

Chapter 3

Cultigen Chenopods in the Americas: A Hemispherical Perspective

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Introduction

Few if any of us working with archaeological plant remains 30 years ago dreamed that a chenopod could by now have achieved Supergrain status in the popular food world. Back then, North American chenopod was considered a lowly weed by most archaeologists, and quinoa was not well known outside of Peru and Bolivia. Now, of course, quinoa is the darling of celebrity chefs around the world, even featured on the cover of *Time* Magazine's September 1, 2011 issue. A Google search for quinoa recipes will turn up millions of results. Boxes of quinoa are sold in chain supermarkets across North America, it is available in bulk at stores catering to the health-conscious, entire cookbooks are dedicated to this single ingredient, and quinoa dishes are offered several times a week in the main cafeterias at our colleges

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M.P. Sayre and M.C. Bruno (eds.), *Social Perspectives on Ancient Lives
from Paleoethnobotanical Data*, DOI 10.1007/978-3-319-52849-6_3

and universities. Its virtues are widely appreciated: a subtle nutty flavor, gluten-free, fuller suite of amino acids, and higher protein content than staple cereals such as rice, wheat, or maize (National Research Council 1989). UNESCO (General Assembly Resolution 66/221) declared 2013 the International Year of Quinoa in recognition of its high nutritional value, deep cultural roots in the Andes, and its potential to aid in resolving world hunger.

This meteoric rise in public appreciation is paralleled by archaeological research that magnifies our understanding of the role and significance played by members of the genus *Chenopodium* in the pre-Colonial Americas. In 1980, quinoa was of course recognized as an important Andean crop, but the timing of its domestication and geographic particulars of its production were not well understood. In eastern North America, *Chenopodium* was included in the pre-maize Eastern Agricultural Complex (EAC), but its domesticated (vs. wild or weedy) status was questioned, and it seemed reasonable to suppose that if domesticated chenopod had been grown in eastern North America, it was probably introduced from Mesoamerica (Wilson 1981). Phylogenetic relationships among species in North, Central, and South America were of considerable concern (Hunziker 1952; Wahl 1952; Wilson 1990; Wilson and Heiser 1979), but the miracles of modern molecular biology were in their infancy, and ancient DNA research was unborn.

What has been learned about *Chenopodium* since, and what we focus on in this chapter, extends far beyond the initial question of how to recognize domesticated *versus* wild populations in the archaeological record. Here, we summarize recent contributions made by archaeologists and colleagues from other disciplines toward understanding the many factors involved in the domestication of *Chenopodium* in North and South America (Fig. 3.1). We focus on these two regions and the domesticated forms of *C. berlandieri* and *C. quinoa*, for two reasons. First, advancements in both regions have emerged from mentorships and collaborations of researchers in these two areas. Second, both of these crops appear to have played a central role in the development of complex societies in each region, yet their roles took very separate paths. Thus, a comparison of chenopod research in North and South America sheds light on processes of domestication and intensification of this particular crop, and also contributes to broader discussions of agricultural developments worldwide.

We begin with research that provides the intellectual and collaborative link between the two regions: the study of seed morphology. While new methods to document micro-morphological markers of domestication in chenopod were first employed in eastern North America, use of these techniques has subsequently clarified what was a complicated process of quinoa domestication in South America and pointed toward a greater diversity than initially anticipated. Since the establishment of the domesticated status of North American chenopods, morphological traits have been used to identify distinct subspecies or varieties of this crop. We then turn to advances in molecular studies, which have recently clarified the independent domestication of chenopods in several different regions across the Americas, but particularly in North America. Molecular studies in the Andes have

