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First records of *Chenopodium* spp./*Amaranthus* spp. starch grains and their relevance to the study of the late Holocene human subsistence in Central Argentina

M Laura López,[1] Matías E Medina[2] and Diego E Rivero[2]

Abstract
The first Sierras of Córdoba (Argentina) evidences of *Chenopodium* spp. and/or *Amaranthus* spp. human consumption were presented in this paper. The identifications were made over micro-botanical remains – starch granules – from grinding tools and pottery from two archaeological sites: Quebrada del Real 1 (*c.* 3000 BP) and C.Pun.39 (*c.* 1000–500 BP). Multiproxy data suggest the management of high-nutritional wild plants and the early knowledge of the post-harvest processing technology required to remove the non-edible portion of seed. Thus, the presence of *Chenopodium* spp. was significant to the study of the subsistence strategies and the small-scale farming spread among the early late Holocene human societies in central Argentina, being especially pertinent as a potential comparison to seek the early phases of food transition in contemporary Andean South America, Mesoamerica, and Eastern North America.

Keywords
Central Argentina, chenopods, Córdoba, early late Holocene, starch grains, subsistence strategy

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Introduction

The archaeobotanical studies carried out in Andean South America have produced significant advances in the knowledge of prehispanic human subsistence, especially regarding human foragers plant consumption, early food production transition, and post-harvest processing activities (Babot, 2011; Dillehay et al., 1989; Hastorf, 1999; Planella et al., 2005, 2011; Rossen et al., 1996). Within this frame, *Chenopodium* and *Amaranthus* seeds and microfossils have been found in sites dated from 7000 BP to the Inka period, showing that human foragers and farming societies used this grains and their wild relatives as food or medicine (Bruno, 2008; López et al., 2011). The remains were found in multiple contexts, including hearth, burial, storage structures, and coprolites. Such diversity suggests that these plants were used in multiple ways and purposes, having probable economic and religious importance.

However, the processing and consumption of *Chenopodium* and *Amaranthus* among the Holocene of Central Argentina are still archaeologically unknown, even when numerous archaeological sites ranging from late Pleistocene to late Holocene were excavated during the last decade (Berberian et al., 2008; Pastor et al., 2008). The lack of information would be related to the inadequacy of recovery methods employed during the fieldwork, the poor preservation conditions and the agrocentrism bias toward maize studies (Babot, 2011; Núñez et al., 2009).

Thus, first direct evidence of processing and consumption of *Chenopodium* spp. and/or *Amaranthus* spp. in two archaeological sites from Sierras of Córdoba (Argentina) – Quebrada del Real 1 and C.Pun.39 – are presented in this paper. The identifications were made over micro-archaeobotanical remains – starch grains – recovered from pottery and grinding tools. The articulation of these microfossil data with previous archaeobotanical studies illustrates the ancient plant usage since early late Holocene. Results were significant to the study of the subsistence strategies and the small-scale farming spread among the late Holocene human societies from central Argentina, where macro-remains have a poor preservation in the archaeological record (Pastor and López, 2010). Furthermore, they were important to South America archaeology, where the consumption of chenopods has been evident since Middle Holocene and might involve the first activities of protection and artificial management of free-living seeds (Chevalier, 2002; Dillehay et al., 2007).

Quebrada del Real 1 (QR1, S 31°40.330′ W 64°53.538′, 1914 m.a.s.l.; Figures 1 and 2) is a rock-cave located in the Pampa de Achala upper mountain grassland range, a non-favorable environment for agriculture (Rivero et al., 2008–2009). The site

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Figure 1. Study area: Córdoba Hill (Argentina). C.Pun.39 and Quebrada del Real 1 (QR1) archaeological sites.

