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ORIGINAL PAPER

Traditional post-harvest processing to make quinoa grains (*Chenopodium quinoa* var. *quinoa*) apt for consumption in Northern Lipez (Potosí, Bolivia): ethnoarchaeological and archaeobotanical analyses

Laura M. López · Aylen Capparelli · Axel Emil Nielsen

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Abstract The aim of this paper is to generate information to assist in the archaeobotanical recognition of post-harvest processing activities related with different enhancement and consumption patterns of quinoa in the Central Andes. Enhancement of the grains involves what local people call "mejorado de los granos". Their main purpose is to reduce as far as possible the presence of saponins, a toxic metabolite, in the grain. Ethnobotanical data were recorded in the village of Villa Candelaria (Southern Bolivian highlands) through the application of standard ethnographic techniques. The types of grain enhancement vary depending on the meal that people want to prepare. We registered three different quinoa enhancements based on intended consumption, (1) as a whole seed, (2) in soups or (3) as *pitu* (a kind of toasted refined flour). Laboratory analysis aimed at identifying distinctive features of grains in different processing stages, as well as evaluating the effects of charring. For both desiccated and charred remains, quinoa processed for *pitu* can be distinguished from that for whole seed/soup. As a case study, archaeological grains of the pre-Inka site of Churupata, located 3 km from Villa Candelaria, were interpreted as quinoa prepared for consumption as whole seed/soup.

Keywords Plateau · Andes · Ethnoarchaeology · Paleoethnbobotany · Quinoa

L. M. López
Cátedra y Laboratorio de Prehistoria y Arqueología,
Universidad Nacional de Córdoba,
Av. Juan Filloy s/n°, (5000) Ciudad Universitaria,
Córdoba, Argentina

A. Capparelli (✉)
Departamento Científico de Arqueología,
Museo de Ciencias Naturales de La Plata,
Paseo del Bosque s/n°, (1900),
La Plata, Argentina
e-mail: aylencapparelli@fcnym.unlp.edu.ar

A. E. Nielsen
Instituto Nacional de Antropología y Pensamiento Latinoamericano,
3 de Febrero 1378 (1426),
Buenos Aires, Argentina

Introduction

Quinoa (*Chenopodium quinoa* Willd, Chenopodiaceae) is a domesticated pseudo-cereal whose grains are considered to be one of the most nutritionally complete foods for humans. Presently, it grows throughout South America from Colombia to Argentina and Chile, with the highest diversity being found in the area between Sicuani (Peru) and Potosi (Bolivia), where it has adapted to variable climatic, soil and cultural conditions leading to the presence of different ecotypes and genotypes (Maughan et al. 2004; Mujica and Jacobsen 2006).

Quinoa is still one of the main subsistence resources for many Andean communities. The use of this plant in the Andes goes back several millennia. Quinoa remains have been found at archaeological levels from several thousands of years BP to the Inka period in different locations of Peru, Bolivia, Argentina and Chile (Holden 1991; Bruno 2008; D'Altroy and Hastorf 2002; Lagiglia 2001; Planella et al. 2005, among others, see Table 1).[1] Hunter-gatherers as well as agricultural societies used this grain and some of its wild

[1] Starch grains of genus *Chenopodium* were also found on ground stone instruments at Quebrada Seca 3 site (Catamarca, Argentina) and dated to 4700 AP (Babot 2004), but in this case, the specific use of quinoa cannot be confirmed because identification was only possible at a genus level.

Table 1 Archaeological remains of quinoa, and other *Chenopodium* taxa likely to belong to the domesticated phenotype, found in Argentina, Bolivia, Chile and Perú