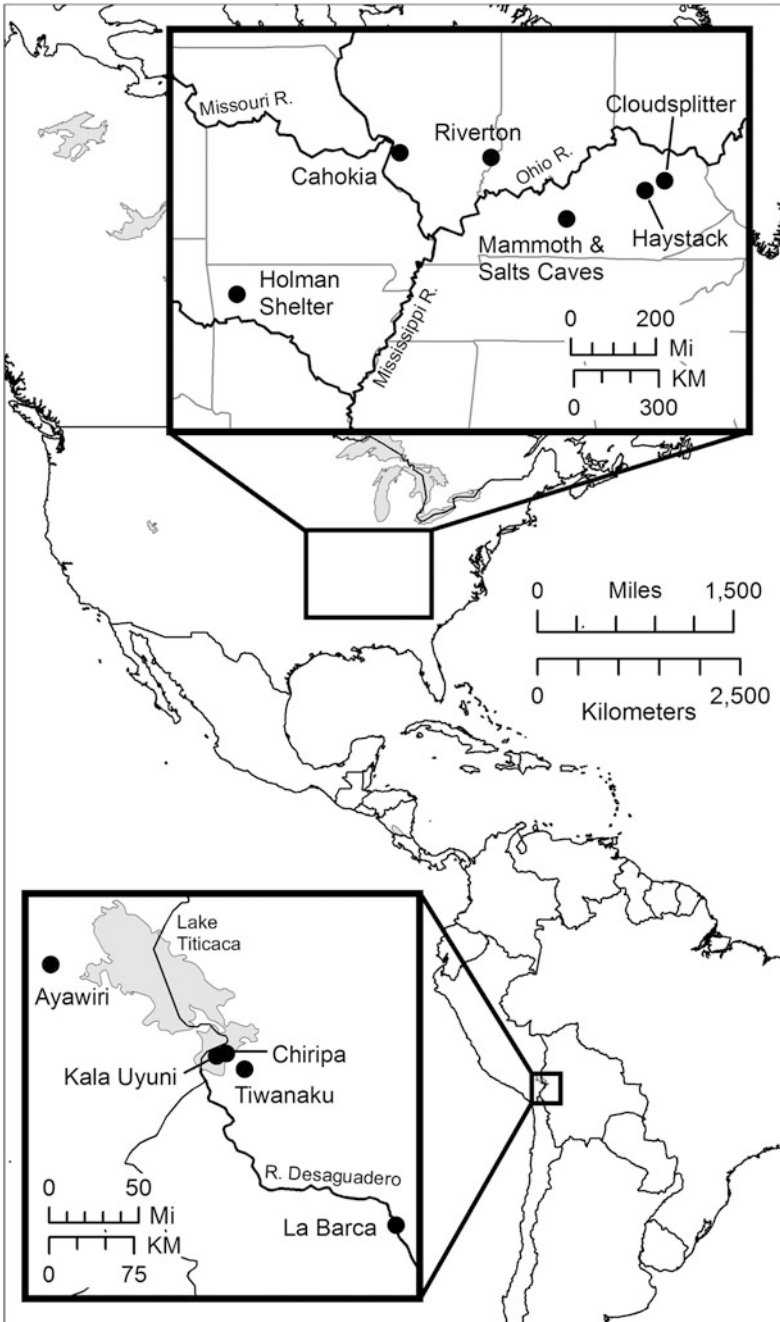


Fig. 3.1 Location of sites mentioned in text

focused primarily on agronomic issues, but many scholars are still working toward identifying the progenitor(s) of quinoa.

These advances in studying the morphology and molecular components of chenopod domestication permit us to explore the more pressing questions of why members of the genus became crops in both regions and what role(s) they played in later agricultural systems of these respective areas. These crops constituted food that was central to and inseparable from considerations of identity, status, ritual, exchange, and sociopolitical life in both of these regions. A comparison of the social and political contexts of chenopod domestication is significant because while this human intervention resulted in very similar biological consequences for the plant, the cultural conditions and consequences for domestication and later intensification were quite different. An appreciation of these chenopods as important foods in each region allows us to reflect upon their individual trajectories in North America and in the Andes.

Morphological Diversity in the Andes

The foundation of archaeological approaches to *Chenopodium* domestication is the study of morphometric attributes of the seeds themselves. Collecting measurements on attributes such as seed size and seed coat thickness using both light and scanning electron microscopy was pioneered by Wilson (1981), Smith (1985a, b), Fritz (1986), Fritz and Smith (1988), and Gremillion (1993) for eastern North American chenopods and then employed by Nordstrom (1990) and Eisentraut (1998) in the Andes. New digital technologies for microscopy have enhanced our ability to collect this type of information with great accuracy and speed. Seed coat thickness can now be measured directly from the SEM image on a computer screen, and seed diameter can be calculated with software (such as ImagePro Plus) that traces the circumference of the seed on a high-resolution image. In both cases, the values are automatically entered into a digital database. These techniques are more accurate than measuring with an ocular micrometer and much faster, permitting us to take more measurements.

Recent research highlights the complexity and diversity of chenopod domestication in the Andean *altiplano*. The botanical situation in the Andes is complicated by the presence of two domesticated species: the well-known quinoa (*C. quinoa*); and a less-appreciated cultigen called kañawa (*C. pallidicaule*), still grown by traditional farmers, often in the most extreme and risk-prone environmental zones. Presenting further challenges, quinoa has a weedy companion, *quinoa negra* (*C. quinoa* var. *melanospermum*), and there is a common wild/weedy species with medicinal properties called *paiko* (*C. ambrosioides*) (Wilson 1990). Bruno (2001, 2006) approached the problem of identifying chenopod types and distinguishing between domesticates and their wild or weedy relatives by coding for a combination of quantitative and qualitative attributes: seed coat thickness; seed diameter; ratio of seed coat thickness to diameter; margin configuration; and seed coat texture.

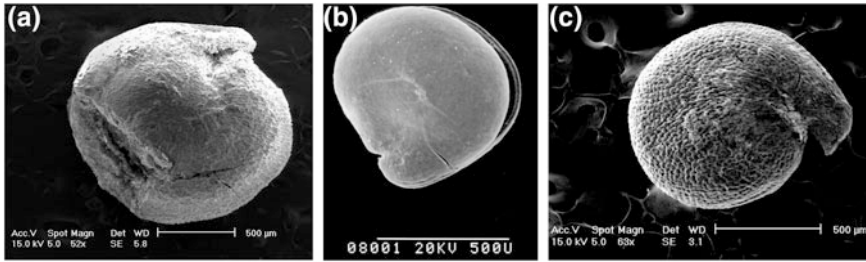


Fig. 3.2 **a** Scanning electron microscope image of a carbonized domesticated quinoa seed (covered by pericarp) from Chiripa, Bolivia, specimen #CCH89. **b** Scanning electron microscope of La Barca Type 1 specimen #LB108. **c** Scanning electron microscope image of a wild kañawa type (Unknown Amaranthaceae Bruno 2008; La Barca Type 2, Langlie et al. 2011) from Chiripa, Bolivia specimen #WU8001. All scales are 500 microns (0.5 mm)