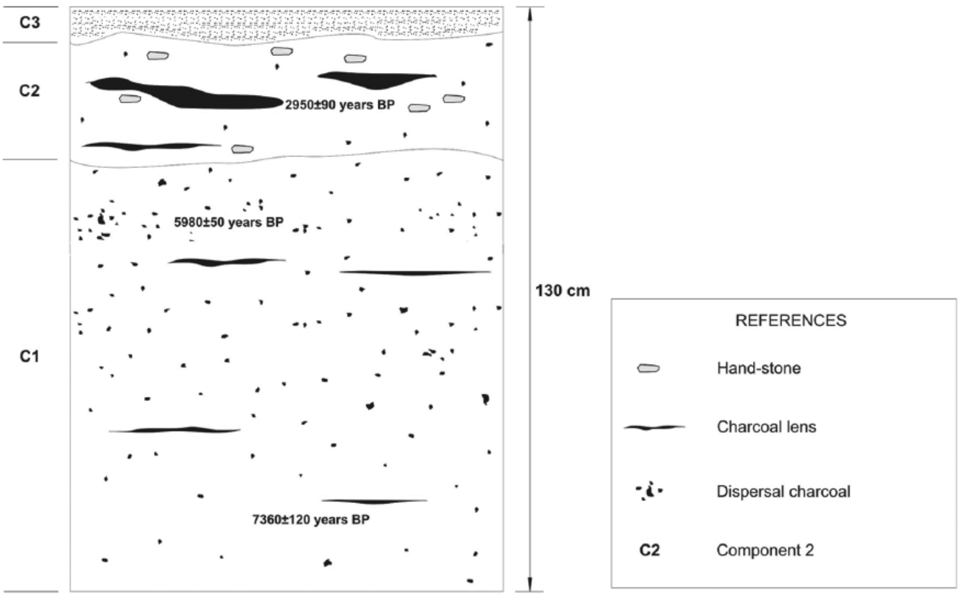

Figure 2. Quebrada del Real 1 site. Profile of the north wall, showing strata, dates, and hand-stone locations.

presents a long-term occupation from *c*. 7400 BP to final late Holocene (*c*. 1000–500 BP). Only the middle layers, called Component 2 (C2), were considered in this article. The C2 archaeological assemblage, dated at 2950 ± 90 BP (LP-2042; charcoal), was characterized by triangular projectile points with slightly to markedly concave bases and no pottery, resembling other Middle Holocene and early late Holocene deposits (Rivero, 2009). The evidence of C2 suggests that the rock-shelter was used by human foragers as a seasonal base-camp, where the main activity was the consumption of faunal resources, mainly ungulates and small-mammals (Medina et al., 2011; Rivero et al., 2008–2009). However, seven hand-stones recovered in stratigraphy were used to seed and plant processing.

C.Pun.39 (S 31°03.376′ W 64°31.685′, 1050 m.a.s.l., Figure 1) is an open-air site located in northern Punilla Valley. The surrounding vegetation is Sierra Chaco (Giorgis et al., 2011) but impacted by the altitude and modern agricultural practices. Only late Prehispanic Period occupations (*c*. 1000–300 BP; sensu Pastor and Berberián, 2007) were identified during its excavation. The pottery, bone, lithic, and archaeobotanical evidence indicates multiple-activities such as farming, foraging, storage, processing, cooking, manufacture and maintenance of artifacts, and so on. Thus, C.Pun.39 was interpreted as a semi-sedentary residential-base or hamlet used by peoples with a mixed foraging and cultivation economy (Medina, 2009; Medina et al., 2008, 2009). Three charcoal samples from overlapping layers were dated at 525 ± 36

Table 1. Microbotanical remains of hand-stone tools at Quebrada del Real 1 site.

