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ARTICLE

Homeland Food Traditions in the Tiwanaku Colonies: Quinoa and Amaranthaceae Cultivation in the Middle Horizon (AD 600–1100) Locumba Valley, Peru

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Abstract
The Tiwanaku civilization (around AD 500–1100) originated in the Bolivian altiplano of the south-central Andes and established agrarian colonies (AD 600–1100) in the Peruvian coastal valleys. Current dietary investigations at Tiwanaku colonial sites focus on maize, a coastal valley cultivar with ritual and political significance. Here, we examine Tiwanaku provincial foodways and ask to what degree the Tiwanaku settlers maintained their culinary and agrarian traditions as they migrated into the lower-altitude coastal valleys to farm the land. We analyze archaeobotanical remains from the Tiwanaku site of Cerro San Antonio (600 m asl) in the Locumba Valley and compare them to data from the Tiwanaku site in the altiplano and the Rio Muerto site in the Moquegua Valley during the period of state expansion. Our findings show high proportions of wild, weedy, and domesticated Amaranthaceae cultivars, suggesting that Tiwanaku colonists grew traditional high-valley (2,000–3,000 m asl) and altiplano (3,000–4,000 m asl) foods on the lowland frontier because of their established cultural dietary preferences and Amaranthaceae's ability to adapt to various agroclimatic and edaphic conditions.

Resumen
La cultura Tiwanaku (ca. 500-1100 dC) se originó en el altiplano boliviano de los Andes sur-centrales y estableció colonias agrarias provinciales (600-1100 dC) en los valles costeros peruanos. Si bien las actuales investigaciones sobre la dieta o alimentación Tiwanaku en sitios coloniales se enfocan principalmente en el maíz, cultivo costero con importancia ritual y política, en esta investigación tomamos un enfoque más amplio sobre las costumbres alimentarias de Tiwanaku. Nuestro objetivo es comparar la adopción de nuevas posibilidades agrarias y culinarias en la diáspora Tiwanaku con la persistencia de cultivos y costumbres agrarias de su hogar tradicional. Realizamos un análisis arqueobotánico de Cerro San Antonio (600 m snm), una colonia de la cultura Tiwanaku en el valle Locumba y comparamos nuestro análisis con los datos del sitio Tiwanaku en el altiplano, y de Río Muerto en el valle de Moquegua durante el período de la expansión política del estado altiplánico. Nuestros hallazgos muestran altas proporciones de cultivos de Amaranthaceae silvestres, maleza y domesticados, lo que sugiere que los Tiwanaku cultivaron alimentos tradicionales en los valles altos (2.000–3.000 m snm) y de los Andes (3.000–4.000 m snm) por ser su dieta cultural de preferencia y por la capacidad de Amaranthaceae para adaptarse a diversas condiciones agroclimáticas y edáficas.

Keywords: paleoethnobotany; foodways; quinoa; amaranth; Tiwanaku expansion

Palabras clave: paleo etnobotánica; estudios de subsistencia; quinua; amaranto; expansión Tiwanaku

Anthropological approaches to food decisions and practices cover the spectrum from adaptationist, structuralist, and culturalist points of view. In agrarian societies, dietary choices encompass logics that range from nutritional balance, cost limitations, and political or economic considerations to flavor and complex traditions of food preferences and practices that may or may not align with those practical considerations (Hastorf 2017). In complex cultural systems, food choices entail political and economic factors constrained by agrarian labor, ecological utility, cost efficiencies, and "prevailing ideologies of food preference" (Smith 2006:488–489).

The dialectic between practical considerations and cultural traditions of culinary practice is especially salient in contexts of diaspora involving the migration or translocation of people to new regions. Hastorf (2017:253) writes, "Culinary traditions are put to the test when people move"; culinary transformations capture immigrant histories and measure the "level of integrity of a group's identity." Indeed, in diasporic contexts, the interplay of dietary modification with dietary traditionalism can be an important proxy in considering change and continuity in migrant cultural identities. We explore this topic using data drawn from frontier communities of the Tiwanaku polity, one of the earliest states to develop in the south-central Andes during what is called the Middle Horizon period (around AD 600–1100).

The Tiwanaku civilization originated in the Bolivian altiplano in a unique highland agropastoral niche located 3,800 m asl (Janusek 2008; Kolata 1986, 2003; Stanish 2003). At the eponymous type site and in its hinterland, altiplano Tiwanaku people herded llamas and alpacas and grew frost-resistant crops, such as quinoa (*Chenopodium quinoa*), kiwicha (*Amaranthus caudatus*), potatoes (*Solanum tuberosum*), and other tuber crops: *oca* (*Oxalis tuberosa*), *ulluco* (*Ullucus tuberosus*), and *mashua* (*Tropaeolum tuberosum*; Bruno 2008, 2014; Goldstein 2005; Hastorf et al. 2006; Kolata 1986, 2003; Lennstrom et al. 1991a, 1991b; Towle 1961; Wright et al. 2003).

Throughout the Middle Horizon (AD 600–1100), the Tiwanaku civilization expanded into lowland coastal valleys (from around 600–1,500 m asl), such as the Moquegua and Locumba Valleys of Peru (Figure 1), where settlers established large colonies to cultivate temperate-zone crops that could not be grown in the Tiwanaku homeland (Goldstein 2005). Lowland cultivars include tropical fruits, such as avocado (*Persea americana)*, psychotropic plants like coca (*Erythroxylum* spp.), cotton (*Gossypium* spp.), molle pepper (*Schinus molle)*, peanuts (*Arachis hypogaea*), beans (*Phaseolus* spp.), sweet potatoes (*Ipomoea batatas*), chili peppers (*Capsicum* spp.), and, particularly, maize (*Zea mays*) (Hernández Bermejo and León 1994; Towle 1961).

In this article, we present a comprehensive analysis of archaeobotanical remains from the Andean Tiwanaku culture's provincial site of Cerro San Antonio (L1) in the Locumba Valley and compare this to data from the contemporary Tiwanaku site of Rio Muerto (M43) in the Moquegua Valley and from the homeland site of Tiwanaku (TIW) in the Bolivian altiplano of the south-central Andes (Figure 1). Highland Tiwanaku settlers occupied the lowland sites of L1 and M43 during the period of state expansion (AD 600–1100). Our goal is to compare the adoption of new agrarian and culinary possibilities in the Tiwanaku diaspora with the persistence of cultivars and preferences from their traditional homeland.

Because of its central importance to Tiwanaku's economic and ritual systems through "vertical complementarity" (Goldstein 2005; Murra 1972), maize has been the focus of dietary reconstructions of the Middle Horizon Tiwanaku expansion. We posit here that other cultivars are also significant and focus our discussion on the frost-resistant Amaranthaceae cultivars, *Chenopodium quinoa* (quinoa) and *Amaranthus* spp. Quinoa was a native and staple food for the Tiwanaku residents of the southern Titicaca Basin (Wright et al. 2003). Although traditionally grown at lower elevations (2,000–3,000 m asl) than the altiplano (around 3,800 m asl), *Amaranthus* spp. would have been recognizable to the Tiwanaku highland people and was likely a "casual food source" to them (Lennstrom et al. 1991a:6, 1991b:6). Given that maize's unique role has captured much of the attention in the discussion of Tiwanaku food investigations, it is helpful to first review the critical position of this lowland crop that bore such inordinate importance in the world's highest-altitude, pristine-state society.

