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Domestication and Prehistoric Distribution

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Abstract

This study reports on the current state of knowledge regarding the history of Chenopodium quinoa in four Andean countries: Argentina, Bolivia, Chile and Peru (Figure 1). The cultural environments in which quinoa was domesticated, adopted, exchanged and/or cultivated in ancient times, were reconstructed using archaeological data and, in particular, on the basis of archaeobotanical research by many specialists in these countries, as well as ethnohistorical sources and observations of the cultural continuities in communities that still produce quinoa using traditional methods.

The study begins with a review of the domestication of Chenopodium. It has been shown that the morphological features of archaeological seeds are the outcome of human manipulation over at least 3 000 years. This indicates that groups of hunter-gatherers in the Late Archaic Period (8000–3000 B.C.) in the Andean region subsisted on wild Chenopodium and applied selection, protection, treatment and transplantation processes that induced changes in its structure resulting in the characteristic features of domesticated quinoa.

The study then investigates archaeobotanical records from the Late Archaic to the Inca period. It outlines the distinctive morphological attributes in each region, the ecological conditions where quinoa was cultivated, the zones of origin and access routes, the various ways it was used, and quinoa's role in the sociopolitical processes of the time.

Finally, the study draws attention to the benefits (or necessity) of continuing regional research, optimizing methodologies and exchanging information and developments among researchers seeking answers to the many unsolved problems, including the presence of seeds not specifically identified as having traits that could match the early stages of the domestication process.

Introduction

Humans in the Americas began to domesticate the fauna and flora some 8 000 years ago. The Andean region was one of the most important centres for domestication, and quinoa (*Chenopodium quinoa* Willd.) was a primary crop. Since its domestication, quinoa has played a key role both in the livelihood and in the social and political systems of Andean societies. Archaeologists are gradually reconstituting this long history with a better understanding of how quinoa was used as a wild plant by hunters and gatherers, its domestication processes and its diffusion and diversification throughout the Andes.

While molecular genetics helps understand where quinoa was domesticated, archaeology provides essential chronological information about when it was domesticated and/or introduced and incorporated into farming systems (Zeder *et al.*, 2006). The settings reveal *why* quinoa was adopted and *what* role it played in the lives of the native peoples, from everyday cooking to rites, political festivities and community ceremonies.

Since the 1990s, archaeologists have developed fieldwork methods to recover seeds of ancient quinoa via flotation or dry screening, and laboratory tests have been done to recognize wild, domesticated and other varieties of quinoa (López *et al.*, in print). Quinoa plants bear fruits (achenes) in large numbers. The achenes structurally withstand natural processes (drying caused by extremely arid environments) and cultural processes (accidental or intentional charring), and quinoa seeds can, therefore, be recovered in a variety of settings in the Andes. The ubiquity of quinoa reflects its importance in the past, and the last 15 years have seen projects implemented in Argentina, Bolivia, Chile and Peru to understand its domestication and past consumption. This study summarizes the project findings published to date, fully aware of the amount of research that remains to be done, especially in those countries (e.g. Ecuador and Colombia) where quinoa growing once played a significant role but does no longer. In all cases, further archaeobotanical research is required.

Domestication of *Chenopodium quinoa*

It is not known exactly where and when *C. quinoa*, was domesticated, but it is certain that its domestication in South America was unrelated to that of Mexican (*Chenopodium berlandieri* spp. *nuttalliae) and North American* (*Chenopodium berlandieri* spp. *jonesianum*) (Kistler & Shapiro 2011; Wilson 1990). Its likely progenitors are C. hircinum, a lowland tetraploid, or some other extinct tetraploid ancestor in the Andes (Fuentes *et al.*, 2009; Wilson, 1990).

During the domestication process, a wide range of morphological changes occurred in the overall plant and in the fruit. Changes in the plant include infructescence compaction, loss of natural shatter mechanisms and uniform maturation of the fruit – all changes that facilitate production (Mujica *et al.*, 2001), although some varieties lack uniform maturation (Daniel Bertero, personal communication). The overriding archaeological evidence lies in the seeds, and the increase in their diameter is one of the most characteristic features. Other micromorphological features are observed, including reduction in thickness of the seed-coat or testa covering the embryo and the perisperm in the seed and preventing premature germination (Hugh Wilson, 1981). In wild populations, the seed-coat tends to be thick, somewhat hard and dark in colour. This prevents penetration of external elements that accelerate the development and growth of the embryo before full maturity, but also protects it from possible dehydration and insect attack. Selective domestication led to a reduction of seed-coat thickness via a genetically recessive trait which can only be maintained through human-made selection. Seed-coat reduction then led to morphological alteration of the fruit margins: wild forms have margins ranging from rounded to biconvex, while domesticated forms have truncated margins due to the flatter morphology of their adaxial and abaxial faces, the growth of cotyledons and the increased volume of the perisperm. Differences also developed in the seed-coat texture: domesticated seeds tend to have a smooth texture, i.e. without protuberances, while wild varieties have a reticulated testa structure (Bruno, 2006; Smith, 1992). Lastly, domesticated forms are characterized by light-coloured pigmentation due to less lignification in the epidermis, and wild-type fruits are dark in colour because of their hard, lignified epidermis (Wilson, 1981).