Source	Length	Width	Thickness	Activity area (cm²)	Condition	N° activity face	Raw material	Microfossil remains	Taxa identified or description	Chronology	Observations
QR1-Level 2	90	80	45	45	Fragment (−50%)	1	–	Phytoliths	Grass (Poaceae) leaves	*c.* 3000–2000 BP	None
QR1-Level 2	106	80	33	69.4/65.8	Whole	2	Granite	Phytoliths	*Zea mays*, Grass (Poaceae) leaves	*c.* 3000–2000 BP	1 broken phytolith
QR1-Level 2	123	80	42	85.1	Whole	1	Granite	Phytoliths	Grass (Poaceae) leaves	*c.* 3000–2000 BP	None
								Starch grains	***Chenopodium* spp.**		
QR1-Level 4	90	84	43	60.5/58	Whole	2	Granite	Phytoliths	*Geoffroea decorticans*	*c.* 3000–2000 BP	None
								Starch grains	***Chenopodium* spp.**, unidentified seed/root		
QR1-Level 4	92	50	33	n/d	Fragment (+50%)	2	Granite	Phytoliths	Grass (Poaceae) leaves	*c.* 3000–2000 BP	None
								Starch grains	***Chenopodium* spp.**		
QR1-Level 4	92	47	38	n/d	Fragment (+50%)	2	Granite	Phytoliths	*Zea mays*	*c.* 3000–2000 BP	None
								Starch grains	***Chenopodium* spp.**, Unidentified seed/root		
QR1-Level 7	100	68	38	55.2/36	Whole	2	Granite	Phytoliths	*Zea mays*, Grass (Poaceae) leaves	*c.* 3000–2000 BP	None
								Starch grains	*Zea mays*		

The text in bold shows the presence of *Chenopodium* spp. and *Chenopodium* spp./*Amaranthus* spp., respectively, in some artifacts in each archeological site.

BP (AA64819), 716 ± 39 BP (AA62339), and 854 ± 39 BP (AA62338; Medina, 2008, 2009).

Materials and methods

The microfossils analysis was focused on hand-stones of QR1 Component 2 (N = 7) and pottery vessel walls of C.Pun.39 (N = 5) associated with wood charcoal dates (Tables 1 and 2). The study followed the methodology described by Piperno and Holst (1998) and Babot (2004) for sampling starch residues on artifact. A work area was set up in the laboratory exclusively for sampling the archaeological artifacts. Organic residues accumulated in cracks, fissures, holes, and crevices of unwashed grinding surfaces were removed using the point of a fine needle. Unwashed internal walls of the potsherd were scraped with a sharp tool to remove food residues. Hand-stones were analyzed over a delimitated area of 8 cm² to balance the extractions between the specimens while the whole surface of ceramics was analyzed. The residue samples were directly mounted on glass slide using immersion oil and covered with a cover slip. All the equipment and the work area were sterilized with distillated water after each extraction to avoid contamination. Sediments adhered to passive areas or non-used facets of each artifacts were also processed to discriminate starch grains and phytoliths incidentally incorporated from those that were intentionally exploited by human in the past. Moreover, sediment samples of cultural strata of sites were analyzed to search and record microfossils adjacent to archaeological artifacts.

Slides were scanned using an optical microscope at 400× to 1000× under transmitted and polarized light to identify botanical microfossils. Single starch grains were identified by the presence of the extinction cross. Compounded starch grains were identified by their brightness. Lugol iodine test was also employed for single or compounded starch grain recognition when necessary (Babot, 2004).