Maize Mania: The Focus on Maize in the Narrative of Tiwanaku Expansion

The Tiwanaku valued maize because it could be brewed into the alcoholic beverage chicha (Biwer and VanDerwarker 2015; Goldstein 2005; Hastorf et al. 2006). Chicha is highly significant to Andean

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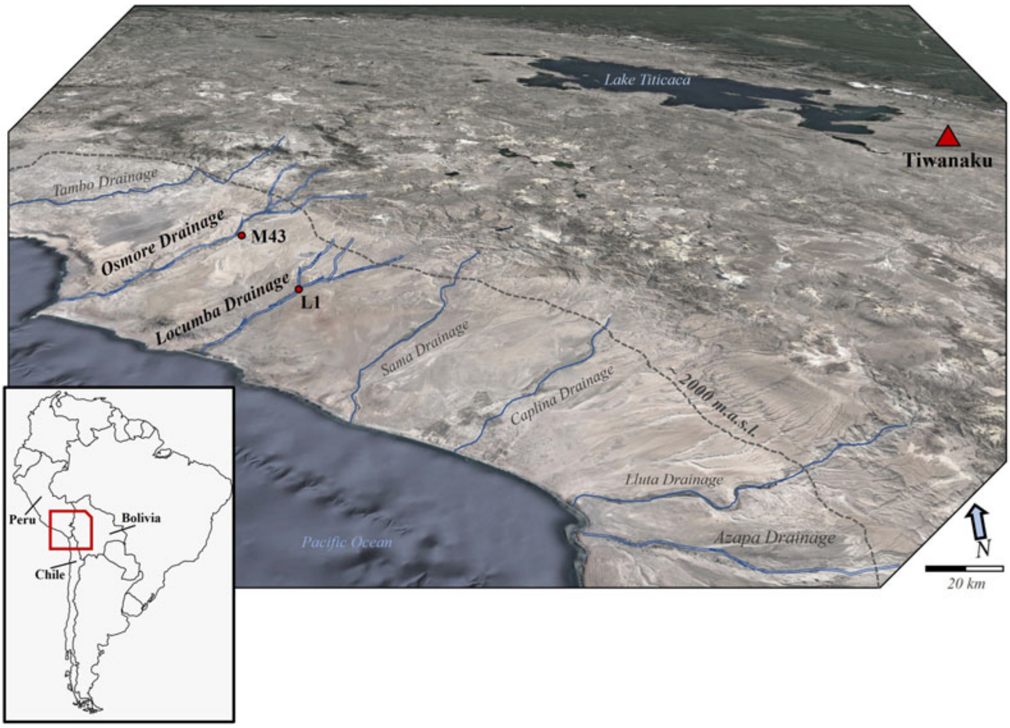

Figure 1. Tiwanaku capital (around 3,860 m asl) and coastal-valley Tiwanaku colonial sites, L1 (600 m asl) and M43 (900 m asl) (figure created by Matthew J. Sitek).

people and is consumed during labor parties, planting and harvesting ceremonies, and feasts in both the Andean past and ethnographic present (Hastorf and Johannessen 1993:118, citing Cavero Carrasco 1986; Skar 1981; Wagner 1978). Allen (1988) describes chicha as a central bonding material, and Hastorf and Johannessen (1993:118) agree, writing, "It is a symbolic seal to contracts—spiritual (e.g., asking for fertility of the herds and land), economic (e.g., work and exchange of goods), and social (e.g., marriage)."

The ancient Tiwanaku of the Bolivian altiplano considered maize to be a luxury imported food. It has poor resistance to frost and thus was nonlocal to the altiplano; however, it is native to the Peruvian coastal valleys (Hastorf et al. 2006). Throughout the Middle Horizon (AD 600–1100), the Tiwanaku settlers expanded from the altiplano and established colonies in the Peruvian coastal valleys to acquire maize and other lowland-valley crops (Berenguer Rodríguez 1998; Goldstein 1989, 1990, 1993, 2003, 2005; Hastorf et al. 2006; Janusek 2002; Knudson et al. 2014; Kolata 1986, 1993; Ponce Sanginés 1980). Although maize was mainly imported to the altiplano from coastal-valley colonies, Tiwanaku altiplano farmers learned to grow the crop in the "microclimatic pockets" near Lake Titicaca (Langlie 2018:170).

Vessels for chicha have served as markers for the Middle Horizon Tiwanaku expansion. The Tiwanaku corporate ceramic style was defined by the new culinary and social practices associated with chicha that emerged in the Titicaca Basin in the earlier Terminal Late Formative (around AD 350–600), and vessels for chicha making and drinking, such as the *kero*, quickly diffused into the maize-growing coastal valleys with the spread of Tiwanaku after AD 600 (Goldstein 2003, 2005). Goldstein (2003) emphasizes the economic role of chicha and how the tradition of sponsored work-party feasting in which chicha was consumed could have been a way for the Tiwanaku polity to control production, one in which alcohol played a vital function in encouraging labor (Dietler 1990:368; Goldstein 2003; Janusek 2008; Kolata 2003). The asymmetrical exchange of labor for chicha began with the Tiwanaku, and the political value of maize developed just as the Tiwanaku expanded into the maize-producing valleys (Goldstein 2003:148).

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The presence of maize in the Tiwanaku homeland and colonial sites also supports the model of Tiwanaku expansion. Maize kernels and cupules have been recovered from various contexts of Tiwanaku's urban and ceremonial center, demonstrating a 25% ubiquity in a region where maize does not readily grow; in addition, cupule morphology suggests that at least some of this maize was imported from the western valleys (Hastorf et al. 2006:430). Maize has been recovered in abundance and high ubiquity from Tiwanaku colonial sites in the Moquegua Valley, specifically from domestic and funerary contexts at Rio Muerto (Vergel Rodriguez and León 2009), domestic contexts at Omo M10 (Muñoz Rojas et al. 2009), and the Omo Temple (Gaggio 2014; Gaggio and Goldstein 2015). In 2008, the Rio Muerto project at the site of M43 recovered 140 whole maize cobs and several human coprolites showing maize consumption from a single 2×3 m domestic unit, suggesting surplus production of maize within the Moquegua Valley (Boswell 2008; Somerville et al. 2015).

Isotopic studies at the Tiwanaku type site suggest that elites enjoyed differential access to imported maize (Berryman 2010), and recent stable isotopic analysis of human skeletal remains spanning 2,000 years shows an increase in C_4 signals, suggesting maize became more important in the Lake Titicaca Basin throughout the Middle Horizon (Miller et al. 2021). Isotope analyses of Tiwanaku settlers in the lowland valleys have demonstrated maize-heavy Tiwanaku colonial diets, particularly among male settlers (Santillan Goode 2018; Somerville et al. 2015). Somerville and colleagues (2015) found that the Tiwanaku colonists consumed more C_4 plants than both earlier non-Tiwanaku people in Moquegua and Tiwanaku people living in the altiplano homeland, correlating the high C_4 dietary signal to maize because of the overwhelming presence of maize at Moquegua Valley Tiwanaku sites.

The maize-heavy diets of Tiwanaku colonists support a model of how Tiwanaku people settled lower-elevation zones to grow frost-intolerant maize and export the cultivar back to the altiplano homeland (Somerville et al. 2015:418). We caution, however, that maize may be overrepresented in isotopic analyses of the provincial Tiwanaku diet, which attribute the C_4 dietary signal to maize even though *Amaranthus* spp. may also contribute to C_4 signatures (Cadwallader et al. 2012; Santana-Sagredo et al. 2021). Similarly, maize's role might be accentuated in macrobotanical samples because of its large seed and cob size and thus visibility in archaeological-coarse screening in hyper-arid desert conditions. Sampling under these conditions often fails to recover smaller seed-size cultivars like members of the Amaranthaceae family. In what follows, we argue that using systematic archaeobotanical sampling and graduated-fine dry-screening techniques reveals other cultivars' equally important role in the provincial Tiwanaku diet. We suggest that the inhabitants of these lowland Tiwanaku sites consumed large quantities of higher-valley and highland Amaranthaceae cultivars in addition to lowland maize.