Molecular studies are currently underway in Argentina and Bolivia to better understand domestication, especially where it occurred and whether or not it was repeated. Initial findings led to the identification of four genetic groups: Altiplano, Dry Valleys, Eastern Humid Valleys, and Transition area (Curti *et al*., 2012). The same SSR markers (microsatellites) were used to molecularly characterize populations from different Andean countries in South America, with the aim of ascertaining the links between origins and subsequent dissemination. The findings revealed germplasm clusters suggesting the presence of longitudinal corridors for the spread of quinoa throughout the Andes (Costa Tártara *et al.*, 2013).

Furthermore, these molecular studies have begun to investigate the domestication syndrome (chan-

ges that distinguish between a species and its wild ancestor species) for quinoa (Daniel Bertero, personal communication). Study of the ratio between testa thickness and loss of dormancy has shown, for example, that no such relationship exists for two germplasms (Ceccato, 2011). Nevertheless, more germplasm samples are needed to assert or invalidate this trait in a domesticated grain, observed in domesticated species, not only in the Andes but also in Mexico and North America.

As archaeologists, in this chapter we present data relative to the period when the first records of domesticated quinoa appeared and the beginning of the human–*Chenopodium* relationship in the Andes.

Archaeological data on Pre-Hispanic distribution of *C. quinoa*

Herein is a summary of published papers containing data on the presence of quinoa in Argentina, Bolivia, Chile and Peru. We highlight the places where seeds have been found, the contexts in which they were used, and data pertaining to their age.The use of direct radiocarbon dating on the botanical material is essential to determine the age of the quinoa domesticated in the different regions. As explained below, contextual dating is utilized to date seeds at many archaeological sites in Argentina, Bolivia, Chile and Peru; this may be problematic and misleading when determining when quinoa was domesticated.

Figure 1: Andean region and geographic areas with archaeological finds of *C. quinoa*. 1a NWA (Argentina); 1b Cuyo (Argentina); 2a Northern Altiplano (Bolivia); 2b Central Altiplano (Bolivia); 2c Southern Altiplano (Bolivia); 3a North (Chile); 3b Coastal Centre and the Andes (Chile); 4 Peru.

Argentina

In presenting the findings on *C. quinoa* in Argentina, the archaeological sites are covered by region. The first region encompasses northwest Argentina (hereafter NWA), with sites located in the provinces of Jujuy, Salta, Tucumán and Catamarca (Figure 1, sector 1a), and the second region covers Cuyo and includes the provinces of Mendoza and San Juan (Figure 1, sector 1b).

Northwest Argentina

The first record of *C. quinoa* in Argentina was presented by Hunziker (1943). It came from the archaeological site of Pampa Grande (Salta), which corresponds to the Precontact Period (500–700 A.D.). It comprises seeds recovered in a funerary setting together with other botanical remains. No taxonomic specifications were given concerning the *C. quinoa* variety found, but the author considers the seeds to be quinoa on the basis of a comparison with seeds cultivated in the Bolivian Yungas. Some specimens were identified only as *Chenopodium sp*., described as ajara (possibly in reference to the wild state). In this same work, Hunziker mentions quinoa seeds recovered in the past by Ambrosetti in Argentinean prehistoric tombs, but provides no further details.

In Salta, Muscio (2004) unearthed charred seeds of *Chenopodium sp*., morphologically similar to quinoa in Matancillas 2 (San Antonio de Los Cobres) and belonging to the early agropastoral groups. Meanwhile, Lennstrom (1992) and D'Altroy et al. (2000) also presented evidence of C*henopodium sp.* at sites in Valdez (1047–1288 A.D.), Puerta de la Paya (1470–1536 A.D.) and Potrero de Payogasta (1279–1660 A.D.). Although only the genus is specified, the seeds are considered domesticated

on account of their morphological traits. Since they were ubiquitous, it was reported that this species was produced and consumed freely following the Inca conquest in the region. Lastly, Amuedo (2010) records the presence of quinoa at La Paya, Kipón, Mariscal, Ruiz de los Llanos and Tero, chronologically located in the Regional Developments Period (900–1450 A.D.).