The starch grains from each sample were observed, photographed, described, and compared with reference collection for taxonomic identification. The attributes taken into account for the starch description were the three-dimensional morphology, grain size, contour and surface strait, hilum shape and size, lamellae visibility, fissures, birefringence properties, extinction cross features, grain visibility by normal and polarized light, and packing of compounded grains (Babot, 2004; Loy, 1994; Perry, 2004; Piperno and Holst, 1998). Reference collection of domesticated and wild plants varies in their origins, including some collected during fieldworks, recovered from archaeological sites, and publications (Babot, 2004; Cortella and Pochettino, 1990, 1994; Korstanje and Babot, 2007; López, 2012, etc.; Figure 3). The comparative material shows that *Chenopodium* seeds have compounded ellipsoidal-shaped starch grains that contain a lot of small polyhedral-shaped single grains, ranging in size from 0.5 to 3 µm long, whereas *Amaranthus* seeds have single spherical and polyhedral-shaped grains that range in size from 1 to 5 µm long (Cortella and Pochettino, 1990; Korstanje and Babot, 2007; López, 2012; Prego et al., 1998; Winton and Winton, 1932). However, post-harvest processing activities would modify several diagnostic features of the starch grains that need to be taken into account during the taxonomic analysis. Grinding activities, for example, break compounded starch grain into small grains, while culinary techniques such as boiling change the size of the grains making it difficult for identification at specific level (Babot, 2003, 2004; Crowther, 2012; Henry et al., 2009; Li et al., 2014).

Results

Starch grains as well as silica phytoliths were isolated from QR1 assemblage (Table 1). Phytoliths indicate that *Zea mays* (maize) cobs and cf. *Geoffroea decorticans* (chañar) fruits were processed and consumed in Sierras of Córdoba *c.* 3000 BP (Pastor et al., 2012; Rivero and López, 2011).

A total of 20 compounded starch grains were recovered in QR1. The grains were ellipsoidal-shaped and their size varies

Table 2. Microbotanical remains of pottery vessel walls at C.Pun.39 site.

Source	Surface treatment	Part of the vessel	Microfossil remains	Taxa identified or description	Chronology	Observation
C3 Level 3 (20–30 cm)	Smoothed	Body of pot	Phytoliths	*Zea mays, Cucurbita* spp., *Prosopis* spp.; Grass (Poaceae) leaves; Unidentified phytoliths	*c.* 850–500 BP	None
			Starch grains	Unidentified seed/root		
C2 Level 4 (30–40 cm)	Polished	Shards of pot	Phytoliths	*Zea mays, Geoffroea decorticans*; Grass (Poaceae) leaves; Unidentified phytoliths	*c.* 850–500 BP	None
			Starch grains	Unidentified seed/root		
C2 Level 6 (50–60 cm)	Smoothed	Shards of pot	Phytoliths	*Zea mays, Cucurbita* spp., *Prosopis* spp.; Grass (Poaceae) leaves; Unidentified phytoliths	*c.* 850–500 BP	None
			Starch grains	Unidentified seed/root		
B1 Level 4 (30–40 cm)	Smoothed	Shards of pot	Phytoliths	*Zea mays, Cucurbita* spp., *Prosopis* spp.; Grass (Poaceae) leaves; Unidentified phytoliths	*c.* 850–500 BP	None
			Starch grains	***Chenopodium* spp./*Amaranthus* spp.**		
A2 Level 4 (30–40 cm)	Smoothed	Shards of pot	Phytoliths	*Zea mays*; Grass (Poaceae) leaves; Unidentified phytoliths	*c.* 850–500 BP	None

The text in bold shows the presence of *Chenopodium* spp. and *Chenopodium* spp./*Amaranthus* spp., respectively, in some artifacts in each archeological site.