Amaranthaceae Cultivars and the Tiwanaku Civilization

Amaranthaceae cultivars may grow in many niches, but we focus here on species originating in the upper-elevation zones of the Andes (2,000–4,000 m asl). Quinoa domestication (*Chenopodium quinoa*, from the Quechua "*kinua*") originated in the Andes (Aguilar and Jacobsen 2003; Garcia 2003; Hernández Bermejo and León 1994). Throughout the Archaic period (8000–3000 BC), hunters and gatherers in Peru, Argentina, and Chile consumed wild species of *Chenopodium*, and their handling likely led to morphological changes in the cultigen (Planella 2019; Planella et al. 2015).

Morphological markers of *Chenopodium* domestication include an increase in seed size, a more prominent "beak," and a smooth, thinner testa, which makes the perisperm visible and results in a lighter seed color (Bruno 2006; Langlie 2019; Langlie et al. 2011). Archaeobotanical studies have uncovered charred *Chenopodium* seeds with morphological characteristics showing emerging human manipulation from two late Archaic Chilean-Andean contexts, dating to 1250–980 BC and 1460–1340 BC (Planella et al. 2005, 2011, 2015).

Altiplano people cultivated domesticated *Chenopodium quinoa* (quinoa) as early as 1500 BC at Chiripa on the Taraco Peninsula of Lake Titicaca (Bruno 2006; Bruno and Whitehead 2003; Bruno et al. 2021) and by 1300 BC in La Barca, Bolivia (Langlie et al. 2011). Early Formative (1600–800 BC) altiplano people practiced small-scale quinoa agriculture (Bruno 2008:22). Quinoa became the primary staple food by the Late Formative (250 BC–AD 500) when its ubiquity surpassed 90% in

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altiplano sites on the Taraco Peninsula (Bruno et al. 2021). At Tiwanaku, studies suggest that the proportions of quinoa increased throughout the Late Formative and that raised fields were created for quinoa cultivation (Wright et al. 2003).

Quinoa was likely the most important food source for the Tiwanaku residents of the southern Titicaca Basin (Wright et al. 2003). Seeds may have thickened soups, been ground into flour, boiled to make *chicha de quinoa* (*aloja*), or malted for alcohol (Cutler and Cárdenas 1947:34, 39; Goldstein et al. 2009; Towle 1961:36). Although quinoa was found in everyone's homes, research suggests that lower-status residents at Tiwanaku consumed quinoa and potatoes more frequently than higher-status residents did (Wright et al. 2003).

Along with quinoa and other frost-resistant crops, amaranth was traditionally grown at 2,000–3,000 m asl (Hernández Bermejo and León 1994:128) and in high elevation along with potatoes (Pearsall 2008:107). Domesticated several times, *Amaranthus* includes three domesticated species, *A. hypochondriacus*, *A. cruentus*, and *A. caudatus* (Gómez Pando and Ríos Alfaro 2020; Mallory et al. 2008; Maughan et al. 2011; Sauer 1967), and was an important food source in the precontact New World (Sauer 1950). *Amaranthus caudatus* (kiwicha) is grown in the Peruvian, Bolivian, and northwestern Argentinian Andes (Towle 1961). By 1500–1000 BC, quinoa, *cañihua* (*Chenopodium pallidicaule*), and *achita* or *coimi* (*Amaranthus caudatus*, kiwicha) were part of the "altiplano economy," along with three kinds of legumes—*tarwi* (*Lupinus mutabilis*), *jiquima* (*Pachyrhizus ahipa)*, and the common bean (*Phaseolus vulgaris*)—and four types of tubers: potato (*Solanum tuberosum*), oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*), and *ulluco* (*Ullucus tuberosus*; Browman 1981:410; Pickersgill and Heiser 1978). Wild *Amaranthus* spp. seeds have been recovered from the Taraco Peninsula and at Tiwanaku (Bruno and Hastorf 2016) and, as mentioned, are described as a "possible casual food source" (Lennstrom et al. 1991a:6, 1991b:6). According to Sauer (1967:104), all amaranth seeds are likely to be edible and taste like cereals when prepared properly, and amaranth leaves and stalks may be boiled as food.

The uses of quinoa and amaranth go beyond food, and the taxa may enter the archaeological record in various ways. For example, Aymara farmers burn dry quinoa grain stalks to create an ash that activates the alkaloids in coca while chewing (Bruno 2008:193, 273), and amaranth seeds have medicinal uses (Biwer 2019:126, citing Brack Egg 1999:27). Each taxon may be thought of as a field weed that is found in "canal-fed small holdings" between 1,400 and 2,500 m asl and in disturbed habitats (Biwer 2019:125; Bruno 2014:7; Bruno and Whitehead 2003:340; Lennstrom et al. 1991a:6, 1991b:6; Sauer 1967:104). This is especially true for *Amaranthus* species because only three of around 60 species are domesticated (Stallknecht and Schultz-Schaeffer 1993; Towle 1961:37) and for wild *Chenopodium* sp. seeds, such as *quinoa negra*, or "quinoa's weedy counterpart" (Bruno 2008:152). As a result, the presence of wild *Amaranthus* spp. or *Chenopodium* spp. at a site might indicate that these seeds were inadvertently brought into the space through field-processing activities (Biwer 2019:125) or might suggest that camelids consumed the seeds, which then entered the site as camelid dung that was burned as fuel (Bruno and Hastorf 2016; Hastorf and Wright 1998).

Study Sites

The Locumba Valley is in the present-day department of Tacna, south of the Moquegua (Osmore) Valley and north of the Sama, Caplina, and the Chilean Lluta and Azapa Valleys. The sector of the Locumba Valley under consideration is no higher than 1,500 m asl in the Peruvian desert region (Figure 1). This area is suitable for irrigating lowland crops, including tropical fruits, coca, peppers, peanuts, beans, chili peppers, and maize. The site of Cerro San Antonio (L1) is in the middle Locumba Valley and is 35 km from the coast at 600 m asl. This multicomponent site covers 166 ha, of which the Tiwanaku occupation comprises three sectors defined by domestic materials (Sectors A, L, and U) and 10 associated mortuary sectors (Sitek 2022; Sitek and Goldstein 2016). Our analysis of Tiwanaku provincial foodways focuses on Sectors A and L, defined by dense surface midden deposits and remnants of domestic architecture, whereas Sector U is characterized by sparse surface scatter.

We compare L1 findings to data from a Tiwanaku colonial site in the neighboring Moquegua Valley and the central Tiwanaku site in the altiplano. The Tiwanaku homeland is located about 3,860 m asl

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and 20 km south of Lake Titicaca. There, people gathered lacustrine resources on small *totora* reed boats, relied on domesticated llamas and alpacas as beasts of burden and as sources of wool and food, and grew frost-resistant crops like quinoa and potatoes (Goldstein 2005). Throughout the Middle Horizon (AD 600–1100), Tiwanaku altiplano people traveled directly to Moquegua for lowland resources and settled at Rio Muerto (Knudson et al. 2014), one of the largest settlements in the valley (Somerville et al. 2015:409). The Rio Muerto site of M43 is in the Moquegua Valley at 900 m asl, sharing a similar ecological placement to the site of L1 in the Locumba Valley.

Methods

Under the Proyecto Arqueológico Locumba (PAL) in 2016 and 2019, Sitek and Goldstein conducted surface collections and household-archaeology excavations in the three Middle Horizon (AD 600–1100) residential sectors at L1. Field excavation in L1 employed a fine-screening method and captured most botanical materials larger than 1 mm in size. Maize remains (kernels and cobs) were the most ubiquitous domesticate recovered, found in 53% of excavated contexts. Both by weight (94.24%) and count (68.11%), most of these fine-screened maize remains were cob fragments. In addition, Sitek collected 134 sediment samples from excavated domestic contexts (Goldstein and Oquiche Hernani 2019; Sitek 2022). From August to September 2019, 36 sediment samples from the primary residential sectors L1A and L1L were selected for archaeobotanical analysis (Figure 2).