This approach enabled Bruno and Whitehead (2003) to document the economic importance of domesticated quinoa and the existence of a crop–weed complex from as early as 1500 B.C.. at Chiripa on the Taraco peninsula in the southwest Lake Titicaca Basin. Recently, Bruno has been working on identifying a chenopod type from the Taraco samples with seeds that are smaller in diameter than quinoa or quinoa negra, have a smooth to canalculated seed coat, and are round in shape, which she labeled as “unknown Amaranthaceae” (Bruno 2008, pp. 292–296) (Fig. 3.2). Analysis is ongoing for comparative collections from Bolivia of wild kañawa seeds, and it is likely that they are a wild form of kañawa (Bruno et al. 2013).

To the south, in the Bolivian province of Oruro, BrieAnna Langlie and colleagues (2011) described a previously unrecognized morphological type of thin-testa chenopod from the La Barca site, a Formative (1500-400 B.C.) Wankarani complex village. After reading Gordon’s (2006) work on modern Mexican chenopods, Langlie added the attribute of “beak prominence” to Bruno’s previous set of seed characteristics, and she used a new digital technique for standardized measurement of seed diameter (Fig. 3.2). Food producers at La Barca grew a distinct type of *Chenopodium* (referred to as La Barca Type 1) that does not correspond to known, modern varieties. It may have eventually crossbred with other domesticated species or varieties, or, alternatively, have gone extinct. Langlie et al. (2011) also recognized a second, less common seed type at La Barca (Type 2) that has similar attributes to the possible wild kañawa described by Bruno from the Taraco Peninsula.

With increased use of flotation and other fine-grained recovery methods from sites throughout the South American Andes, chenopods are frequently being recovered and the details of their morphology are being examined (López et al. 2015). Archaeobotanists are using these measures to describe the morphological traits of seeds to determine their domesticated status (Planella et al. 2010, 2011) as well as describe their diversity in later periods (López and Nielsen 2012). This work not only contributes to the understanding of when and where particular crops were grown (Planella et al. 2014), but it opens our minds to patterns of selection that can

vary across ecological zones, and it raises the potential of exploring seed exchange, cultural interaction, and the formation of regional cuisines. With this potential in mind, we now return to eastern North America.

New Morphological Evidence in Eastern North America

Eastern North American chenopod seeds and fruits—especially those from rock-shelter caches—were pivotal in early SEM studies where researchers established baseline methods for measuring testa thickness and scrutinizing coat texture of directly AMS-dated specimens (Smith 1985a, b; Wilson 1981). The Flotation Revolution opened the sluiceways to recovery of literally millions of chenopod seeds from storage pits, trash pits, and other contexts across the Midwest, Upland South, and Trans-Mississippi South. Thin-testa cultigen forms had been bred by 1800 B.C., and farmers grew chenopod along with other members of the EAC throughout the first millennium B.C., the first millennium A.D., and into the first half of the second millennium A.D. (Fig. 3.3). The domestication process, as reflected in a reduction in seed coat thickness, resulted from automatic seedbed competition (DeWet and Harlan 1975), in conjunction with intentional selection by early cultivators.

Newly excavated material has broadened our views, but so has reanalysis of samples uncovered decades ago. In 2009, Smith and Yarnell published an article showing that both pale and dark, thin-testa chenopod seeds dating to 1800 B.C.

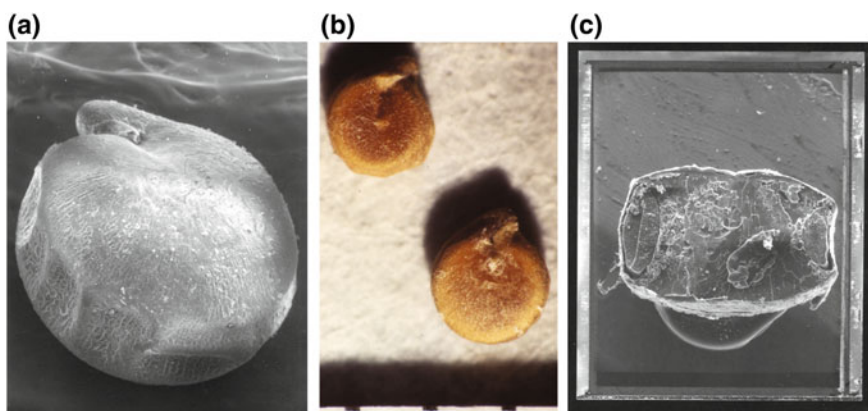


Fig. 3.3 **a** Scanning electron micrograph at $40\times$ magnification of desiccated 2000-year-old, thin-testa chenopod fruit (seed covered by pericarp) from the Edens Bluff site, Benton County, Arkansas. University Museum, University of Arkansas, accession number 32-3-391. **b** Pale chenopod fruits from Holman Shelter, Madison County, Arkansas, approximately 1000 years old. University Museum, University of Arkansas, accession number 34-22-3. **c** Scanning electron micrograph at $45\times$ magnification of cross section of pale chenopod fruit from Cow Ford, Benton County, Arkansas. University Museum, University of Arkansas accession number 32-17-22