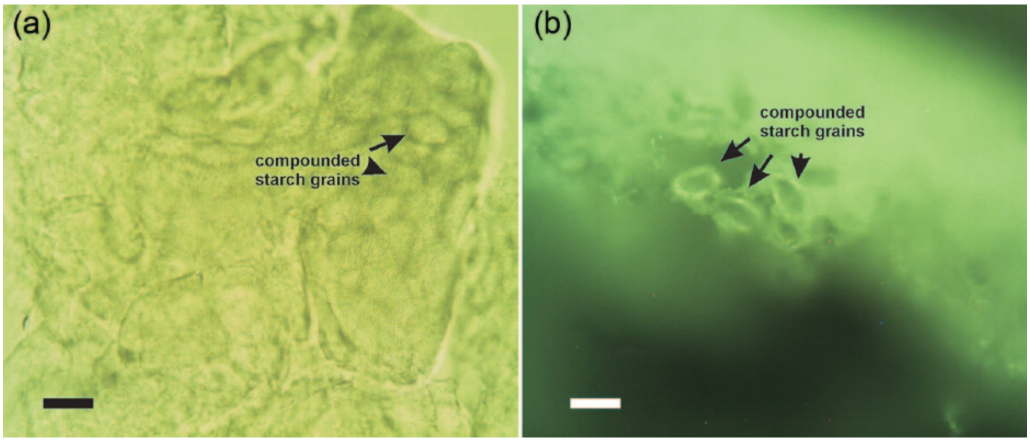

Figure 3. Compounded starch grains of weed. Current comparative material of free-living *Chenopodium quinoa* var. *melanospermum* (ajara). (a) Optical microscope with a direct light source (b) and with polarized light. Scale bar = 20 µm.

from 10 to 30 µm. No extinction crosses were observed under polarized light, but the intensity of birefringence was greater. Lugol iodine test corroborated the presence of compounded starch grains that were taxonomically assigned to *Chenopodium* spp. (Figure 4). The control sample of QR1 suggests that starch grain microfossils were absent from the sediments.

Macro- and micro-remains assigned to *Zea mays* (maize), *Phaseolus vulgaris* (common bean), *Phaseolus lunatus* (pallar-been), *Cucurbita* spp. (squash), *Geoffroea decorticans* (chañar), and *Prosopis* spp. (carob tree fruits) were recovered in C.Pun.39 (López, 2005; Medina et al., 2009). Moreover, a high percentage of Chenopodiaceae–Amaranthaceae (Cheno-Ams) was identified in the Layer 6 sample (525 ± 36 BP) pollen assemblage, with values that are distant from the modern analog (see Medina et al., 2008). Thus, the palynological analysis indicates the cultivation of Andean crops around the site and/or anthropic disturbation by trampling or fallow (Smith, 1992). The high percentage of Brassicaceae in the pollen spectrum, another pioneer plant that thrives in areas recently disturbed by human activities, supports the second option.

Hundreds of starch grains documented in the C.Pun.39 (Table 2) pottery assemblage were disjoined individual granules of about 1–6 µm in diameter, ovoid and spherical-shaped with no distinction between lamella or hilum. Starch grains were not easy to identify under normal light, and they did not shine under polarized light. Iodine test corroborated the presence of individual starch grains (Figure 5). Crystalline sand was also recorded in C.Pun.39. Starch grains and crystalline sand were taxonomically assigned to *Chenopodium* spp./*Amaranthus* spp. because of the absence of complete or partially complete rounded compound grains of *Chenopodium quinoa* or the 'starch chunks' of *Amaranthus* spp., which were considered diagnostic features of these specie/genera, respectively (Babot, 2004; Korstanje and Babot, 2007). The control samples from C.Pun.39 show that starch grains were absent from the sediments.

Discussion

Taxonomic identification of macro-remains, phytoliths, and pollen in QR1 and C.Pun.39 proved to be of great importance for the archaeology of central Argentina, with its economic implications discussed in different papers (Medina et al., 2008, 2009; Pastor et al., 2012; Pastor and López, 2010; Rivero and López, 2011).