Analyzing 0.5 L of each sample was sufficient because the desert environment of the Locumba Valley allows for excellent macrobotanical preservation. Decomposers do not grow in this desiccated context (Gallagher 2014), and dry-sieving techniques are most appropriate. Implementing flotation would have required unnecessary labor; more importantly, adding water to dry sediment samples may damage delicate, desiccated macrobotanical specimens (Pearsall 2000; Wagner 1988; White and Shelton 2014). In the recovery process, each sample was sifted through 4.0 mm, 2.0 mm, 1.0 mm, and 0.5 mm sieves, using a brush to ease sediment and remains through the mesh.

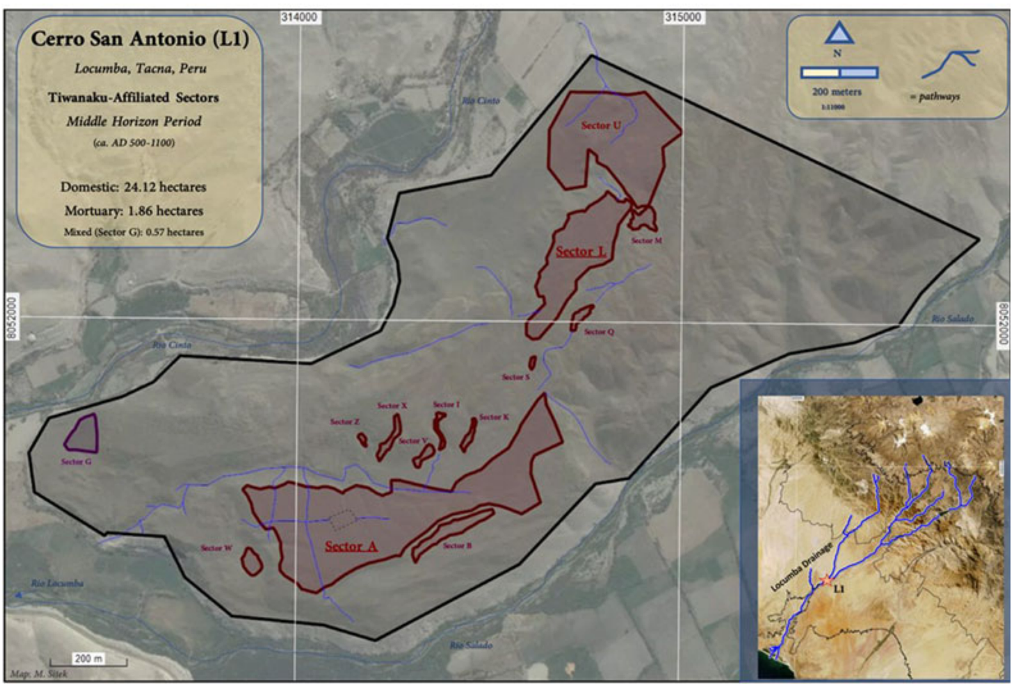

Figure 2. Site of Cerro San Antonio (L1). Archaeobotanical samples analyzed are from the primary residential sectors L1A and L1L (figure created by Matthew J. Sitek).

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After the samples were sieved, inorganic and organic materials were manually extracted from the fractions of each sample, using a stereomicroscope for the smaller fractions. The findings were identified using a preliminary photographic seed reference guide that Cindy Vergel created for Moquegua Tiwanaku sites in 2008 (Vergel Rodriguez and León 2009) and that Giacomo Gaggio supplemented in 2014; this guide has been extensively expanded and amended with the help of Jade d'Alpoim Guedes, Matthew Biwer, Maria Bruno, and Christine Hastorf. Finally, identified specimens were counted, weighed, and recorded (Supplemental Table 1).

To explore the importance of homeland altiplano foods at the site of L1, we contrasted the proportions of higher-valley and highland (about 2,000–4,000 m asl) Amaranthaceae seeds to lowland-associated (around 0–2,000 m asl) cultivars, molle fruits, peanut seeds, bean seeds, algarrobo endocarps, maize kernels and cobs, and ají seeds (Figure 3). Considering taphonomy, our analysis involved (1) maize kernels and (2) both maize kernels and cobs. Maize kernels might seem more appropriate for taxa comparisons involving consumable seeds and fruits. One might argue, however, that the tiny yet durable Amaranthaceae seeds—which also exist in large numbers on one panicle and easily bounce and fall—are more likely to be preserved than maize kernels, which were consumed and often boiled to make chicha. Maize cobs were discarded and thus more likely to be preserved than maize kernels.

Figures 4 and 5 show the relative proportions of highland to lowland foods at L1 based on taxa counts and weights. In the count-based analyses, each whole and fragmented seed has a value of 1

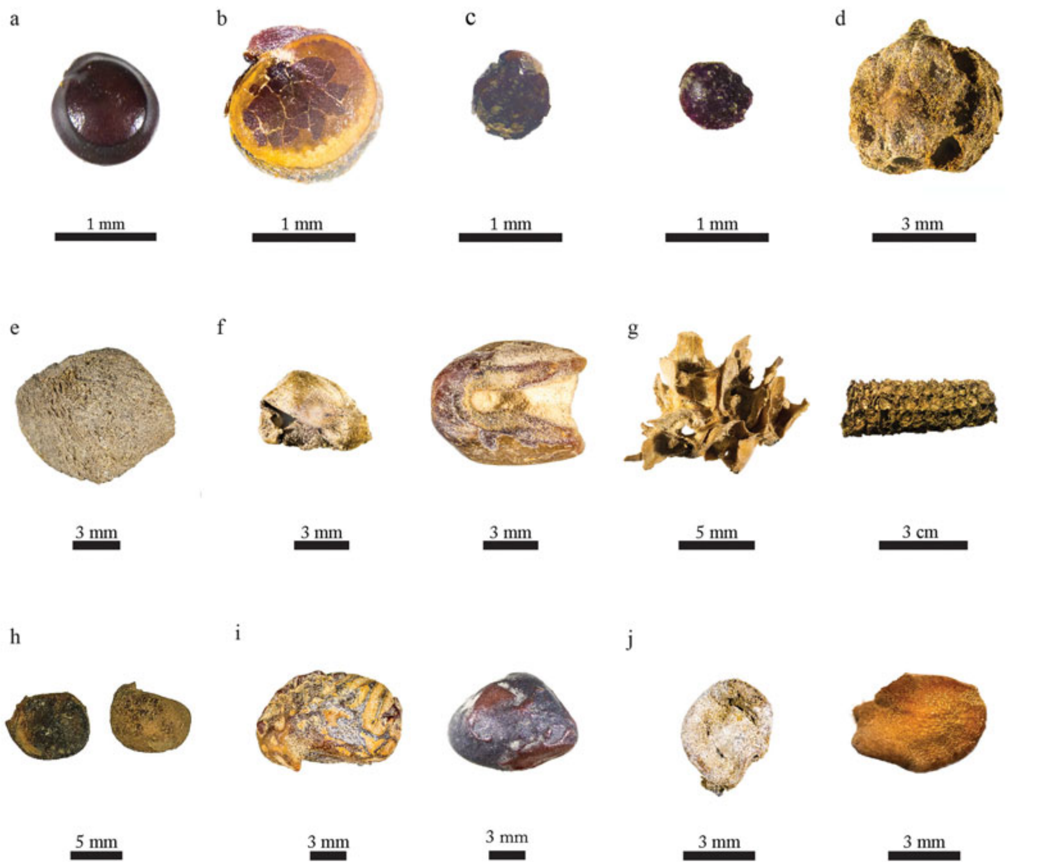

Figure 3. L1 food taxa: (a) *Amaranthus* sp. seed; (b) *Chenopodium quinoa* seed; (c) wild *Chenopodium* sp. seed (labeled as "cf. *Chenopodium* sp." in Garvin_PAL2019PEB_data) from L1 with reference to a wild *Chenopodium* sp. seed from M43 (photograph by Cindy Vergel); (d) *Schinus molle* fruit; (e) *Prosopis* sp. endocarp; (f) *Zea mays* kernels; (g) *Zea mays* fragment and whole cob; (h) cf. *Arachis hypogaea* seed; (i) *Phaseolus* spp. seeds; and (j) *Capsicum* spp. seeds (except where noted, photographs by Daniel Echecopar). (Color online)