were present in curated collections from the Riverton site in southern Illinois, excavated by Howard Winters during the 1960s. In 1963, Richard Yarnell collected and floated 50 samples from Riverton, giving us one of the first flotation-recovered assemblages of ancient plant remains from the Americas. Some samples came from contexts including middens directly adjacent to burned clay floors interpreted as “prepared house platforms” (Smith and Yarnell 2009, p. 6562). Hundreds of seeds—including 540 uncharred, “bone-colored” chenopod specimens—were remarkably well preserved due to the clay deposits, allowing documentation of intact pericarp still surrounding the inner epiderm layer and the space where the outer epiderm would have been had it not been reduced to nothingness as a result of domestication.

The presence of pale chenopod in North America more than 1000 years earlier than previously known is terribly exciting, but just as important is the fact that it is grouped at Riverton with lesser numbers of thin-testa *C. berlandieri* ssp. *jonesianum*, thicker-testa chenopod seeds that probably represent a weedy companion, bottle gourd rind (*Lagenaria siceraria*), domestic-sized sunflower (*Helianthus annuus* var. *macrocarpus*) and marshelder seeds (*Iva annua* var. *macrocarpa*), and squash rind (*Cucurbita pepo*). The Riverton site is the earliest North American setting in which so many known and potential crops were grown together as a complex by low-level food producers. Smith and Yarnell (2009) stress the importance of the fact that innovations in food production took place here in resource-rich river valleys subject to no discernible population packing or political pressure, by people also harvesting large quantities of nuts, deer, fish, and other animals.

Just as the methodology originally applied in North America has been utilized in Mexico (Gordon 2006) and South America (Bruno 2006; Langlie et al. 2011), those of us working in the U.S. can now learn from improvements and insights made by our Andeanist colleagues. The early presence of two cultivated chenopod types—pale and black—at Riverton makes it important to look more closely for morphological variability across space and through time in the Eastern Woodlands. As at La Barca, we might expect that early farmers bred cultivars that were either better adapted to local soil and climatic conditions or were preferred for reasons such as color, taste, or cooking properties. Variability has been noted, but we are now in a far better position to apply digital imaging, more standardized measurement, and multiple attribute analysis to key assemblages.

For example, an intriguing assemblage from Cahokia’s sub-Mound 51, a feasting deposit dating to A.D. 1050–1100, includes both charred and uncharred material, the latter having been preserved unburned due to rapid, deep burial (Pauketat et al. 2002). When Fritz and students at Washington University at St. Louis examined the seed-rich samples from this deposit, we hoped to find pale chenopod fruits. However, early Cahokia’s cultigen chenopod—judging by this deposit—all seemed to have been black and *chia*-like (Fritz 2000; Roberts 1996). Still, the thin-testa specimens are quite large reaching 2.2 mm in diameter. Other attributes including beak prominence and details of testa texture and thickness need

to be studied using this and numerous other well-preserved collections. If a distinct variety can be documented for the sub-Mound 51 deposit, it may help us reveal ritual and social dimensions of large-scale gatherings in Cahokia's Grand Plaza.

Ancient and Modern DNA

While there has been no debate that the origin of quinoa was in South America, when *Chenopodium* emerged as a potential crop grown in eastern North America, the debate focused on whether it was independently domesticated or introduced as a cultigen from Mesoamerica (Fritz 1984, 1986; Gilmore 1931). In recent years, the archaeological record itself has been seen as supporting independent domestication. More and more flotation samples from sites in the U.S. Midwest Riverine Area yielded chenopod seeds, projecting a history of: (a) early harvesting of morphologically wild populations, followed by selection of seeds with high proportions of thin seed coats; (b) the presence of seeds with intermediate testa thicknesses representing a probable weedy companion that evolved in the agroecological niche; and (c) the existence of both pale and black, thin-testa morphotypes. This is very different from the situation in Mexico, where evidence for pre-Colonial cultigen chenopod is elusive, in spite of Mesoamerica's rich history as a center of agricultural origins (McClung de Tapia and Rios-Fuentes 2006).

Recent analysis of ancient and modern DNA appears to confirm the independent domestication of *Chenopodium* in eastern North America. Kistler and Shapiro (2011) successfully isolated chloroplast plastid DNA from uncharred archaeological specimens from Cloudsplitter and Haystack rockshelters in eastern Kentucky and from Holman Shelter in Northwest Arkansas. Kistler and Shapiro compared the ancient haplotypes to those of modern wild *C. berlandieri* from eastern North America (17 accessions, including some collected outside the range of EAC agriculture) and from *C. berlandieri* ssp. *nuttalliae* from Mexico (6 accessions). In addition, five samples of modern *C. berlandieri* ssp. *zshackei* and four of *C. berlandieri* ssp. *sinuatum* from western North America were analyzed, and one *C. album* was included as an outgroup. Out of 44 single ancient seed samples, sufficient DNA for amplification and sequencing came from 12 seeds, some pale and some dark thin-testa. All of these conformed genetically to the wild eastern North American haplotype pattern, which was distinct from that of all modern Mexican cultigens. Kistler and Shapiro (2011, p. 3552) conclude that, "chenopod was locally domesticated in eastern North America from native wild populations independent of the cultivated Mexican lineage." This provides "compelling support for the development of an entirely indigenous agricultural complex in ENA."