Starch analysis identified the first archaeological evidence of *Chenopodium* spp./*Amaranthus* spp. in Sierras of Córdoba. The genera *Chenopodium* and *Amaranthus* have been recorded in several archaeological sites in Andean South America since Middle Holocene to Inka times, suggesting a temporal tendency toward the manipulation and the domestication of these species. Many archaeological sites from Bolivia, Chile, Peru, and Argentina show remains of *Chenopodium* spp. and *Amaranthus* spp. since *c.*

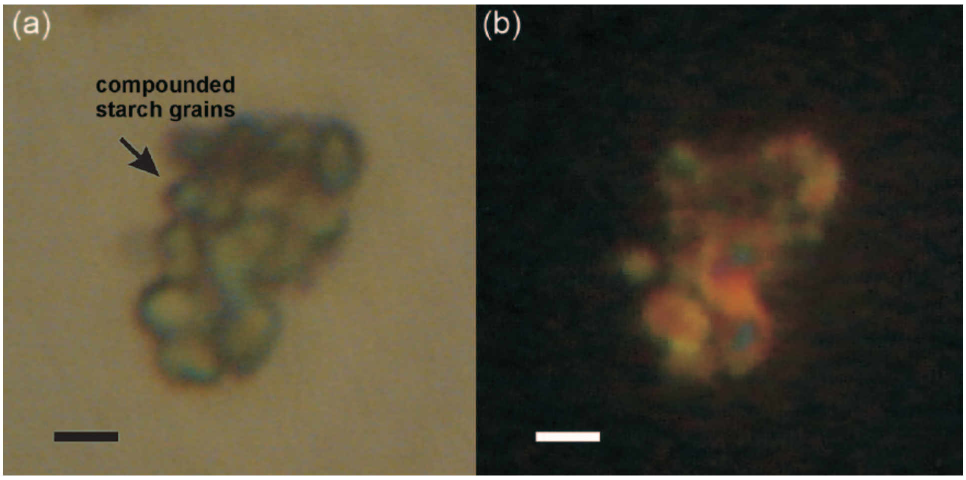

Figure 4. Archaeological starch grains of *Chenopodium* spp. from Quebrada del Real 1 (QR1) site. (a) Optical microscope with a direct light source (b) and with polarized light. Scale bar = 20 μm.

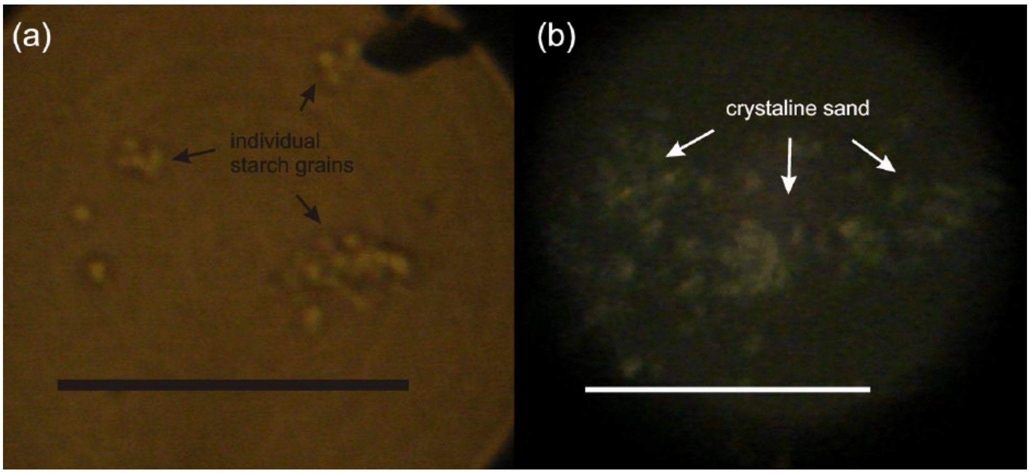

Figure 5. Archaeological starch grains of *Chenopodium* spp. or *Amaranthus* spp. from C.Pun.39 site: (a) starch grains and (b) crystalline sand. Scale bar = 20 μm.