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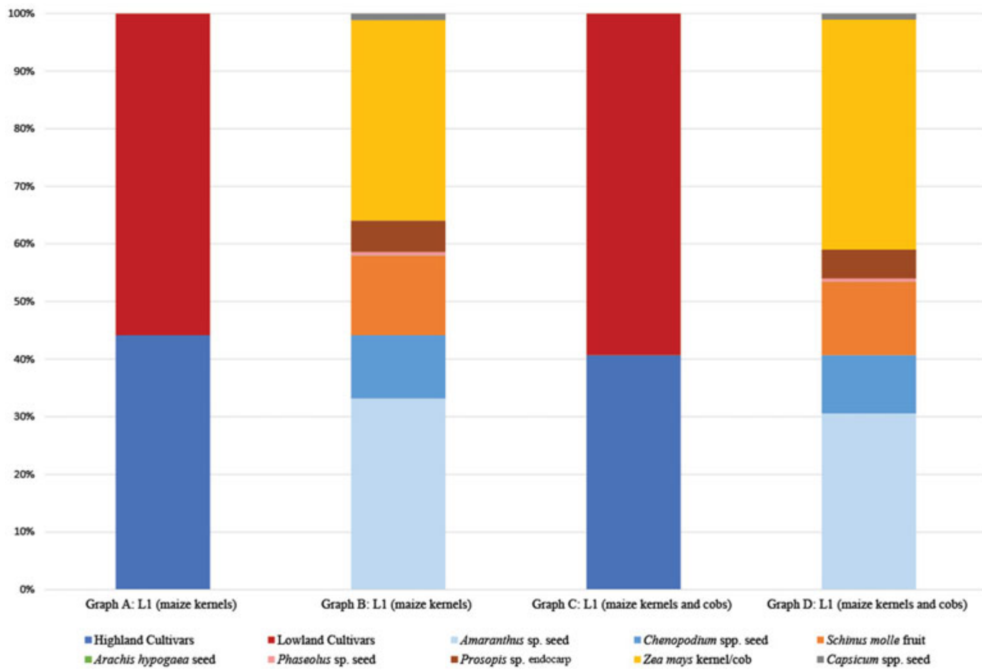

Figure 4. L1 count-based comparisons (n = 36). Graphs A and C show the total proportion of higher-valley and highland taxa (*Chenopodium* spp. and *Amaranthus* sp.) and the total proportion of lowland taxa. Graphs B and D show individual-taxa proportions. Graphs A and B use only maize kernels for calculations, and Graphs C and D include both maize kernels and cobs.

because a fragment includes more than 50% of the seed. The Fabaceae category includes seeds split down the axis of the hilum, so a "half-seed" is given a value of 0.5. Whole and fragments of maize cobs are each given a value of 1. The graphs comparing weights are most helpful in illustrating the diversity in the set of lowland foods and highlighting the significance of more massive seeds with low counts but with high nutritional or caloric value.

We then compared the L1 food taxa proportions to the same set of cultivars at the altiplano Tiwanaku type site (Hastorf et al. 2006; Wright et al. 2003) and the Rio Muerto M43 site in Moquegua (Goldstein 2005; Vergel Rodriguez and León 2009). Archaeobotanical comparisons with the Tiwanaku capital are complicated by the radically different preservation conditions of the wet Bolivian altiplano, which necessitated flotation methods for archaeobotanical analysis. Nonetheless, it was possible to draw some comparisons from the Tiwanaku database (Wright et al. 2003; Christine Hastorf, personal communication 2022). Our analysis used counts of *Chenopodium* spp., *Amaranthus* sp., maize kernels, *Capsicum* sp., and domesticated legumes from 664 Tiwanaku (TIW) samples[1] from six units. TIW tubers were purposely excluded from the analysis, because Amaranthaceae cultivars are the focus of this study.

Excavation of Rio Muerto M43 Unit 6, an exceptionally well-preserved stratified household midden in the M43F domestic sector, produced comparable sediment samples for archaeobotanical analysis. As at L1, large quantities of macrobotanical remains recovered from M43 field-screened collections emphasized larger cultigens, like maize and beans, whereas the archaeobotanical data tell a different story.

The L1, M43, and TIW comparative analysis involved counts and only maize kernels (Figure 6). We note that L1 includes an outlier sample excluded from the L1, M43, and TIW comparative analysis. Sample L1-4161 contained 481 maize kernels (11 whole and 470 fragments) of the 498 kernels (16 whole and 482 fragments), or 96.59% of the total kernel count at L1 (Supplemental Figure 1). The TIW data included a domesticated legume category ("DOMLEGUM"), so to deal with seed-identification uncertainties, we combined *Arachis hypogaea* seeds, *Phaseolus* spp. seeds, and *Prosopis* spp. endocarps to form a Fabaceae category for L1 and M43. Moreover, TIW wild

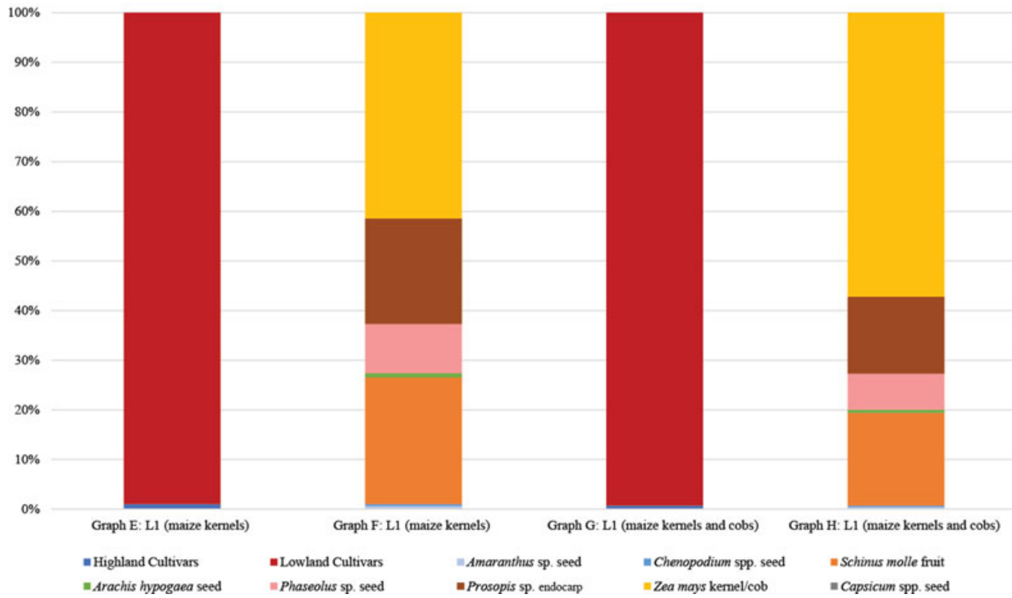

Figure 5. L1 weight-based comparisons (*n* = 36). Graphs E and G show the total proportion of higher-valley and highland taxa (*Chenopodium* spp. and *Amaranthus* sp.) and the total proportion of lowland taxa. Graphs F and H show individual-taxa proportions. Graphs E and F use only maize kernels for calculations, and Graphs G and H include both maize kernels and cobs.