Independent phylogenetic analysis of DNA—both nuclear and plastid—from modern cultigen chenopod populations and their wild relatives is being done at the University of Wisconsin by Brian Walsh and Eve Emshwiller. Preliminary results reported in 2011 are consistent with independent domestication in Mesoamerica and South America, and future ancient DNA work is planned to further refine the

phylogenetic origins of archaeological domestic forms in eastern North America (Walsh and Emshwiller 2011).

While there is little doubt that quinoa was domesticated in South America, its wild progenitor and the specific region (or possibly regions) where domestication took place are still undetermined. Because of its growing prominence as a food crop, the majority of genetic research in quinoa has been motivated by possibilities for cultivar improvement and adaptability. Many of these studies, reviewed thoroughly by Fuentes and Zurita-Silva (2013), have focused on the evolution and genetic basis of agronomically important performance traits (Balzotti et al. 2008; Maughan et al. 2009; Reynolds 2009), population structure and diversity with emphasis on cultivated forms (Christensen et al. 2007; Costa Tártara et al. 2012; delCastillo et al. 2007; Fuentes et al. 2009; Wilson 1988, 1990), and characterization of genome structure and arrangement (Bhargava et al. 2006, 2007; Jarvis et al. 2008; Maughan et al. 2004, 2006; Palomino et al. 2008), largely with respect to breeding goals. Recently, quinoa researchers have integrated genomic approaches such as whole transcriptome and high-throughput expressed sequence tag (EST) sequencing, and high-throughput genotyping (Maughan et al. 2012; Raney et al. 2014; Reynolds 2009). These tools are being used, for example, to analyze gene expression under varying field conditions and among lineages differing in growth attributes, as well as to improve models of genome structure and inheritance, the latter being especially complex issues in tetraploid quinoa. These studies signal a shift toward characterizing quinoa's adaptive pathways and population structure at the whole genome scale, and the resulting datasets will likely also prove useful in refining our understanding of the emergence of domestic forms in South America.

Comparing and Contrasting Sociocultural Contexts

Because of these advances, we are currently situated to better understand the sociopolitical contexts of chenopod domestication and its cultivation history in both ENA and the Andean *altiplano*¹. While chenopods share a common morphology and ecology, there are interesting contrasts in the roles that they played as crops and foods in cultural and political developments of the two regions.

Eastern North America

Late Archaic (c. 4000–1000 B.C.) North American societies in the Midwest riverine area established settlements along major and minor river valleys as well as in

¹The Andean region is expansive, and domesticated chenopods likely had distinct trajectories in its subregions. We focus here on our primary research areas in the Bolivian *altiplano* (a high plain that runs between the eastern and western Andes ranges).

upland settings. Tracts of oak-hickory forests, savannahs, and bottomland terraces were managed by fire and other strategies to enhance productivity and hunting efficiency (Delcourt and Delcourt 2004; Smith 2011). Exchange networks facilitated the spread of exotic objects, raw materials, ideas, seeds, and people themselves (Jefferies 1996). As summarized by Smith (2011, p. S481), "... between 5000 and 3500 BP the oak-savannah and oak-hickory forest regions were inhabited by a large number of small autonomous societies, some if not all of which were experimenting to various degrees with the cultivation of local seed plants and sharing their success and failure, as well as their seed stores, along well-established networks of interaction." Domesticated bottle gourds were present across the region by this time, and the native eastern *Cucurbita pepo* ssp. *ovifera* had been domesticated and distributed widely, as had sunflowers and the closely related crop known as marshelder (Rieseberg and Harter 2006; Smith 2006a, 2014). Chenopod entered plots of open, disturbed, enriched soil in or near settlements where early low-level food producers closely observed the properties of a growing number of seed-bearing plants and selected those most attractive to them for storage, propagation, and geographic spread.

Cultural contexts of initial chenopod domestication appear relatively nonhierarchical and disconnected from ritual activities, as far as we can discern. However, by 500 B.C., during the Early Woodland period, chenopod and other members of the EAC had become increasingly visible at places such as Salts and Mammoth Caves, Kentucky, where cavers seeking spiritually charged minerals and underground experiences left direct dietary evidence in the form of paleofeces demonstrating that chenopod contributed heavily to their diets (Crothers 2012; Gardner 1987; Yarnell 1974). Middle Woodland peoples (c. 300 B.C.–A.D. 400) who participated in the construction of elaborate Hopewellian mortuary earthworks and exchanged beautifully crafted objects made of exotic stone, shell, and copper had further increased reliance on cultigen chenopod and other EAC crops (Fritz 1993; Fritz and Smith 1988; Smith 1992a, 2006a, b). Masses of charred chenopod seeds have been recovered from pits dating to the Late Woodland period (c. A.D. 400–1000), a time of less obvious pan-regional ritual display, but significant nonetheless for demographic growth preceding the rise of Mississippian mound centers (Johannessen 1993; Simon 2000; Simon and Parker 2006).