In the province of Catamarca, in Antofagasta de la Sierra, Olivera (2006) discovered *Chenopodium sp.* in Cueva Cacao 1 (between 710 ± 60 and 870 ± 60 A.D.), while Rodríguez *et al.* (2006) presented evidence of *C. quinoa* in Punta de la Peña 4 (1190–1390 A.D.), where seeds, inflorescence branches and flowering stem were all taken from a hearth. These macroremains were recovered together with other domestic and wild plant species and are evidence of the high dietary consumption and, for the first time, the existence of the association *C. quinoa/Deyeuxia eminens* (the former is edible, the second was used as a tool for toasting the seeds). Furthermore, at Peñas Chichas 1.3, Aguirre (2007) recorded stems of this pseudocereal with signs of cutting – indication that it was harvested early in that region.

Caló (2010) identified *Chenopodium sp.* seeds from the archaeological site of Cardonal (Catamarca). On the basis of the morphological features of a group of seeds, Caló carried out a comparison with *C. quinoa*. It should be noted that, given the uncertainty of the morphometric features of the seeds, only the genus was identified and it was argued that it was consumed by the inhabitants of the southern sector of the Calchaquí Valley. Lastly, archaeological rescue excavations performed at the Las Champas site (Tinogasta) (1275–1435 A.D.) (Norma Ratto, personal communication) led to the recovery of seeds including *C. quinoa* var. *melanospermum* from a funerary context. The ajara showed signs of boiling or soaking in water and it is possible that ajara was consumed as part of a burial ritual – an indirect indication of quinoa cultivation in the region.

In Jujuy, charred grains of *C. quinoa* were recovered at the Finispatriae site (Rio Grande de San Juan) (800–1300 A.D.), on the border between Argentina and Bolivia. The archaeobotanical material was found in what was once a waste disposal area and, therefore, it can be deduced that quinoa was consumed by the inhabitants of the site (Nielsen et al., 2013).

Starch grains represent the earliest findings of this pseudocereal in northwest Argentina. Babot (2004) recovered microremains in milling instruments at the Los Viscos site (Catamarca) (320 ± 230 B.C. – 1130 ± 50 A.D. – Korstanje, 2005) and at Cueva de los Corrales (Tucumán) (50 B.C. – estimated chronology). Although only the genus was identified, with no differentiation between *Chenopodium* and *Amaranthus*, there was clearly a high level of consumption of pseudocereals by hunter-gatherer groups. Furthermore, in Antofagasta de la Sierra, Babot (2004) presented evidence of starch grains of *Chenopodium sp*. cf. *C. quinoa* in milling tools at Punta de la Peña 9.1 sites (520 ± 60 A.D.) and Quebrada Seca 3 (levels 2b [2] dated 2550 B.C., and 2b [3] dated 2750 B.C.). At the Morro Relincho site (Formative traits), Korstanje (2005) found small grains of quinoa-type starch in the sediment, inferring the possibility of quinoa production.

Cuyo

In San Juan, in the period of the Ansilta culture (around 500 B.C.), Lagiglia (2001) presented a list of places where quinoa was found, including Gruta de los Morrillos de Ansilta, Gruta Granero, Punta del Agua de los Morrillos, La Pintada and Gruta de Chacaycito. The seeds are merely referred to as "quinoa" and no genus or species is specified. In an analysis of the sites related to the Aguada culture (500–900 A.D.), Gambier (2002) mentions the presence of *C. quinoa* as a crop species, without specifying which particular sites supplied this evidence. Lagiglia (2005) later described individual contexts, as in the case of Gruta Los Morrillos, where quinoa was retrieved from a waste site in cave 1, while a "*C. quinoa loaf*" was recovered in cave 2, and human coprolites were found at a lower level with traces of this pseudocereal. At the Gruta Río Fierro site, 25 g of C. quinoa were found in a burial setting, while the recovery of C. quinoa var. quinoa and *C. quinoa* var. *melanospermum* was recorded at Gruta Río Salado.

Regarding Mendoza, the sites related to the Atuel II culture (around 300 B.C. until the Spanish incursion) contain a wide range of Andean pseudocereals. Hernandez *et al*. (1999–2000) presented the

archaeobotanical records for the Agua de los Caballos 1 site (San Rafael), noting seeds of *Chenopodium sp.* In addition, Lagiglia (2001) presented evidence of several chronologically earlier sites, including Gruta del Indio del Rincón del Atuel (250 ± 70 B.C.), Cueva Pájaro Bobo de Ponontrehue (60 ± 70 B.C.) and Reparo de las Pinturas Rojas (390 ± 110 A.D.), with evidence of *C. quinoa* var. *quinoa* and *C. quinoa* var. *melanospermum*. No further details were provided concerning the sites and contexts, except for Gruta del Indio, where, years later, Lagiglia (2005) explained that *C. quinoa* was found in a basket made of pampas grass and reeds, noting that it had been in use in Cuyo for over 2 200 years. This site is mainly linked to funeral functions (Gil and Neme, 2010).

Castro and Tarragó (1992), on the basis of the presence of *C. quinoa* and other archaeobotanical remains at the San Juan and Mendoza sites, proposed the existence of socio-economic processes associated with the adoption of agriculture – similar to that which occurred in Chile and northwest Argentina during the Late Archaic Period.