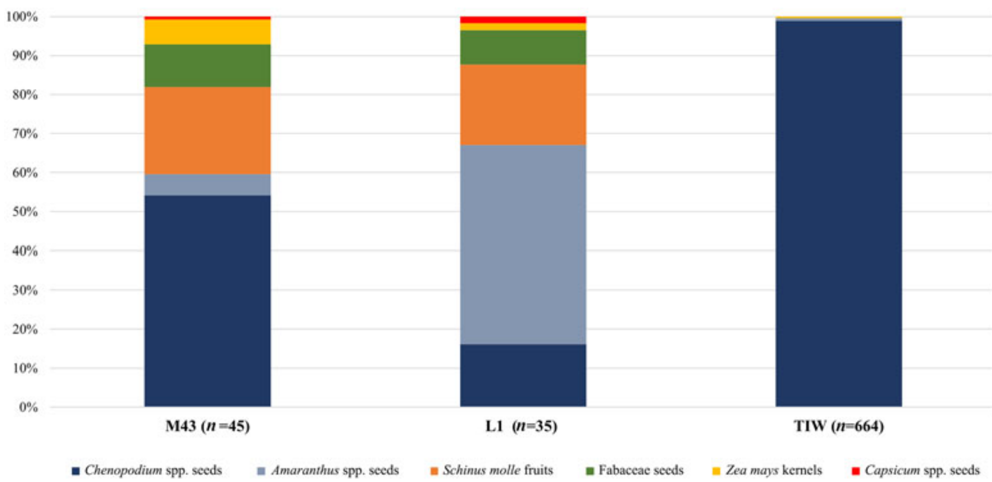

Figure 6. Count-based, food-taxa comparisons at the Tiwanaku colonial sites M43 (900 m asl; Goldstein 2005; Vergel Rodriguez and León 2009), L1 (600 m asl), and the Tiwanaku altiplano capital (around 3,860 m asl; Hastorf et al. 2006; Wright et al. 2003).

Leguminosae/Fabaceae ("WILDLEG") were excluded from the analysis. After reviewing the 2008 Moquegua Tiwanaku photographic collection, we also recognize that the M43 *Amaranthus* spp. category may have included some wild *Chenopodium* sp. seeds.

Food Taxa Recovered at Cerro San Antonio (L1)

We compared the proportions of eight historically and ethnographically important food taxa at the site of L1 in the Locumba Valley (Figure 3).[2] In addition to quinoa, amaranth, and maize cultivars, we

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explored *Arachis hypogaea* (peanut), *Capsicum* spp. (ají), *Phaseolus* spp. (bean), *Prosopis* sp. (algarrobo), and *Schinus molle* (molle).

Peanuts served as a nutritious complement to the coastal diet of precontact Peru. They were toasted, fried, boiled, and ground into *chicha de maní* (Cutler and Cárdenas 1947:34; Fernández Honores and Rodríguez Rodríguez 2007:107; Masur et al. 2018; Stalker 1997). Ají flavors largely contribute to Andean cuisine (Chiou et al. 2017; Pearsall 2008). Peruvian peoples regularly grew beans in the temperate coastal and middle valleys by the Middle Horizon (AD 600–1100). The bean, a nitrogen-fixing plant high in the amino acid lysine, agriculturally and nutritionally complements maize, a nitrogen-depleting plant deficient in lysine but higher than the bean in caloric value (Biwer 2019; Mt. Pleasant 2016; Towle 1961).

Algarrobo and molle are notable multipurpose plants of coastal Peru (Fernández Honores and Rodríguez Rodríguez 2007; Goldstein and Coleman 2004; Hernández 1942:280; Towle 1961). Archaeological evidence suggests that people ingested raw algarrobo pods and processed pods into syrup. They may also have ground pods into flour for beverages or a porridge mix (Capparelli and Lema 2011). Molle seeds may have served as a condiment, resembling black or white pepper (Goldstein and Coleman 2004:525).

L1 Comparisons of Amaranthaceae Cultivars versus Lowland Cultivars

Table 1 includes raw counts and weights of the eight food taxa at L1. Count-based taxa comparisons show that highland-associated Amaranthaceae cultivars account for 40%–44% of the archaeobotanical assemblage. These figures do not change dramatically when either using only maize kernels or combining maize kernels and cobs (Figure 4). When weight is measured, the proportion of Amaranthaceae cultivars drops considerably, comprising 0.73%–1.01% (Figure 5). As in the count-based graphs, molle and maize are significant, and the importance of *Prosopis* sp. becomes more apparent in the weight-based graphs. Finally, the low counts of cf. *Arachis hypogaea* and *Phaseolus* spp. seeds that are not visible in the count-based graphs are visible in the weight-based comparisons.

Comparing Diets at L1 to the Moquegua Tiwanaku Colony M43 and the Tiwanaku Capital

Figure 6 overwhelmingly emphasizes *Chenopodium* spp. as the dominant cultigens at the Tiwanaku capital (98.88%). At TIW, *Amaranthus* spp. represents only 0.67%, and combined lowland cultigens

Table 1. L1 Taxa Counts and Weights.

Taxa[a]	L1 Count ($n = 36$)	L1 Weight (g) ($n = 3\ 6$)	L1 Sample 4161 (maize outlier) Count	L1 Sample 4161 (maize outlier) Weight (g)
Amaranthus sp. seeds	475	0.127	3	0.000
cf. *Arachis hypogaea* seeds	1	0.181	1	0.181
Capsicum spp. seeds	16	0.000	0	0.000
Chenopodium quinoa seeds	126	0.074	0	0.000
Chenopodium sp. (wild) seeds[b]	31	0.000	8	0.000
Phaseolus spp. seeds[c]	9	1.978	0	0.000
Prosopis sp. endocarps[d]	78	4.226	6	0.402
Schinus molle fruits	197	5.086	6	0.192
Zea mays cobs	122	7.327	0	0.000
Zea mays kernels	498	8.266	481	7.658

[a] The Garvin_PAL2019PEB_data sheet includes "whole" and "fragment" categories, where each fragment is greater than 50% of the taxon. Whole and fragment taxa are each given a value of 1 to create the sum counts for this table.
[b] Wild *Chenopodium* sp. seeds are labeled as cf. *Chenopodium* sp. in Garvin_PAL2019PEB_data.
[c] The Garvin_PAL2019PEB_data sheet includes "half" *Phaseolus* spp. seeds, each given a value of 0.5 to create the sum counts for this table.
[d] *Prosopis* sp. endocarps are labeled as seeds in Garvin_PAL2019PEB_data.

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maize, *Capsicum* sp., and Fabaceae comprise 0.45%. L1 and M43 colonial residents had remarkably similar diets, relying heavily on Amaranthaceae cultivars: L1 shows 67.06% Amaranthaceae (16.09% *Chenopodium* spp. and 50.97% *Amaranthus* spp.), and M43 shows 59.54% Amaranthaceae (54.16% *Chenopodium* spp. and 5.38% *Amaranthus* spp.).

Although more L1 sediment samples should be analyzed, the L1 preliminary findings (2019) and the M43 archaeobotanical findings (2008) highlight Amaranthaceae cultivars in the diet. This contrasts with the emphasis on maize in the Moquegua diet derived from excavation findings (Gaggio 2014; Gaggio and Goldstein 2015; Muñoz Rojas et al. 2009; Vergel Rodriguez and León 2009), maize-cupule analysis (Hastorf et al. 2006), and isotope analyses (Santillan Goode 2018; Somerville et al. 2015). In short, the archaeobotanical findings subvert our perspective and show that inhabitants of Tiwanaku colonial sites heavily consumed cultivars from their homeland and upper Andean zone.

Discussion: The Implications of Amaranthaceae at L1

The preeminent cultigen of Tiwanaku, *Chenopodium quinoa*, and a similar cultigen, *Amaranthus* spp., contributed significantly to the Tiwanaku colonial diets at Cerro San Antonio (L1) and Rio Muerto (M43). At L1, Amaranthaceae seeds are found in samples recovered from hearths, domestic-waste contexts, and a storage pit containing maize and beans.