7000 BP, suggesting that these plants have been used in multiple ways and have had economic and social importance, until present times (Babot, 2011; Bruno, 2006, 2008; Chevalier, 2002; Hastorf, 2002; López, 2010, 2012; López et al., 2011; Planella et al., 2005, Planella and Tagle, 2004, among others). The identification of starch grains on grinding tools and sediments from North-Western Argentina has demonstrated that the genera were incorporated into the subsistence *c*. 4700 BP, being cultivated since 3600 BP (Babot, 2004, 2011; Babot et al., 2009; Korstanje, 2005). The oldest microfossils of *Chenopodium* from Argentina were recorded in Quebrada Seca 3 (Catamarca province) and dated at *c*. 5000 BP, showing post-harvest evidence of roasting, removing pericarp, and dry grinding (Babot, 2011). A fragment of *Chenopodium* stem dated at *c*. 3500 BP was recovered at Peñas Chicas 1.3 (Catamarca province), being the first evidence of non-food use of this taxa (Aguirre, 2007). Data from Central Chile also suggest that human foragers manipulated *Chenopodium* spp. since late Archaic period *c*. 3300 BP, supporting the evidence of an intensification process that led to a domestication of *Chenopodium* (Planella et al., 2005, 2011; Planella and Tagle, 2004; Tagle and Planella, 2002).

The presence of compounded grains in QR1 indicates the human consumption of *Chenopodium* spp. as a subsistence resource *c*. 3000 BP. This is not the situation of C.Pun.39, where starch grains did not show diagnostic features to identify genera at specific level (i.e. rosette, compound complete and/or semi complete grains, starch fragments, etc.) and microfossils were assigned to *Chenopodium–Amaranthus* (see Babot, 2004; Korstanje and Babot, 2007). However, the chronology and the cultural context of the sites allow hypothesizing over the taxonomic status of the recorded specimens. QR1 Component 2 presents hunter-gatherer occupations dated on early late Holocene. Even when domesticated maize was recorded in QR1 – probably obtained from Andean farming societies (Pastor et al., 2012/4) – the local cultivation was not demonstrated with this chronology. Thus, the recorded micro-remains might correspond to wild species such as *Chenopodium hircinum* or *Chenopodium ambrosioides*, annuals camp-following plants with high edible biomass, added to the diet as a result of a forager intensification process (Aldenderfer, 1998; Kuznar, 2001). On the other hand, in C.Pun.39, there are radiocarbon dating and evidence suggesting farming activities (Medina, 2008, 2009; Medina et al., 2008; Pastor and López, 2010). Thus, the microfossils should be associated with small-scale farming of Andean crops like *Chenopodium quinoa* or *Amaranthus caudatus* and/or secondary vegetational configuration of weedy plants. The anthropic disturbation should not be discarded, mainly when the high-frequency of Cheno-Ams and Brassicaceae pollen reinforces this argument (Medina et al., 2008). The archaeobotanical data from QR1 allows to start considering the manipulation, processing, and consumption of *Chenopodium* spp. in Central Argentina since early late Holocene, with a chronology similar to the Andean region. The compounded characteristics of the starch grains lead to infer that the hand-stones were not strictly used to grind

Chenopodium spp. grains. The starch aggregation evidences a low intensity grain beaten with hand-stones, mainly to remove the pericarp and their steroid compound that has a bitter taste and a toxic effect called *saponina* – saponin – (Fontúrbel, 2003; López, 2012). Thus, these data not only suggest an early knowledge about the annual growth of the plants but also about the technology required to remove the non-edible portion of the seeds.

Floristic census conducted in Pampa de Achala suggests that *Chenopodium* spp. and *Amaranthus* spp. were not abundant in the Sierras of Córdoba upper mountain grassland range (Cabido et al., 1998; Giorgis et al., 2011). Thus, their presence in QR1 is indicative of the early late Holocene hunter-gatherer mobility that links the high-mountain environment with the spring-summer occupation of the low-land Sierra Chaco environment (Rivero, 2009) where Cheno-Ams were relatively more abundant (Cantero et al., 2001; Giorgis et al., 2011; Núñez and Cantero, 2000). The first archaeological consequences of these human behavior might be the cyclic seasonal reoccupation of the valley open-air residential sites and the continual anthropic disturbance of the ground habitat setting, creating the ideal environment that favored camp-follower weedy plants such as *Chenopodium* spp. (Smith, 1992).

