, although this evidence is not directly related to the adoption of maize in the Southwest, which occurred earlier (Wills 1988:68-69).

These researchers have not considered the archaeological remains of substantial houses and storage features on the margins of the Colorado Plateau that date as early as 8000 B.P.. Some Archaic settlement systems include relatively sedentary phases. Overwintering habitation structures and storage pits are known for most of the Archaic period (Metcalf and Black 1991; Stiger 1986). These houses are very similar to those found in later agricultural periods in the Southwest. Many of the early habitation sites are found in "marginal" mountainous areas (often over 6000 feet elevation, and in the northern parts of the Southwest) from northern New Mexico to southern Wyoming. There is evidence of bulk procurement and storage of plant foods to support these winter occupations.

Comparative studies of Archaic and early Formative lithic technology, settlement patterns, and architecture conclude that, at present, the main archaeologically recognizable distinction between Archaic and Basketmaker winter-habitation sites is the presence of corn (Stiger 1986; Stiger and Larson 1992). Based on these comparative studies, one may argue that the introduction of corn did not greatly change the existing subsistence-settlement system. Most likely, corn was integrated into an overwintering subsistence pattern. Prior to corn's introduction, stored plant foods were probably seeds and nuts. These stored plant foods are important to understanding the Archaic and the way early farming was incorporated into the subsistence system.

It is probably safe to surmise that Archaic subsistence varied from region to region. In some areas, corn might have replaced or supplemented *Chenopodium* or piñon-nut collection. In other areas, corn might have been incorporated into a grass-gathering subsistence base.

> Thus introducing maize basically adds to an existing lowland summer base camp without changing the seasonality of the settlement pattern. In addition, we can see how a further step could develop where water, additional resources, and reliable maize agriculture are all located at the same spot—resulting in a lowland agricultural pithouse village occupied year round, such as seen at Milagro (Matson 1991:242).

We may see two different processes favoring corn's integration into existing subsistence systems. Corn probably had the advantage of being poppable longer after storage than did wild-grass seed. Additionally, corn fields might have been planted in areas where native plants produced low yields. If corn was used as Minnis (1985) suggested, i.e., similarly to earlier grass seed, then it could have been stored for a longer time than grass and remained poppable. If corn was used similarly to some other stored plant food with a long "shelf life," then it probably gave additional control over the geographic distribution of harvests; corn could be planted in otherwise low-resource yield areas. Minnis (1985) has also suggested that cultivated plants replaced or supplemented parts of a subsistence system already in place, a system that possibly included planted or encouraged wild plants.

These two processes might have been active in different subsistence-system situations, such as low elevations and high elevations. Additionally, there might have been a biological process favoring the spread of corn into cultural systems with limited farming of wild plant species.

## CONCLUSION

Consumption of stored ripe grass seed has further nutritional implications for human populations. Consider a hypothetical situation of two competing agricultural systems, one based on grass seeds (such as popcorn) high in vitamin E, and one on a seed plant low in vitamin E (perhaps a cheno-am or composite). Given identical situations of other variables, such as mobility, overwintering on stored resources, or social organization, the system based on grass seed might experience increased fecundity due to increased vitamin E intake.

Obviously, fecundity is only partly dependent on fertility. Cultural actions such as abortion, infanticide, and social rules may have greater influence on fecundity than does fertility. However, given identical situations in a labor-based system in which births are valued, increased vitamin E intake may positively influence the reproductive potential of humans within that system. Such a cultural system would have the potential for increased growth and reproduction as a system, and, perhaps, a competitive edge over a less fertile system.

If popcorn had been introduced into a region whose inhabitants were already using planted, encouraged, or even wild crops stored for overwintering, such competition would have encouraged the expansion of corn-growing systems. Farming may not be archaeologically recognizable if the agriculture was based on a plant other than an archaeologically recognized cultivar.

Basketmaker-like habitation sites with houses and storage pits are known from throughout the Western Archaic period (Stiger 1986). Absent any radiocarbon determinations, the main difference between Basketmaker and Archaic seems to be the presence of corn remains in the former. Evidence of horticulture using non-genetically modified plants, as suggested by Minnis (1985), would not be recognized as such by archaeologists.

The transition from hunting-gathering to agriculture may be difficult to observe and explain if we look only at indicator traits, such as houses, storage pits, and corn, in the archaeological record. The way resources are integrated into subsistence systems might be much more complex than generally considered. However, examination of the variation in resource roles would provide important clues to how and why cultures change.

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## REFERENCES CITED

Allen, H.
1974 The Bagundji of the Darling Basin: Cereal Gatherers in an Uncertain Environment. *World Archaeology* 5:309-322.

Ames, S.
1972 Occurrence in Foods. In *The Vitamins*, vol. 5, edited by W. Sebrell and R. Harris, pp. 233-248. Academic Press, New York.

Arons, H. L., and E. F. Paschall
1975 Common Sugars and Starches. In *Nutrients in Processed Foods: Fats-Carbohydrates*, edited by P. L. White, D. C. Fletcher and M. Ellis, pp. 85-97. Publishing Sciences Group, Acton, Massachusetts.