Amaranthus sp. comprises 75.16% of the L1 Amaranthaceae assemblage (Figure 7). The large proportion suggests that this weedy seed grew locally at L1 and that Tiwanaku colonists came across a familiar crop or at least one that resembled quinoa. Weedy *Amaranthus* spp. grow in disturbed habitats (Lennstrom et al. 1991a:6, 1991b:6) and at sea level (Hernández Bermejo and León 1994). No domesticated *Amaranthus* sp. seeds, like kiwicha, have been recovered from L1 (Figure 8). Weedy *Amaranthus* seeds were likely growing among field crops or in pastures where camelids graze, so these seeds may have entered domestic spaces in camelid dung that was burned for cooking (Garvin 2020); this was a common Tiwanaku altiplano practice (Bruno and Hastorf 2016). It is also possible that Tiwanaku colonists consumed the *Amaranthus* sp. seeds, along with the leaves and stalks (Sauer 1967:104).

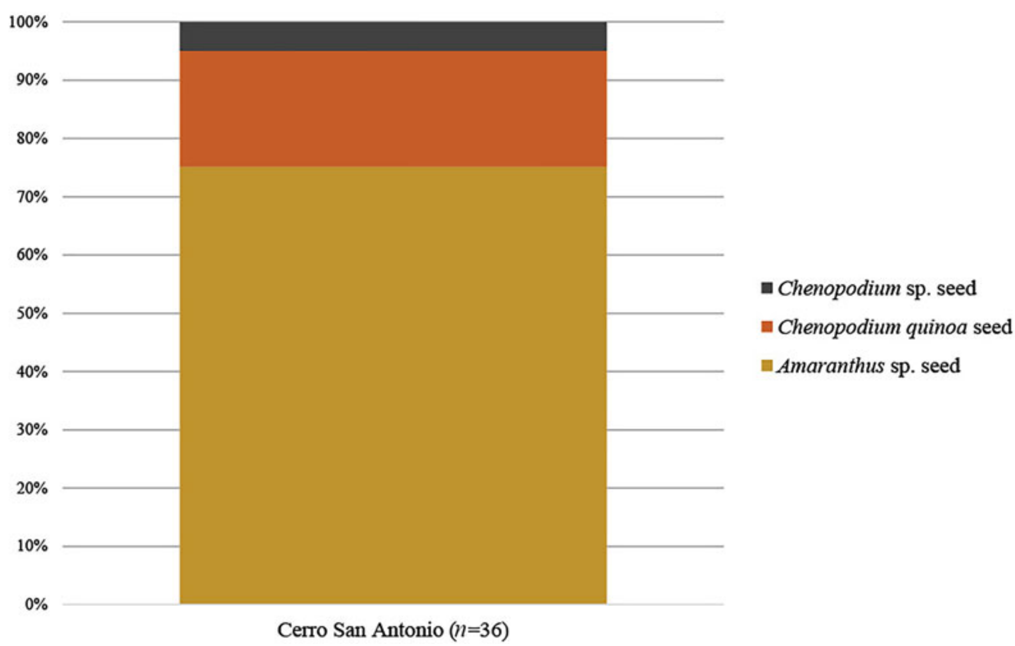

Figure 7. L1 Amaranthaceae proportions. (Color online)

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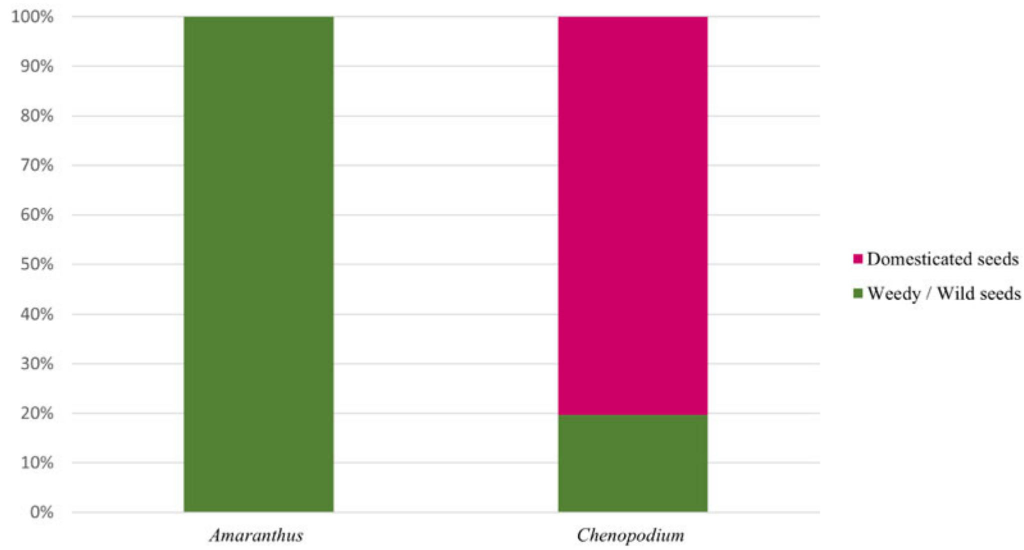

Figure 8. L1 Amaranthaceae domesticated seeds versus wild/weedy seeds (n = 36). (Color online)

Chenopodium quinoa comprises 19.94% of the Amaranthaceae assemblage (Figure 7), and its presence at L1 suggests that Tiwanaku colonists continued to consume the highland-associated cultivar by either acquiring harvested altiplano quinoa through trade or growing quinoa in the Locumba Valley.

One might argue that L1 residents acquired quinoa through trade. According to John V. Murra's (1972) vertical archipelago model, the Andean nonmarket system of production and exchange developed from small groups of people colonizing complementary ecological zones of the vertically complex ecological landscape, engaging in economic activities suitable to the zones, and acquiring resources from the different ecological zones through exchange. We might speculate that the Tiwanaku colonists left the altiplano (3,800 m asl) and established permanent or long-term residence at L1 in the Locumba Valley (600 m asl). At L1, the colonists cultivated food crops, beans, and maize that readily grew in this lowland zone and then exchanged these cultivars for highland quinoa. As mentioned, quinoa is native to the altiplano and was the most important food source for Late Formative and Tiwanaku residents of the Titicaca Basin (Wright et al. 2003). Considering this long-standing tradition and the demonstrated Tiwanaku trade of lowland crops to the highlands, it is possible that the same caravans could have brought highland chenopod produce to the lowlands or that lowland settlers brought highland crops home after visiting Tiwanaku for seasonal festivities.

Yet Tiwanaku colonists instead may have grown quinoa locally in Locumba. First, quinoa and amaranth are known to adapt to various agroclimatic and edaphic conditions (Table 2). This is because of their high genetic variability developed over their history of domestication in the altiplano and dynamic Andean environments, where crops are susceptible to frost, limited rainfall, a high rate of evapotranspiration, low soil-water retention, and saline soils (Garcia et al. 2015:26–27; Jacobsen et al. 2003; Nascimento et al. 2014). Quinoa grows in places like the altiplano salt desert of Bolivia, with just 200 mm of rainfall (Aguilar and Jacobsen 2003:39, citing Mujica et al. 1998; Jacobsen et al. 2003:102) and even in the Atacama Desert (Fuentes and Bhargava 2011; Garcia et al. 2007; Jacobsen et al. 2003).

Present-day, traditional altiplano farmers are intimately connected to quinoa biodiversity and use practices adapted to variable, adverse conditions. Andrews (2017:20–21) compiled a list of 195 quinoa names as only part of an even more extensive ethno-taxonomy used by Aymara farmers. In dry conditions, present-day altiplano farmers strategically mix quinoa varieties, such as the drought-resistant *Kcoitos* native gray variety, frost-resistant *Witullas* and *Wilas* varieties, and the more desirable but less hardy white quinoa (Aguilar and Jacobsen 2003). Such strategies can hedge bets between desirable and

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Table 2. Quinoa Cultivation and Adaptability.