The unintentional dispersal of wild plants of economic importance for human societies through abandon and reoccupation of base-camps should be classified as a pre-agricultural system that involved weedy plants handling as a niche construction process (Smith, 2007, 2011). Thus, the Sierras of Córdoba early late Holocene should evidence the early farming practices through the artificial management of plants with high nutritional value and the knowledge to remove the saponin through a post-harvest processing activities which required grinding technology as well as cultural transmission (Wollstonecroft et al., 2008). As such, it serves as a potential comparison to other cases in the world during the early phases of the food producing transition, especially Andean South America, Mesoamerica, and Eastern North America (Bruno, 2008; Gremillion et al., 2008; Smith, 1992).

Chenopodium spp./*Amaranthus* spp. of C.Pun.39 were recovered from carbonized food residues on pottery fragments, indicating the use of vessels for cooking. The starch grains did not appear gelatinized, suggesting that the pseudocereal grains were cooked at low temperature (Henry et al., 2009). The starch grains were disaggregated and showed the lack of polarization cross and disturbance of birefringence, traces that suggest grinding activities prior to cooking (Babot, 2003). Moreover, the low visibility and the absence of milky appearance of the grain evidenced the intentional removal of the saponin, a post-harvest activity necessary prior to consumption.

The Spanish documents from early colonial period (XVI–XVII centuries AD) recorded numerous references about the consumption of domesticated quinoa and its importance among native peoples in Sierras of Córdoba. Nevertheless, archaeological evidence has been absent for decades, being the research effort recently forwarded on farming evidence (Medina et al., 2008, 2009; Pastor and López, 2010). *Chenopodium* spp./*Amaranthus* spp. from C.Pun.39, if they were domesticated species, show that the late prehispanic peoples developed a mixed foraging and cultivation economy which included the typical 'American tetrad' – maize, bean, squash, and chenopod/amaranth – (Medina et al., 2009; Pastor and López, 2010). However, the absence of diagnostic features makes the specific level identification difficult, and these taxa should evidence the continuity of the pre-agricultural manipulation of the wild plants originated during the early late Holocene. Moreover, the use of crop/weeds plants association along the wild-to-domesticated *continuum* should not be discarded during the late Prehispanic Period (1000–360 BP) because of the wild plant resistance against frost and drought. Thus, the wild genera might have been exploited intensively, especially in a mixed foraging and farming economy with high degree of residential mobility (Bruno, 2008; Gremillion, 1993; López, 2012).

Conclusion

A preliminary approach to the archaeological consumption of *Chenopodium* and/or *Amaranthus* in Sierras of Córdoba was conducted in this paper. The starch grain analysis and the cultural context showed that the plants were harvested, processed, and consumed by humans since early late Holocene, including in a wild-to-domesticated continuum during the late Prehispanic Period.

However, interpretation of plant usage is still fragmentary and biased by a chronological hiatus of *c*. 2000 years and the absence of a good reference collection of wild chenopods starch grains. This situation forces to incorporate microfossil data from sites that were not analyzed – including 'classic sites' from central Argentina (González, 1960; González and Crivelli, 1978; Menghin and González, 1954) – as well as the excavation of new sites, focusing now in the archaeobotanical remains recovery, the improvement of reference collection, and the archaeological attention to the human–plant–landscape interaction. Another problem to solve is the difficulty to recognize the wild as opposed to the domesticated species of *Chenopodium–Amaranthus* and the traces left by human activities commonly associated with the production, processing, and consumption of these plants (Bruno, 2008; López et al., 2011). Thus, the archaeobotanical analysis is going to play an important role in further studies defining the archaeological taxa and reinforcing or modifying the implications exposed in this paper.

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