Sites	Filiation and chronology[a]	Location	Species identified	Sources
Puente del Diablo	Early Formative 2450–1450 BP	Salta, Argentina	*Chenopodium quinoa*	Lema pers. comm.
Pampa Grande	Early Formative 1250 BP	Salta, Argentina.	*Chenopodium quinoa* *Chenopodium* sp. *Amaranthus caudatus* var. *leucospermus* y var. *alopecurus*. *Amaranthus* sp.	Hunziker 1943a
Puerta de La Paya	Inca 480–414 BP	Salta, Argentina.	*Chenopodium* sp. (likely quinoa)	Lennstrom 1992
Cortaderas Bajo	Inca 480–414 BP	Salta, Argentina.	*Chenopodium* sp. (likely quinoa)	Lennstrom 1992
Valdez	Inca 480–414 BP	Salta, Argentina.	*Chenopodium* sp. (likely quinoa)	Lennstrom 1992; D'Altroy et al. 2000
Potrero de Payogasta	Inca 480–414 BP	Salta, Argentina.	*Chenopodium* sp. (likely quinoa)	Lennstrom 1992; D'Altroy et al. 2000
Cardonal	Early Formative 2550–1050 BP	Catamarca, Argentina	*Chenopodium* sp. likely *C. quinoa* and/or *C. pallidicaule*	Caló 2010
Cueva Cacao 1	1080±60 BP 1240±60 BP	Catamarca, Argentina.	*Chenopodium* sp.	Olivera 2006
Punta de la Peña 4	760–560 BP	Catamarca, Argentina.	*Chenopodium quinoa*	Rodríguez et al. 2006
Gruta de los Morrillos de Ansilta, Vega de los Pingos, Gruta Granero, Alero del Lagarto, Punta del Agua de los Morrillos, Río Fierro, Arroyo Los Arroyos, Gruta del Cortaderal Quemado, Río Salado, Río Colorado, La Pintada, Gruta de Chacaycito, Terraza de Chacaycito, Alero de los Corredores, Hornillas de Arriba, La Colorada de la Fortuna, Establecimiento de Guillermo y Bauchaceta.	Ansilta Culture 3950 BP? – 2450 BP	San Juan, Argentina.	"quínoa".	Lagiglia 2001
Sine Data	Aguada Culture 1300–1050 BP	San Juan, Argentina.	*Chenopodium quinoa*	Gambier 2002
Agua de los Caballos 1	Atuel II Culture 2250–1800 BP	Mendoza, Argentina.	*Chenopodium* sp.	Hernández et al. 1999/2000
Reparo de las Pinturas Rojas, Reparo del Salto del Morado, Cueva 1 del Cerro Negro del Escorial, Reparos de El Rincón, Gruta del Puesto de Las Tinajas, Cueva del Zanjón del Morado, Cueva silo de las Lomas del Cerro Negro, Cueva Pájaro Bobo de Ponontrehue, Zanjón de los Buitres de Ponontrehue.	1560±110 BP 1360±60 BP 2010±70 BP	Mendoza, Argentina.	*Chenopodium quinoa* var. *quinoa* *Chenopodium quinoa* var. *melanospermun Amaranthus caudatus*	Lagiglia 2001
Gruta del Indio	2200±70 BP	Mendoza, Argentina.	*Chenopodium quinoa* var. *quinoa* and var. *melasnospermum Amaranthus caudatus Amaranthus* sp.	Castro and Tarragó 1992; Hunziker and Planchuelo 1971; Lagiglia 1974, 2001; Hernández 2002
Agua de Las Tinajas	2340 BP	Mendoza, Argentina.	*Chenopodium quinoa* var. *quinoa*	Castro and Tarragó 1992
Sine Data	Cultura Chiripa 3300–1900 BP	Titicaca, Bolivia.	*Chenopodium quinoa* var. *quinoa* *Chenopodium quinoa* var.	Browman (1986, in Bruno 2006), Bruno 2005, 2006, 2008; Bruno and