Bolivia

PThe primary findings of *C. quinoa* are concentrated in three regions of the Bolivian Altiplano: north, particularly around Lake Titicaca (Figure 1, section 2a), centre, in the Lake Popóo and Oruro region (Figure 1, section 2b) and south, around the Salar de Uyuni (Figure 1, section 2c).

Northern Bolivian Altiplano – Lake Titicaca region.

Records in this region, mainly from the Taraco peninsula and the Tiwanaku Valley, come only from charred botanical macroremains. To date, they derive from various contexts spanning the Formative Period (1500 B.C. – 300 A.D.) and the Tiwanaku Period (300–1100 A.D.)

Kidder (1956) found charred remains of plants in niches of the "houses" of the Chiripa Mound, the most well-known Formative site. Towle (1961) later identified them as quinoa seeds. In the 1970s, Erickson (1976) analysed macrobotanical remains from Chiripa for his undergraduate thesis, and identified many seeds of the *Chenopodium* genus, including the *C. quinoa* species. Browman (1989) examined more samples and, given the differences in size of the *Chenopodium* seeds, proposed that the larger seeds (1–2 mm) were quinoa.

Archaeobotanical studies conducted since 1992 by Hastorf and her students in the Taraco Archaeological Project (PAT) have revealed high densities of several species of *Chenopodium* (Bruno, 2008; Langlie, 2008; Whitehead 2007). In a detailed analysis of the morphological features of the *Chenopodium* seeds – especially the seed-coat or testa – Bruno (2006) identified domesticated quinoa species and their wild counterpart, *C. quinoa* var. *melanospermum* (Bruno and Whitehead, 2003).

The Taraco Archaeological Project has obtained several direct radiocarbon dates for quinoa seeds from the Chiripa, Kala Uyuni, Sonaji and Kumi Kipa sites. The earliest are from Chiripa and Kala Uyuni (around 1500 B.C.) and the most recent are dated 400 A.D. in Kala Uyuni. All these studies reveal the presence of *Chenopodium* seeds alongside several other wild species, such as gramineae, legumes and malvaceae.

Research carried out by Bruno and Whitehead (2003) found that, during the Early Formative Period or Early and Middle Chiripa phase (1500–800 B.C.), agriculture was developed on a small scale, and quinoa – as well as ajara and black quinoa – was grown and harvested. In the Middle Formative Period (Chiripa, 800–200 B.C.), a significant decline in the archaeological presence of ajara began, indicating changes in the management (weed control, processing) and use of crops. This included its use in rituals, suggesting that quinoa was an important food crop. Studies of the various contexts in Taraco sites – from floors and niches in public and ceremonial structures to domestic waste sites – have shown that quinoa was both a household and a ritual food and had a role in social and political events during the Formative Period.

Studies conducted on sites associated with the earliest state in the region – Tiwanaku – demonstrate that quinoa continued to play an important part in small farms and in the diet of highland peoples at that time. The Wila Jawira project – led by Kolata and the first archaeobotanical studies from the urban site of Tiwanaku and other rural sites in the Tiwanaku Valley and Lukurmata – identified *Chenopodium* seeds in 93% of the samples analysed (Wright et al., 2003).

Schultz (2010) studied the Pirque Alto site (Cochabamba) – Formative Period (1800 B.C. – 300 A.D.) and Middle Horizon Period (600–1000 A.D.) – and recorded the presence of *C. quinoa*, indicating the cultigen's social and ideological significance.

Central Bolivian Altiplano

Langlie conducted a morphological study of *Chenopodium* seeds recovered from a hearth at the La Barca site (Langlie, 2008; Langlie *et al.*, 2011). La Barca is a Wankarani site from the Formative Period (1800 B.C. – 400 A.D.) in the department of Oruro. The seeds examined by Langlie were quite different from the domesticated and wild quinoa, observed in the Lake Titicaca region.. Although the seed-coat was relatively thin, its reticulated texture and biconvex margins were similar to wild black quinoa. Furthermore, it had a very prominent "beak", differentiating it from Titicaca quinoa. Langlie suggests that these seeds may be an early and distinct variety of domesticated quinoa developed in the Oruro region. A definitive identification has not been possible to date due to a lack of similar comparative samples. Nevertheless, their presence is indication of the diversity found in the early stages of quinoa domestication.

Southern Bolivian Altiplano

Research conducted by Nielsen and colleagues for the Southern Altiplano Archaeological Project (PAAS) recovered quinoa in different settings at numerous archaeological sites chronologically situated between 900 and 1550 A.D.

The residential areas of the elevated defensive sites (pukaras), Churupata (1285–1380 A.D.), Mallku Pukara (1310–1630 A.D.) and Pukara de Sedilla, provided carbonized seeds of *C. quinoa*. The seeds came from cooking stoves, and on the basis of the diagnostic traits of pre-consumption processing (Lopez et al., 2012), it can be inferred that they were used after saponin extraction and eaten as whole seed (boiled) and/or in soup.