Mississippians (c. A.D. 1000–1550) are generally categorized as maize-based farmers under whose influence most of the native EAC crops declined in importance, but the archaeobotanical record from the Central Mississippi Valley—especially the American Bottom area where Cahokia Mounds is located—shows unambiguous evidence for intensification of chenopod, maygrass (*Phalaris caroliniana*), erect knotweed (*Polygonum erectum*), and little barley (*Hordeum pusillum*) along with maize at the end of the first millennium A.D. (Lopinot 1997; Simon and Parker 2006). The contents of the sub-Mound 51 feasting pit at the edge of Cahokia's Grand Plaza, discussed above, attest to the continuing popularity of chenopod and other EAC crops in communal gatherings during the climax of this extremely complex civic-ceremonial center (Pauketat et al. 2002). Surprisingly, maize was poorly represented in this enormous deposit. Not until the greater

Cahokia region was mostly depopulated 600–700 years ago did the native seed crops drop out of the agricultural system that had for centuries sustained the largest, densest, and most politically complex center north of Mesoamerica.

Causes for the decline of chenopod production in eastern North America after c. A.D. 1200 continue to be debated and may never be fully understood. A hemispherical view that encompasses the trajectory of quinoa through the present day raises a red flag against falling back on the suspiciously ethnocentric explanation that *C. berlandieri* ssp. *jonesianum* and other small native grains were inherently inferior to maize in productivity, taste, storability, or other qualities that must have mattered to Mississippian people, including chiefs or priests, during the first half of the second millennium BP. Sociopolitical factors cannot be discounted, however, and should be considered along with ecological ones. Maize did rise to economic dominance; two of the EAC crops—sunflowers and eastern ovifera squashes—were still widely grown and eaten; and, after A.D. 1200, common beans (*Phaseolus vulgaris*) were finally incorporated into late prehistoric farming systems in the Eastern Woodlands. In contrast, chenopod, maygrass, marshelder, erect knotweed, and little barley disappeared as crops without written documentation, although an early eighteenth century French description of a plant called *choupi-choul*, sown casually by Natchez Indians in mudflats, is likely to be a reference to chenopod (Smith 1992b).

As part of the shift to a system that focused on maize, beans, and squashes, farmers increasingly concentrated on individual plants that grew in discrete clusters, a classic pattern being the “hills” of intercropped Three Sisters agriculture as practiced by historic Iroquois-speaking tribes (Mt. Pleasant 2006). Small grains that were probably broadcast by hand rather than planted in holes dug by digging sticks or hoes seem to have become relegated to peripheral patches in regions where they had once played a major economic role. Furthermore, dramatic population shifts occurred across the Midwest prior to A.D. 1492, and the impacts of pre-Colonial emigration and relocation must have disrupted both agricultural traditions and cuisines even before Old World invaders and diseases began wreaking havoc. The American Bottom, former home to thousands of participants in the Cahokian social system, was largely depopulated after A.D. 1350, as were adjoining expanses of what archaeologists call the Vacant Quarter (Edging 2007). Whatever the causes of chenopod’s decline, this issue warrants further examination by researchers studying the complex dynamics of past foodways and traditional farming systems.

The Andean Altiplano

Hunters and foragers spread out across the arid highland Andes during the late Archaic period (3200–1800 B.C.) as the environment became more suitable for human habitation with warmer temperatures, increased rainfall, and patches of vegetation flourishing near lacustrine and riverine zones (Rigsby et al. 2003). These early inhabitants seasonally occupied logistical encampments across diverse

ecological areas (Aldenderfer 1989; Capriles Flores 2014). Intensification of hunting wild camelids led to management of these herds, and llamas and alpacas were fully domesticated and incorporated into the subsistence economy of transient groups around 2200 B.C. (Mengoni Goñalons and Yacobaccio 2006, p. 239). To water and feed their animals, camelid herders moved between pockets of ecologically diverse areas along the shores of rivers and lakes. Due to its weedy tendencies and role as a food for camelids, chenopods likely proliferated in the fertilized soils of corrals and in disturbed human encampments. It is within these anthropogenic areas that chenopods were likely brought under cultivation as the result of a mutualistic relationship between camelids, chenopods, and humans (Kuznar 1993; Pearsall 1992). Along with chenopods, several local tuber species were also domesticated including another crop of modern worldwide importance, the potato (*Solanum tuberosum* L.) (Hastorf 2006; Spooner et al. 2005).