			melanospermun	Whitehead 2003
Churupata pukara site	Late Regional Developments Period 700–500 BP	Colcha K, Nor Lipez, Bolivia.	*Chenopodium quinoa* var. *quinoa*	Lopez et al. this volume
Sine data	Sine data	Arica, Chile.	*Chenopodium quinoa*	Safford 1917 in Hunziker 1943b
Sine data	Chinchorro Culture	Chile.	*Chenopodium quinoa*	Ulhe 1922 in Hunziker 1943a
Tiltil, Quillagua, Tarapaca, Calama	Sine data	Chile.	*Chenopodium quinoa*	Latchman 1936 in Hunziker 1943a
Tulán 54, Tulán 58	Atacama Formative 3000–2240 BP	Quebrada Tulán, Chile.	*Chenopodium* sp.	Holden 1991
La Patagüilla 2, Las Morrenas 1, Tejas Verdes 4, La Granja	Arcaic-Early Formative 3250–2980 BP	Región central de Chile.	*Chenopodium* sp. *Chenopodium quinoa Chenopodium album Chenopodium* sp. (possibly *pallidicaule*) Amaranthaceas	Planella and Tagle 2004; Planella et al. 2005
Cerro de la Cruz	Inca 560–460 BP	Norte de Santiago, Chile.	*Chenopodium quinoa*	Tagle and Planella 2002
Cerro del Inga	Inca 560–460 BP	Chile Central	*Chenopodium quinoa*	Tagle and Planella 2002
Las Pircas I	Middle Preceramic 7690–7950 BP	Peru	*Chenopodium quinoa*	Dillehay et al. 1989 in Chevalier 2002, Rossen et al. 1996 in Chevalier 2002
Sine data	Sine data	Ancón, Perú.	*Chenopodium quinoa* W.	Hunziker 1943b
Jiskairumoko	Late Arcaic 5350–3950 BP	Peru	*Chenopodium* sp.	Aldenderfer et al. 2008
Cueva Pachamachay	5000 BP	Peru	*Chenopodium* sp. (possibly *C. quinoa* or *C. pallidicaule*)	Nordstrom (1990 in Bruno 2006) Pearsall 1989
Cueva Panaulauca	4950 BP	Peru	*Chenopodium* sp. (possibly *C. quinoa* or *C. pallidicaule*)	Bruno 2006; Pearsall 1989
Cueva Pancan	4950–650 BP	Peru	*Chenopodium* sp.	Bruno 2006
Cueva Quelcatani y sitio Camata	2740±50 BP	Peru	*Chenopodium* sp.	Bruno 2006
Sine Data	Chiripa Culture 2750–1450 BP	Peru	*Chenopodium quinoa*	Bruno 2005
Kala Uyuni	Chiripa Culture 2750–1450 BP	Titicaca, Peru	*Chenopodium quinoa* W. *Amaranthus* sp.	Bruno 2008
Tunanmarca	950–400 BP Fase Wanka I-II-III.	Valle Mantaro, Peru	*Chenopodium* sp. ("quínoa")	D'Altroy and Hastorf 2002
Umpamalca	950–400 BP Fase Wanka I-II-III.	Valle Mantaro, Peru	*Chenopodium* sp. ("quínoa")	D'Altroy and Hastorf 2002
Hatunmarca	950–400 BP Fase Wanka I-II-III.	Valle Mantaro, Peru	*Chenopodium* sp. ("quinoa")	D'Altroy and Hastorf 2002

[a] All the original data were transformed in years BP

relatives. Quinoa remains have been found in multiple contexts, including hearths, burials, storage structures, human digestive tracts and coprolites. Such diversity suggests that this plant was used in multiple ways and for different purposes, having probably both economic and religious importance. The interpretation of this variation, however, requires a better knowledge of the traces left by various human activities commonly associated with the production, processing and consumption of this plant. Our goal in this paper is to contribute to this knowledge by presenting ethnoarchaeological data recorded in Villa Candelaria, a farmer's community of the southern Bolivian Plateau, one of the main quinoa producing areas of the world. Our emphasis will be placed on the recognition of postharvest practices (Capparelli et al. 2010). Archaeobotanists in the Old World have successfully developed interpretative models of post-harvest crop processing based on ethnographic and experimental observation (e.g. Hillman 1981, 1984; Jones 1984). The post-harvest period treated here comprises from the long-term bulk storing of the grains, due immediately after harvest and threshing, to the short-term storing of the grains already apt for meal preparation and consumption. The post-harvest treatment of the grains during this period is particularly important because it involves a series of procedures that are necessary in order to take away some metabolites that are toxic for human consumption.

The paper is organized in four sections. The first one summarizes some general characteristics of the plant; the second one presents ethnoarchaeological data recorded in the Lípez region relevant for the paper's purposes. Thirdly, we analyse and characterize the botanical samples of each different processing activity, which were obtained by means of the interviewees, in order to detect grain morphological indicators that allow the recognition of these practices at an archaeological level. Finally, we apply ethnoarchaeological and experimental data to one Bolivian archaeobotanical quinoa sample. We hope this study will allow us in the future to take interpretation further with regards to the past use(s) of this species, allowing the distinction of different types and stages of processing and kinds of meal production.