Further archaeobotanical recovery was made in storage areas. These are located at the defensive sites of Laqaya (1236–1479 A.D.), Mallku Pukara (1310–1630 A.D.) and Jirira Vinto (1300–1400 A.D.), and in isolated places associated with Chinuil Vinto, Cueva del Diablo (1310–1460 A.D.), Lojo, Qhatinsho 1 (720–1630 A.D.), Oqhañitaiwaj and Paco Cueva farmlands. The identified species of *C. quinoa* include seeds and leaves, stems and infructescence rachis. With the exception of the Laqaya site, archaeological plant material was stored desiccated, and information is therefore available on taxonomic varieties and the various types of quinoa. At the Laqaya site, charred seeds were found in a chullpa stone tower located in the central plaza of the site. In addition to the individual seeds, which could be analysed, a mass of perisperm with grains and the remains of attached quinoa grainswas recovered. The mass had the morphology of a bowl, possibly used to extract seeds from the silo, and its negative mould remained after a fire in this part of the site. The archaeological context offers two possibilities as to why quinoa was stored in this tower in the plaza: for community consumption in the political commensalism system, or for protection by the embodiment of the Ayllu ancestor (represented by the chullpa tower) and use in community celebrations as part of the agricultural cycle (Lopez and Nielsen, 2012).

The presence of *C. quinoa* var. *quinoa* is reported at all sites near Salar de Uyuni, and, in addition, *C. quinoa* var. *melanospermum* is reported at Jirira Vinto, located at the foot of Cordillera Intersalar (north of Salar de Uyuni). Considering the agricultural systems in the two areas, it is believed that the presence of ajara in Jirira Vinto may be due to a production system in which it was not in competition with quinoa and was therefore tolerated, possibly maintained, and harvested for food consumption in times of scarcity (Lopez, 2012).

It has been established that *C. quinoa* var. *quinoa* was stored in two different stages of post-harvest processing. The first stage was bulk storage prior to saponin extraction, possibly with the intention of planting in the next cropping season. Based on fruit colour and diameter, the types recorded resemble quinoas known today as White or Yuraj Real Cashlala, Pasankalla, Pink or Puca, Orange and Black, depending on the key adopted (Lopez, 2012).The Purple and Toledo types may also be present, but they have not been accurately identified as their features overlap with other types (Lopez *et al*., 2012). The second stage involved grains after saponin extraction, stored ready for consumption. These grains reveal traces of parch-

ing, indicating that they were consumed as whole seed (boiled) and/or soup, and as pitu or toasted grain flour (Lopez, 2012). This points to consumption patterns similar to current practices. Pitu or pito is currently consumed both during the agricultural production stage (planting and harvesting), and during transportation of products to be sold (llama caravan trade). Toasted quinoa is consumed in agricultural fields at the end of the working day.

Chile

For archaeobotanical findings of quinoa, Chile is divided into northern Chile (Figure 1, sector 3a) and central Chile (Figure 1, sector 3b). Central Chile is then subdivided into mountains, valleys and coastline.

Northern Chile

The first findings of *C. quinoa* in Chile were revealed by Safford (1917, in Hunziker, 1943) who extracted whole plants of the species in Arica. Meanwhile, Uhle (1919) recovered quinoa from funerary contexts with mummified individuals from the Chinchorro culture. They were groups of fishermen, hunters and pre-agricultural gatherers who lived on the arid coastline before 3000 B.C. (Arriaza and Standen, 2002). However, there were no morphological descriptions to corroborate whether or not it was a domesticated species, although Uhle did suggest that this quinoa was the result of contact with the highlands. Recent archaeobotanical studies in coastal ravines demonstrate the presence of *C. quinoa* at Chomache 1 (1600–600 B.C.) (Núñez, 1986). Its presence is minimal, but is indication that it came from the lower valleys in the interior and from the highlands, where production was more feasible. These early pieces of evidence suggest that quinoa may have initially arrived on the coast from other areas (including the southern coast of Peru), since there are insufficient data to support local domestication or horticulture associated with early coastal developments (Vidal, 2007).

During the Formative Period (1000 B.C. – 500 A.D.), in the interior valleys of Tarapaca and the oases, the presence of high-elevation crops was detected on pampa sites, including charred quinoa seeds in the villages of Ramaditas and Guatacondo, with morphological traits ascribable to *C. quinoa* (Rivera *et al.*, 1995; Magdalena Garcia personal communication). In the early Gatchi phase (1200–350 B.C.), although not confirmed formally, seeds akin to the *Chenopodium* genus were recovered, but their charred state prevented the attribution of a more precise taxonomic category (Vidal, 2007). It has been suggested that it was a far more dynamic period for contact with trans-Andean areas, such as northwest Argentina and the southern highlands (Nunez *et al.*, 2002–2005).