Banks, W., C. T. Greenwood, and D. D. Muir
1973 The Structure of Starch. In *Molecular Structure and Function of Food Carbohydrate*, edited by G. G. Birch and L. F. Green, pp. 177-193. J. Wiley and Sons, New York.

Barnett, J. E. G.
1973 The Structural Basis of Carbohydrate Digestion and Absorption. In *Molecular Structure and Function of Food Carbohydrate*, edited by G. G. Birch and L. F. Green, pp. 216-233. J. Wiley and Sons, New York.

Beazell, J. M., C. R. Schmidt, and A. C. Ivy
1939 On the Digestibility of Raw Potato Starch in Man. *Journal of Nutrition* 17:77-83.

Beckett, P. H., and R. S. MacNeish
1987 The Archaic of South Central New Mexico. Manuscript on file, Environmental Management Office, Fort Bliss, Texas.

Berry, M. S.
1982 *Time, Space, and Transitions in Anasazi Prehistory.* University of Utah Press, Salt Lake City.
1985 The Age of Maize in the Greater Southwest: A Critical Review. In *Prehistoric Food Production in North America,* edited by R. I. Ford, pp. 279-307. Anthropological Papers No. 75. Museum of Anthropology, University of Michigan, Ann Arbor.

Bettinger, R. L., and M. A. Baumhoff
1982 The Numic Spread: Great Basin Cultures in Competition. *American Antiquity* 47:485-503.

Binford, L. R.
1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4-20.

Binford, L. R., and W. Chasko
1976 Nunamiut Demographic History: A Provocative Case. In *Demographic Anthropology,* edited by E.B.W. Zubrow, pp. 63-143. University of New Mexico Press, Albuquerque.

Brubacher, G., and O. Wiss
1972 Vitamin E Active Compounds, Synergists, and Antagonists. In *The Vitamins,* vol. 5, edited by W. Sebrell and R. Harris, pp. 255-258. Academic Press, New York.

Carmichael, D. L.
1986 *Archaeological Survey in the Southern Tularosa Basin of New Mexico.* Historic and Natural Resources Report No. 3. Environmental Management Office, Division of Engineering and Housing, Fort Bliss, Texas.

Cowan, R. A.
1967 Lake-margin Ecologic Exploitation in the Great Basin as Demonstrated by an Analysis of Coprolites from Lovelock Cave, Nevada. *University of California Archaeological Survey Reports* 70(4):21-35.

DeQuille, D.
1963 *Washo Rambles.* Westernlore Press, Los Angeles.

Dick, H. W.
1954 The Bat Cave Pod Corn Complex: A Note on its Distribution and Archaeological Significance. *El Palacio* 61(5):138-144.

Euler, R. C.
1964 Southern Paiute Archaeology. *American Antiquity* 29:379-381.

Farrell, P. M., J. G. Bieri, J. F. Fratantoni, R. E. Wood, and P. A. Di Sant'Agnese
1977 The Occurrence and Effects of Humans Vitamin E Deficiency: A Study in Patients with Cystic Fibrosis. *The Journal of Clinical Investigation* 60:233-241.

Fry, G. F.
1976 *Analysis of Prehistoric Coprolites from Utah.* Anthropological Papers No. 97. University of Utah, Salt Lake City.

Gibson, R. S.
1990 *Principles of Nutritional Assessment.* Oxford University Press, New York.

Hurst, C. T.
1942 Completion of Work in Tabeguache Cave. *Southwestern Lore* 8:7-16.

Irwin-Williams, C.
1979 Post-Pleistocene Archaeology, 7000-2000 B.C. In *Southwest,* edited by A. Ortiz, pp. 31-42. Handbook of North American Indians, vol. 9, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C.

Jennings, J. D.
1964 The Desert West. In *Prehistoric Man in the New World,* edited by J.D. Jennings and E. Norbeck, pp. 149-174. University of Chicago Press, Chicago.