Chenopods are estimated to have been domesticated toward the end of the Archaic period as early as 3000 B.C. (Bruno 2006, p. 43), but currently the only direct evidence of the domesticated form dates to the Early Formative period (around 1500 B.C.) at several sites in the Lake Titicaca basin (Bruno 2001; Eisentraut 1998). It was during the Formative period from 1500 B.C. to A.D. 400 that many of the social consequences of plant and animal domestication appear such as: the transition from transhumance to sedentary village life (Bandy 2004), increased craft specialization with common iconographic themes (Browman 1980), early signs of status differentiation (Rose 2001), and the development of unified religious traditions (Burger et al. 2000). Throughout the *altiplano* as the Formative period progressed, economically specialized farmers, fishers, and pastoralists all complemented their diets with domesticated chenopods (Bruno 2006; Bruno and Whitehead 2003; Eisentraut 1998; Langlie 2011; Langlie et al. 2011). Chenopods appear regularly in the archaeological record both in household food middens but also in unique ritual and political contexts. High densities of a wild chenopod, possibly *C. pallidicaule* (relative of the domesticate kañawa/cañihua), are found burned in situ above clay floors in Middle Formative sunken courts at the site of Kala Uyuni (the Achachi Coa Collu sector), on the southern shores of Taraco Peninsula, Bolivia (Bruno 2008, pp. 308, 309). At the site of Chiripa, on the northern shore of the Taraco Peninsula, residents stored large quantities of quinoa in bins of small structures that were part of a platform mound (Bruno and Whitehead 2003; Towle 1961). The Chiripa mound is one of the most prominent examples of Formative period corporate architecture in the region (Bandy 2001) and was continuously used for political and ceremonial purposes for generations (Hastorf 2003). The storage of quinoa in this location indicates that it was more than a mundane foodstuff during Formative period times.

The complex economic and political interactions that began in the Formative period coalesced into the first state in the southern Andes, Tiwanaku (A.D. 500–1000) (Janusek 2008; Kolata 1993). The civic-ceremonial center of the state was located just 20 km southeast of the shores of Lake Titicaca and the Taraco Peninsula, but the state's influences reached southern Peru, northern Chile and Argentina, and central Bolivia. The economic foundations of the state involved both

extensive trade networks aided by llama caravans (Browman 1980), as well as intensified agriculture (Kolata 1986). Tiwanaku leaders coordinated the expansion of raised field agriculture along the shores of Lake Titicaca (Janusek and Kolata 2004; Kolata 1986, 1991). These productive agricultural systems ensured high yields of chenopods and tubers necessary to sustain growing populations. Imported maize took on an important new political role in the region with the Tiwanaku state (Hastorf et al. 2006). Fermented maize beer was an essential part of state ceremonies and celebrations as evidenced by specialized drinking and fermentation vessels (Goldstein 2003), as well as increased C4 levels in human isotopes (Berryman 2010). Archaeobotanical studies show, however, that local chenopods and tubers continued to provide the basis of *altiplano* diets even at the urban center of Tiwanaku (Wright et al. 2003).

Around A.D. 1100, Tiwanaku collapsed and increased social tensions and climatic variability erupted into all out warfare throughout the southern highlands during the Late Intermediate period from A.D. 1000 to 1450 (Arkush 2008). People abandoned the Tiwanaku center, and populations dispersed across the landscape. For defense, warring groups strategically coalesced in hillforts (Albarracín-Jordan 1992, pp. 227–284; Arkush 2011; Bauer and Stanish 2001; Stanish 1994, p. 322). Recent archaeobotanical analysis indicates that these groups relied heavily on chenopods for subsistence (Langlie and Arkush 2016). Specifically, several dense caches of charred chenopods were found during excavations at the Late Intermediate period site Ayawiri, located west of Lake Titicaca near Puno, Peru. These caches were found in various household contexts such as pits below house floors and cooking hearths. These data indicate that even though there was climatic instability and minimal political or religious continuity in the *altiplano* after A.D. 1100, farmers maintained their long-held agricultural traditions and foodways. Additional evidence indicates this was the case throughout the far southern *altiplano* as well. Examination of uncarbonized quinoa stores in the Lipez region of Bolivia (near the Argentine border) shows that LIP farmers were cultivating a wide number of varieties for distinct culinary purposes (López and Nielsen 2012).

Around A.D. 1450, the Inca conquered the Lake Titicaca basin. Socially, politically, and economically the entire Andean region was integrated into the Inca Empire until Spanish forces took over approximately 90 years later (Rowe 1945). When the Spanish arrived, they documented the important role of quinoa to the Inca economy. For example, Betanzos (1996 [1557]) noted that when Topa Inca Yupanque consolidated the Inca Empire in the latter half of the fifteenth century, he ordered all the lords who oversaw the hinterlands to construct storehouses (known as *qollqa*) in the capital city Cuzco, and to fill these granaries with dried provisions brought in from those regions, particularly crops. Quinoa was mentioned as one of these staple finance foods, supplying sustenance for common city dwellers, elite royal politicians, warriors, and all who lived in the capital city. The Inca also demanded that the conquered regions provide laborers to help produce various crops on provincial fields, including quinoa (D’Altroy and Hastorf 1992, pp. 264–273). Several archaeologists have investigated the large number of storehouses found in Cuzco as well in the provincial centers (Bauer 2004, pp. 96–97; D’Altroy and

Hastorf 1984; LeVine 1992; Morris 1976), and thousands of charred quinoa grains have been archaeologically recovered from excavated storehouses (D’Altroy and Hastorf 1984). The tribute collection and redistribution of quinoa and other foods by the Inca provided payment, sustenance, and support for state-financed activities throughout the Andes (D’Altroy and Hastorf 1984; Earle 1992, p. 335).