South of Salar de Atacama, tin he Antofagasta region, Holden (1991) mentions the possible presence of a domestic variety of *Chenopodium* in coprolites at the Tulan 54 and 58 sites (1400–470 B.C.). The low ratio indicates a relative lack of importance in the inhabitants' diet. McRostie (2007) exercised greater caution, referring to charred specimens at Tulan 54 as cf. *C. quinoa*. They presented the morphometric traits of quinoa, but damage to the testa made it difficult to make a clear categorization. Among the microremains analysed, there is mention of "starch aggregates" similar to patterns in the Amaranthaceae family, together with other species corroborating the existence of links with trans-Andean areas and the highlands, as well as pointing to the likely involvement of outside groups with ritual elements.

In the highlands of Tarapaca, human occupancy in residential areas of the Huasco Sur sites, all from the Formative Period (900 B.C. – 900 A.D.), left traces of wild varieties of Amaranthaceae and, at just one of these sites, carbonized seeds of *C. quinoa* as the only cultivated species recorded (Magdalena Garcia and Alejandra Vidal, personal communication). Given the great heterogeneity of lifestyles at this time in the Tarapaca region, the absence of maize and other elements led the authors to propose that the Salar sector was a place of transition between the Pica Oasis and North Lípez, and it probably was not well connected with the Tarapaca valleys, lacking links with other sites in the Formative Period. Given the absence of suitable environmental conditions for cultivation, quinoa could have originated in Bolivia and then come from the precordillera ravines during the Late Intermediate Period. As for the Camiña 1 site (1250–1450 A.D.) – an extensive settlement with agglutinated structures in the Tarapaca region – there is evidence of quinoa which may have originated in the highlands, this time in a new so-

cio-economic context with production on the platforms adjacent to the site (Garcia and Vidal, 2006).

It is, therefore, clear that there are insufficient data to ascertain the domestication of quinoa in these areas. Researchers share a consensus on transverse and longitudinal mobility and the exchange of products and goods between the highlands, inland low valleys, ravines and coastline since the Archaic Period. This may have increased during the Formative Period, including products for use in rituals, resulting in established cultivation in the Late Intermediate and Late Periods. It is possible that trans-Andean contacts and contacts with the highlands were instrumental in the process of adopting cultigens.

Quinoa played an important role in the rituals of the Incas. It was known as *chisiya mama* (mother grain) and was used in celebrations and offerings to mark the planting and harvesting of this valuable food. With the Inca incursion into Chilean territory (1440 A.D.), these ceremonial activities were introduced to the vanquished populations, also bringing improvements in infrastructures for cultivation, irrigation and storage.

Cordillera of Central Chile

In central Chile, the pre-Hispanic presence of *Chenopodium* has been confirmed at archaeological sites in the Andean foothills and mountains of the central valley and coast, between the basins of the Choapa and Maule rivers. Further south, there have been findings in the regions of Biobío, Araucanía, Los Lagos, and the islands of Chiloé, Mocha and Santa Maria. Accelerator mass spectrometry (AMS) was applied to charred quinoa seeds found on Santa Maria Island, and it is estimated that they were used during the period 1030–1460 A.D. (Massone *et al.*, 2012).

Chenopodium is the first plant resource with traces of human intervention found in central Chile. It dates back to the Archaic Period (3000–300 B.C.), when it was used by Andean hunter-gatherers, before the acquisition of maize by farming societies in the Early Period (from 300 B.C. to 1000–1200 A.D.). This has been established by stable isotope analysis (Falabella et al., 2008). In the high Andean region, opposite Santiago, there are two sites (2070 and 2500 m asl) with evidence of consumption of *Chenopodium*. Both are hunter-gatherer sites, without pottery, Late Archaic IV Period (Cornejo *et al.*, 1998), and they were temporarily occupied during thawing and snowless seasons from August/September to March/April. The El Plomo site (1460–1340 B.C.) has evidence of *Chenopodium* sp. cf. *C. quinoa*, with similar amounts of charred and other desiccated specimens. The desiccated specimens do not have a radicle, their diameters do not exceed 0.8–1 mm and their perisperm retain a natural ivory white colour with a truncated/rounded margin, no testa, and a prominent embryo (beak) (Planella *et al.*, 2011). *Chenopodium* cf. *C. quinoa* was recovered at Alero Las Morrenas 1 (1250–980 B.C., AMS direct dating with seeds). All specimens were carbonized, and taxonomic classification was, therefore, not possible in terms of variety or species. With diameters of up to 1.4 mm, most specimens featured radicles detached from the rest of the seed or the seed's extremity was swollen or bloated, probably due to carbonization (Planella *et al.*, 2005, 2011).