Ecological Zone	Modern Quinoa Cultivation
Upper Andean Zone	Quinoa monoculture is usually practiced in upper elevations (3,800 m asl), where lowland cultivars cannot grow (Tapia 1979:17). According to Gómez Pando and colleagues (2015), Peruvian farmers use traditional techniques to farm quinoa in the upper zones (3,800 m asl) and in the higher valleys (2,300–3,500 m asl).
Andean/Coastal-Valley Zone	In the inter-Andean valleys of Peru, quinoa is grown with corn and beans or along the perimeter of potatoes (Tapia 1979:17). Gómez Pando and colleagues (2015) note how Peruvian farmers use modern mechanized irrigation technologies and high inputs of chemical fertilizers to farm quinoa in the lower Yunga zone (500–2,300 m asl).
Coastal Zone	Quinoa is grown at sea level in southern Chile (Tapia 1979:19). Peruvian farmers use modern mechanized irrigation technologies and high inputs of chemical fertilizers to farm quinoa in the Peruvian coastal areas (0–500 m asl; Gómez Pando et al. 2015).
Soil Type	Quinoa Growth and Adaptability
Well-drained soil, nearly neutral pH	Quinoa thrives in well-drained soils (Garcia et al. 2015).
Clay soils	Quinoa grows in clay soils (Garcia et al. 2015).
Pure sand	Quinoa grows in pure sand with 200 mm of rainwater (Garcia et al. 2015; Jacobsen et al. 2003).
Acidic soils	Quinoa tolerates acidic soils like those of Cajamarca (pH 4.5; Garcia et al. 2015; Mujica et al. 2001).
Alkaline soils	Quinoa tolerates alkaline soils like those of the Bolivian salt depressions (pH 9; Garcia et al. 2015; Mujica et al. 2001).
Mean Temperature	Quinoa Growth and Adaptability
15°C–20°C	Quinoa thrives in this ideal mean temperature (Garcia et al. 2015).
10°C–25°C	Quinoa tolerates mean temperatures from 10°C to 25°C (Garcia et al. 2015).
Extremely high temperatures	Extremely high temperatures may induce flower abortion or pollen death in quinoa varieties with less heat tolerance (Jacobsen et al. 2003).

productive varieties and those adapted to potential adverse conditions. Additionally, traditional communities grow quinoa in a spatial and temporal rotation known as the *aynoqas* system. Although temporal rotation alternates different crops and fallow to avoid soil depletion, the sociospatial aspect of *aynoqa* also scatters each family's holdings within the larger communities to include parcels in lower and higher microenvironments with different susceptibilities to frost and drought risks (Aguilar and Jacobsen 2003:33–34, 36).

It is likely that ancient Tiwanaku farmers, like present-day altiplano farmers, would have known of quinoa biodiversity and the relative drought, salt, pH, and temperature resistance of different varieties and would have brought a comparable set of strategies for quinoa cultivation under lowland desert conditions. Moreover, it does appear that quinoa was present in at least some lowland and desert contexts outside its center of domestication by the Formative (1800 BC–AD 400) or even earlier (Table 3).

The mixture of domesticated and wild *Chenopodium* at L1 offers insight into whether quinoa arrived via trade or was cultivated locally. López and Recalde (2016:432) present the first reliable evidence of quinoa and *ajara*, or *quinoa negra,* from the Sierras del Norte of Central Argentina (around 700–300 BP); they suggest that the "Andean crop/weed complex" mitigated crop failure. They also note that precontact people consumed quinoa and weed seeds (López and Recalde 2016:431, citing Lagiglia 2005; López 2012; Ratto et al. 2014). During the Early Formative (1600–800 BC), altiplano people harvested and consumed quinoa's weedy counterpart, *quinoa negra* (*Chenopodium quinoa* var. *melanospermum*) in equal or greater proportions than domesticated quinoa (Bruno 2008:22, citing

Table 3. Archaeological Evidence of Quinoa in Lowland and Desert Contexts.

Period	Archaeological Evidence of Lowland Quinoa Cultivation
Preceramic Context	Owen's findings (2009) suggest that quinoa was part of a precocious agricultural complex in Preceramic contexts in Peru's coastal Osmore Valley and increased in frequency in Early Ceramic contexts.
Formative Context (1800 BC–AD 400)	Watson and colleagues (2010) mention evidence of quinoa cultivation at the Alto Ramirez Formative culture (1800 BC–AD 400) sites of Playa Miller 7 and AZ-70 in the Azapa lowland valley of Northern Chile. However, the original citation does not mention quinoa (Muñoz Ovalle 2004). Quinoa is present at Pampa del Tamarugal, Guatacondo, Pircas, and Caserones sites in the Tarapacá region of the extremely dry Atacama Desert (Uribe et al. 2020:88). Formative farmers did not, however, use ^{15}N-enriched seabird guano—as became the norm in the Late Intermediate period (AD 1000; Santana-Sagredo et al. 2021)—suggesting that early cultivation may have been limited.
Middle Horizon (AD 600–1100)	*Chenopodium* spp. is present at sites in the higher tributaries of western Andean valleys, such as the Wari enclave of Cerro Baúl (Biwer 2019; Goldstein et al. 2009; Moseley et al. 2005:17270) and the Tiwanaku sites of Omo (Gaggio and Goldstein 2015:216) and Rio Muerto (Vergel Rodriguez and León 2009).

Bruno 2001:96–98). In contrast, in the Middle Formative (800–250 BC) people selected seeds and separated *quinoa negra* from the food supply (Bruno and Whitehead 2003:352).

If quinoa arrived at L1 via trade, quinoa would likely have been carefully processed and cleaned before trade (Ren et al. 2020), leaving few wild *Chenopodium* spp. seeds in the L1 assemblage. Instead, we found that wild *Chenopodium* sp. comprised 4.91% of the Amaranthaceae assemblage (Figure 7) and 19.75% of the *Chenopodium* spp. seeds at L1 (Figure 8). We argue that the significant presence of wild *Chenopodium*, along with weedy *Amaranthus* seeds, suggests that the L1 Tiwanaku colonists cultivated, prepared, and consumed Amaranthaceae in the Locumba Valley (AD 600–1100) and ultimately reinforced their Tiwanaku homeland identities through these food-related activities.

Conclusion

Dietary investigations of the Middle Horizon Tiwanaku expansion (AD 600–1100) have primarily focused on maize because of its unique economic and ritual roles (Gaggio 2014; Gaggio and Goldstein 2015; Hastorf et al. 2006; Muñoz Rojas et al. 2009; Santillan Goode 2018; Somerville et al. 2015; Vergel Rodriguez and León 2009). We argue that Tiwanaku colonial diet studies should focus more on the presence of Amaranthaceae and other cultivars through archaeobotanical fine screening and taxa comparisons based on counts and weights. Although more samples from L1 should be analyzed, our archaeobotanical analysis found that L1 and M43 residents shared remarkably similar mixed diets, largely including Amaranthaceae cultivars. L1 colonists reinforced their Tiwanaku altiplano identities and cultivated, prepared, and consumed Amaranthaceae cultivars on the lowland frontier because of the strong presence of domesticated, wild, and weedy Amaranthaceae seeds. By cultivating quinoa in a region well outside its natural range, Tiwanaku colonization marked a significant step in developing this important cultivar's ability to adapt to various agroclimatic and edaphic conditions.

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Competing Interests. The authors declare none.

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Supplemental Figure 1. Original archaeobotanical data from the Tiwanaku colonial site of Cerro San Antonio (L1; Garvin 2020).

Supplemental Table 1. Count-Based, Food-Taxa Comparisons at the Tiwanaku Colonial Sites M43 (900 m asl; Goldstein 2005; Vergel Rodriguez and León 2009), and L1 (600 m asl), and the Tiwanaku Altiplano Capital (~3,860 m asl; Hastorf et al. 2006; Kolata 2003; Wright et al. 2003). The L1 outlier sample 4161 is included.

Notes

1. The TIW database includes 10 duplicate sample numbers with different taxa values, so these 10 samples were excluded from our analysis.
2. See Garvin (2020) for a more comprehensive archaeobotanical analysis.

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