After the Spanish conquest of the Andes, quinoa continued to be a mainstay in the diet for indigenous inhabitants of the region. Perhaps this was due to quinoa’s central importance not just as a vigorous crop and nutritious food, but also central to Andean rituals as a fermented beverage. For example, the Jesuit priest Father Bernabe Cobo observed while visiting the Andes in the seventeenth century that quinoa was a supremely important as chicha beer. He elaborates that at the time of conquest chicha (whether made from quinoa, maize, or molle berries) was “the height of their glory... (Andean people) never celebrate an event, whether joyful or sad, in any way other than by dancing and drinking to excess” (Cobo 1979, p. 135). In the nineteenth century, when Prussian geographer and naturalist Alexander von Humboldt traveled through Columbia, he discerned that quinoa was for indigenous people of the Andes what “wine was to the Greeks, wheat to the Romans, cotton to the Arabs” (Popenoe et al. 1989, p. 151). Although the Spanish conquerors found quinoa to be an exotic product, and later considered it an “Indian” foodstuff, its cultivation was never prohibited, and quinoa continued to provide nutritive sustenance for families (Hunziker 1952). In modern times, chenopods continue to be a pillar of the Andean *altiplano* diet, with quinoa only recently gaining worldwide popularity.

On the heels of the European conquest of the Americas, New World domesticates such as maize, potatoes, chili peppers, and tomatoes were brought to Europe and integrated into Old World cuisines. However, quinoa did not become an important part of this Columbian Exchange. Apparently the Spanish tried to grow quinoa seeds in Spain, but they failed because the seeds “arrived dead” (Tapia 2015, p. 4). Furthermore, Europeans such as Cobo (1945 [1663]) confused quinoa with the native weedy amaranth that grew on the Iberian Peninsula. This confusion likely contributed to the worldwide obscurity of quinoa outside of South America throughout the colonial era (Tapia 2015, p. 4).

Conclusions/Current and Future Directions

Chenopodium is now an icon for revival of “lost” crops (Gremillion 2014; National Research Council 1989), enabling us to learn about past foodways and to eat more healthy food today. Although this food was not “lost” to the Andeans who still eat it and now share it with the world, archaeobotanists continue to provide key insights into its domestication and prehistory in the Andes, and perhaps more significantly in eastern North America, where this crop was genuinely lost. Morphological studies integrating new techniques with old-fashioned microscopy of exceptionally preserved museum collections as well as newly excavated ones not only are refining

the story of when and where chenopods were domesticated, but are also revealing the amazing diversity of varieties and subspecies cultivated by farmers north and south. Future research into how this diversity played out in different culinary contexts promises to enrich our understanding of how these crops were shaped by and contributed to the transformations of social and political life of these ancient societies. The molecular secrets of both ancient and modern chenopods are being unraveled, and their anatomical variability categorized.

The comparison of chenopods in eastern North America and the Andean *alti-plano* reveals important differences between the trajectories of this food in both regions; there are, however, some interesting similarities. In both areas, chenopods likely introduced themselves as camp followers to foraging people's settlements in early gardens and, in the Andes, in corrals. As farmers encouraged the plant in garden plots and courtyard processing areas, it appears to have become an important contributor to both daily and special meals of early complex societies in both regions. The introduction of maize into the Andes, particularly as a food of ceremony and political clout, presented a challenge to the role of quinoa; yet, quinoa appears to have remained important to local farmers and managed to make its way into some political feasts. It is likely that quinoa's status as a reliable, decentralized foodstuff that could be cultivated at higher elevations than possible for maize allowed it to thrive during the Late Intermediate Period of the Andes. In eastern North America, the domesticated *Chenopodium* species did not enjoy a similar, strategic advantage; several centuries after maize was intensified, but before the European intrusions, the crop had lost its place as one of the most important grains produced across the Midwest and northern Southeast.

Altiplano farmers in the Andes also faced imperial incursions into their lives, first with the Inca and then the Spanish. The quinoa crop lost some of its acreage to barley and other Eurasian crops, but it continued to play a role in indigenous households. Thanks to these farmers, we can enjoy it today. Although it may seem unlikely, and would probably be quite challenging, the re-domestication of eastern North American *Chenopodium berlandieri* is not beyond the capabilities of modern researchers. The ecological and economic implications of this revival in our modern sociopolitical contexts would certainly add another interesting chapter to the long history of domesticated chenopods.

Acknowledgements We are deeply indebted to Christine Hastorf for her contributions that not only generated a great deal of the archaeological material we discuss, but also established the framework for integrating archaeobotanical data with everything else. Chenopod research benefits from Christine's vision of food and regional cuisines as central to and inseparable from considerations of identity, status, exchange, and the development of politically complex societies. As a project P.I., lab director, teacher, and theoretical innovator, Christine influenced, inspired, and enabled much of this research. We also sincerely thank Dr. Lynne Rouse for drafting the Fig. 3.1 map.

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