A cultigen domestication process in this mountainous area is quite unlikely due to the adverse weather conditions (restricting the possibility of farming practices) and the limited periods of human settlement. On the other hand, it has been suggested that the proximity to mountain passes on the eastern slope of the Andes favoured contacts and the exchange of goods, knowledge and innovations, including early cultigens or varieties of quinoa (Planella et al., 2011). Nevertheless, the dates given for the above-mentioned sites are prior to the dates obtained in Mendoza, Argentina, and are notoriously earlier than the dates reported on the coast and in the central valley.

Central Chile: valley and coastal areas

In the valleys of the coastal foothills of the Bernardo O'Higgins and Maule regions, and in scattered areas up to the Islands of Chiloe, *quinwa* or *dahue* (Mapuche ethnonym) is still grown today. In the O'Higgins region, there is pre-Hispanic archaeological evidence of *Chenopodium* at Early Ceramic Period sites (400–1000 A.D.) (Planella and Tagle, 1998; Tagle and Planella, 2002). In the carbonized macroremains (diameters of 1.3–1.8 mm), it was impossible to view the diagnostic attributes of the perisperm, which is always trans-

lucent or crystalline in Coastal ecotypes (Bertero, 2007) but rarely so in Andean varieties, with some exceptions – e.g. the humid valleys of northwest Argentina. For this reason it is not possible to determine the original diameter of the fruit. Quinoa growing today in the coastal region of central Chile presents characteristics or attributes associated with archaic traits linked to wild varieties (Wilson, 1988). It is, therefore, argued that the crop has remained in an original area of domestication (Bertero, 2007). This author and colleagues, with new contributions in their interdisciplinary line of research on quinoa, reinforce the hypothesis that central-southern Chile was an independent centre of domestication, in addition to the central Andes (Bertero *et al.*, 2013), and they support the proposal made by Planella and Tagle (2004) concerning local anthropogenic manipulation of quinoa in central Chile.

The earliest evidence of *Chenopodium* sp. in the valley was found in starches recovered in a milling instrument at the Lenka Franulic site of early potters groups (200 B.C. – 200 A.D.) (Tykot et al., 2009). Other early sites with evidence of Chenopodium are El Mercurio (120–150 A.D., Phase I) in the valley (Planella et al., 2010), and Las Brisas 3 (38 B.C. – 224 A.D.) on the coast (Rivas and Gonzalez, 2008).

Morphological analysis of archaeological specimens of *Chenopodium* is not straightforward at central valley and coastal sites. During the Early Ceramic Period, diameters range between 0.8 and 1.8 mm (Planella and Tagle, 1998; Tagle and Planella, 2002; Quiroz and Belmar, 2004). Larger sizes are not observed until the Late Intermediate Period (1040–1450 A.D.), under the Aconcagua culture (diameter 1.5–2 mm) (Planella 2005). A significant change in seed size of *Chenopodium* sp. (likened to quinoa, given its equatorial band), is also seen: from the most ancient levels at the Early Ceramic Lonquén site (100 B.C. – 900 A.D.) to the Late Intermediate El Cebollar site (815–1075 A.D.) (Quiroz and Belmar, 2004). These data point to an escalation in human–plant relations, possibly leading to tests and domestication procedures of *Chenopodium*. Belmar and Quiroz (2004) also noted changes in average sizes at Diaguitas culture sites in the semi-arid north, Chalinga and Illapel valleys, for specimens dated 1210–1520 A.D., distinguishing between the pre-Inca smaller diameter and Diaguita-Inca. During the Late Period and with the Inca occupation in the central area (Garceau *et al.*, 2010; Rossen et al., 2010; Martinez, 2012), diameters of about 2 mm are observed in numerous samples of ubiquitous charred macroremains.

Rossen *et al.* (2010) analysed the implications of the presence of quinoa, together with other local crops at the fortified site of Cerro Grande de la Compañía, under pre-Inca and Inca occupation (1310–1480 A.D.). *C. quinoa* is present in various contexts, which accounts for its selective storage in qollqas (separated from maize) and its use in residential areas. Archaeological records of quinoa (and of maize) in pre-Inca regional sites increase with the introduction of new mechanisms for intensifying cultivation, and with its increased use in the diet and in the political-ceremonial sphere.

In the central Andean area of Chile, the sporadic presence of quinoa has only emerged in waste sites of human settlements. In contrast, in the coastal foothill valleys and "secano" lands, cultivation of the Coastal variety has long been a traditional activity, from the chronological depth indicated or even earlier (200 B.C. – 200 A.D), with quinoa one of a group of cultigens associated with maize, pumpkin, squash and bean (Planella and Tagle, 1998, 2004).

Peru (Figure 1 sector 4)

En In 1880, Wittmack and Rochebrune first reported the discovery of quinoa in archaeological excavations. They uncovered fruits, leaves and even *C. quinoa* flour in funerary contexts at Ancón (Hunziker, 1943). Early studies by Uhle (1919) and MacNeish (1969, in Lumbreras, 2003) in Ayacucho record seeds identified as domesticated quinoa at a very early date (5500–5000 B.C.). However, subsequent direct dating of the archaeobotanical material (e.g. beans) in the same context gave later dates, suggesting that it is unlikely that the quinoa found was as ancient as initially thought (Bowman *et al.*, 2005).