Kerr, R. W.
1950 *Chemistry and Industry of Starch*. Academic Press, New York.
Langworthy, C. F., and H. J. Deuel, Jr.
1920 Digestibility of Raw Corn, Potato, and Wheat Starches. *Journal of Biological Chemistry* 42:27-40.
1922 Digestibility of Raw Rice, Arrowroot, Canna, Cassava, Taro, Tree-Fern, and Potato Starches. *Journal of Biological Chemistry* 52:251-261.
LeBlanc, S. A.
1982 The Advent of Pottery in the Southwest. In *Southwestern Ceramics: A Comparative Review*, edited by A. H. Schroeder, pp. 27-52. The Arizona Archaeologist No. 15. Arizona Archaeological Society, Prescott.
Mason, K. E.
1944 Physiological Action of Vitamin E and Its Homologues. *Vitamins and Hormones* 2:107-154.
Mason, K. E., and M. K. Horwitt
1972a Effects of Deficiency in Animals. In *The Vitamins*, vol. 5, edited by W. Sebrell and R. Harris, pp. 272-292. Academic Press, New York.
1972b Effects of Deficiency in Man. In *The Vitamins*, vol. 5, edited by W. Sebrell and R. Harris, pp. 293-309. Academic Press, New York.
Matson, R. G.
1991 *The Origins of Southwestern Agriculture*. University of Arizona Press, Tucson.
Matson, R. G., and B. Chisholm
1991 Basketmaker II Subsistence: Carbon Isotopes and Other Dietary Indicators from Cedar Mesa, Utah. *American Antiquity* 56:444-459.
McGee,H.
1984 *On Food and Cooking: The Science and Lore of the Kitchen*. Charles Scribner's Sons, New York.
McGregor, J. C.
1982 *Southwestern Archaeology*. University of Illinois Press, Urbana.
Metcalf, M. D., and K. D. Black
1991 *Archaeological Excavations at the Yarmony Pit House Site, Eagle County, Colorado*. Cultural Resource Series No. 31. Bureau of Land Management, Denver.
Minnis, P. E.
1985 Domesticating People and Plants in the Greater Southwest. In *Prehistoric Food Production in North America*, edited by R. I. Ford, pp. 309-339. Anthropological Papers No. 75. Museum of Anthropology, University of Michigan, Ann Arbor.
Muir, J.
1979 *My First Summer in the Sierra*. Houghton Mifflin Company, Boston.
Roust, N. L.
1967 Preliminary Examination of Prehistoric Human Coprolites from Four Western Nevada Caves. *University of California Archaeological Survey Reports* 70(4):49-88.
Scott, M. L.
1969 Studies on Vitamin E and Related Factors in Nutrition and Metabolism. In *The Fat Soluble Vitamins*, edited by H. DeLuca and J. Suttie, pp. 355-368. The University of Wisconsin Press, Madison.
Schroeder, A. H.
1963 Comments on Gunnerson's "Plateau Shoshonean Prehistory." *American Antiquity* 28:559-560.
Sokal, R.J., W. F. Balistreri, J. H. Hoofnagle, and E. A. Jones
1985 Vitamin E Deficiency in Adults with Chronic Liver Disease. *The American Journal of Clinical Nutrition* 41:(1)66-72.

Southgate, D. A. T.
1976 *Determination of Food Carbohydrates.* Applied Science Publishers, London.

Stevenson, M. (Coxe)
1915 *Ethnobotany of the Zuni.* Pp. 31-102 in Thirtieth Annual Report of the Bureau of American Ethnology for the Years 1908-1909. Washington.

Steward, J. H.
1938 *Basin-Plateau Sociopolitical Groups.* Bulletin 120. Bureau of American Ethnology, Smithsonian Institution, Washington, D.C.

Stiger, M.
1977a *Anasazi Diet: The Coprolite Evidence.* Unpublished Master's thesis, Department of Anthropology, University of Colorado, Boulder.
1977b Dietary Analysis of Human Coprolites From 42Sa683, Glen Canyon. Manuscript on file, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.
1980 *Archaeological Inventory and Cultural Assessment, Curecanti National Recreation Area, Colorado.* Occasional Studies in Anthropology No. 7b. Midwest Archaeological Center, National Park Service,Lincoln.
1986 *Technological Organization and Spatial Structure in the Archaeological Record.* Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

Stiger, M., and M. Larson
1992 A Radiocarbon Date from the Cottonwood Cave Corn Cache and Problems Interpreting the Origins of Farming in Western Colorado. *Southwestern Lore* 58:26-36.

Sweetman, M. D., and I. MacKellar
1954 *Food Selection and Preparation.* J. Wiley and Sons, New York.

Thomas, D. H.
1971 *Prehistoric Subsistence-Settlement Patterns of the Reese River Valley, Central Nevada.* Unpublished Ph.D dissertation, Department of Anthropology, University of California, Davis.

Tindale, N. R.
1977 Adaptive Significance of the Panera or Grass Seed Culture of Australia. In *Stone Tools As Cultural Markers: Change, Evolution and Complexity,* edited by R. V. S. Wright, pp. 345-349. Humanities Press, New Jersey and Australian Institute of Aboriginal Studies, Canberra.

Van Ness, M. A.
1986 *Desha Complex Macrobotanical Fecal Remains: An Archaic Diet in the American Southwest.* Unpublished Master's thesis, Department of Anthropology, Northern Arizona University, Flagstaff.

Watt, B. K., and A. L. Merrill
1975 *Composition of Foods.* USDA Agricultural Handbook No. 8. Government Printing Office, Washington, D.C.

Weatherwax, P.
1954 *Indian Corn in Old America.* The MacMillan Company, New York.

Wills, W. H.
1988 *Early Prehistoric Agriculture in the American Southwest.* School of American Research Press, Santa Fe.

Woodbury, R. B., and E. B. W. Zubrow
1979 Agricultural Beginnings, 2000 B.C.–A.D. 500. In *Southwest,* edited by A. Ortiz, pp. 43-60. Handbook of North American Indians, vol. 9, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C.

Zapsalis, C., and R. A. Beck
1985 *Food Chemistry and Nutritional Biochemistry.* John Wiley and Sons, New York.