Dillehay *et al.* (2007) present evidence of *Chenopodium* at the Nanchoc Valley sites (northwestern Peru) (Figure 1, sector 4), which, given their association with a dated hearth, are placed chronologically between 5500–6000 B.C. The specimens are charred and dry and their identification as *C.*

quinoa cannot be confirmed due to the presence of grooves in the seed, distinguishing them from herbarium specimens.

Pearsall (1980, 1989) measured *Chenopodium* seeds from Pachamachay and Panaulauca Cuevas (around 3000 B.C.) in Junín – sites representing the shift from hunter-gatherers to farmers and herders – and suggested, on the basis of their size (0.75–1.00 mm), that these seeds were domesticated. Nordstrom (1990) examined seeds from Panalauca and from Pancan and confirmed that the seeds had thin and smooth testas, meaning that they were indeed domesticated. The seeds came from contexts dated 3000–700 B.C. Pearsall (2008) proposed that quinoa cultivation may have started in approximately 3000 B.C.

In the Andes, west of Lake Titicaca, Eisentraut (1998) studied archaeobotanical samples of Late Archaic–Early Formative (5000–1000 B.C.) sites at Quelcatani, and Formative (1500–800 B.C.) sites at Camata. Among several wild species, domesticated and wild quinoa (black quinoa) seeds were identified. Although some domesticated seeds came from a layer associated with the Late Archaic Period, direct dating of a quinoa seed indicated the Early Formative period (740 ± 50 B.C.). Furthermore, Murray (2005) identified *Chenopodium* grains at the Jiskairumoko site as from the Late Archaic Period (around 3400–2000 B.C.). However, direct dating indicated the Formative Period (Mark Aldenderfer, personal communication). Nevertheless, due to the presence of domesticated seeds at various Formative sites on the north coast (Rosen, 2010), the central Andes and Lake Titicaca basin, we can speculate that the domestication process began before 3000 B.C.

D'Altroy and Hastorf (1984) studied Inca storage structures (qollqas) in Mantaro Valley and revealed the presence of Chenopodium sp., considered as quinoa, together with other plant products and ceramic pots – an indication as to how seeds were stored during this time. In their study, the authors identified the different storage methods used (only maize, only quinoa, or all crops together: maize, quinoa, poroto or beans). In subsequent archaeological research spanning the Wanka periods (beginning around 1000 A.D.), Hastorf (1990, 2002), studied the organization of groups inhabiting the region and how they organized the extraction of resources in the Andes. After identifying *Chenopodium* sp. as possible quinoa in Mantaro Valley, Hastorf inferred its consumption and production with other crops. She assessed changes in settlement patterns associated with quinoa production, noting that production increased when settlements moved to regions at higher altitudes, and decreased in the other direction. She also noted that, unlike maize, quinoa does not reveal differences in consumption between the elite and the workers in society. Thus, Hastorf concludes that, while maize was the main focus of Inca production, other resources – depending on the productive areas – were equally important.

Conclusions

In this study of four distinct geographical and cultural areas in the Andes, both differences and convergences emerge in the search to understand the history of quinoa, its economic significance and its social, ritual and political implications.

Archaeological studies explain how wild species of *Chenopodium* were consumed by hunters and gatherers in the Archaic Period (8000–3000 B.C.) in Peru, Argentina and Chile. Although there is no direct evidence of their activities, these populations initiated the changes that led to the domestication of quinoa. While many gaps remain to be filled in order to determine when and where quinoa was domesticated, available data suggest that domestication occurred in the centre-south Andes before 3000 B.C. Indeed, domesticated seeds have been found in these countries dating back to this period, and direct radiocarbon dating places archaeological quinoa at around 2000 B.C. in the Andes of central Chile.

In addition to place of origin and/or domestication, each area had its own particular cultural niche where the acquisition and use of this pseudocereal took place. Once domesticated, quinoa became a subsistence crop for societies from the Formative Period through to the Inca Empire. There are quinoa remains in domestic settings, evidence that it was an everyday part of the diet, but also in contexts associated with rituals, funeral and politics, where it will have been consumed in community events. Although it appears that it lost ground to maize in political contexts in Tiwanaku (Goldstein, 2003) and Inka states, quinoa continued to play a significant role in the diets of communities in cold

and arid regions.

Recent research, at local and regional level, in addition to the discovery and identification of varieties never before reported, opens up new perspectives for the exchange of knowledge and reassessment of the role of *Chenopodium* in feeding native peoples. Furthermore, these studies support the continued cultivation of quinoa and promote its increasing acceptance in Western diets.

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