General characteristics of *C. quinoa*

C. quinoa is a species belonging to the *Chenopodium* section, *Cellulata* subsection of the *Chenopodium* genus (Aellen and Just 1943). The species distributes throughout western South America, from Colombia to Chile, and includes both free-living and domesticated cultivated populations (Wilson 1988a, b). The latter, *C. quinoa* var. *quinoa*, is an annual herbaceous plant resistant to soil salinity. It reaches a height of 0.20 to 3 m depending on environmental conditions, genotype and soil fertility. It grows at altitudes ranging from 0 to 4,000 m above sea level (asl), but the best production is achieved between 2,500 and 3,800 m asl, in places with 250–500 mm of annual precipitation and 5–14°C of mean annual temperature. General features of the plant include an erect, cylindrical to angular main stem with ramifications and alternate leaves. The colour is green to red with pigmented grooves, depending on the genotypes. The inflorescence is a panicle. Fruits, dry, one-seeded and derived from an upper ovary are interpreted as achenes. The thin pericarp which covers the seed makes the fruit an urticle. The fruit is surrounded by a perigonium. Fruits are discoidal to lenticular, range from 1.6 to 2.3 (less frequently up to 2.7) millimetres in diameter and have a central starchy perisperm (more or less vitreous or floury) and peripheral embryo. The alveolate pericarp adheres to the seed. Seed shape is discoidal to lenticular with truncate edge; its diameter ranges from 1.5 to 2.2 (less frequently 2.6) millimetres. Seed tegument is thin, alveolate to smooth (Hernández Bermejo 1992; Hunziker 1943a, 1952; Martínez Ungria 1989; Planchuelo 1975; Cárdenas 1969; López Fernández 2008). The different colours of the perigonium (green, red, yellow), pericarp (white-yellow or more or less orange, pink, red or black) and episperm (white-translucent, light brown or black) are responsible of the various colours that can be present in the quinoa inflorescence (Gandarillas 1968). Although sometimes morphological features between cultivated (domesticated) and free-living population, (*C. quinoa* var. *melanospermun*) overlap, the latter has fruits generally smaller than the cultivated populations, with thicker black/brownish episperm and not truncated margins (Wilson 1988b:486).

Over 2,000 different ecotypes of quinoa have been recognized, which were interpreted by Cusack (1984) as indicators of the extent to which quinoa was cultivated under ancient systems, specially the Inca one, and adapted to the many micro-climates of their mountain state. In an attempt to classify this variation,[2] Gandarillas (1982) has grouped quinoa according to their botanical characteristics and place of origin in the different inter-Andean valleys. On the other hand, Tapia (1982, 2000) recognised five major quinoa groups established according to the agro-ecological characteristics of their area of origin, as well as morphological and physiological features (such as height, and reproductive cycle, among others) of the crops. These groups include: (1) valley quinoa (growing below 3,600 m of altitude in the inter-Andean valleys of Colombia, Ecuador, Peru and Bolivia), (2) plateau quinoa (growing above 3,600 m of altitude along the plateau of Peru,

[2] See Cusack (1984), Bertero (2001), Tagle and Planella (2002) for a description of the different quinoa classification attempts.

Bolivia, northern Chile and Argentina), (3) saltflat quinoa (adapted to extremely alkaline soil and arid conditions of southern Bolivia), (4) sea-level quinoa (growing in the cool rainy, forested regions of central and southern Chile) and (5) Subtropical quinoa (growing in the tropical low-altitude Yungas of Bolivia).

Wilson classified quinoa through biosystematic studies based on electrophoretic (allozyme variation) and morphometric (leaf and fruit) characters (Wilson 1980, 1988a, b, 1990). He proposes that this species is constituted by two well-separated elements, (1) the coastal Chilean element, which apparently includes only domesticates (this is equivalent to the Sealevel quinoa of Tapia et al. above) and (2) the Andean element, which includes both free-living and domesticated populations of Colombia, Ecuador, Peru, Bolivia, northern Chile and Argentina (assignable to the rest of the quinoa groups of Tapia et al.). Within the Andean quinoa element, Wilson (1988a, b) distinguishes a northern component, which includes Valley quinoas from Peru, Ecuador and Colombia; and a southern component, which includes Valley quinoa from Bolivia, northern Chile and Argentina, as well as Plateau, Salflat and Subtropical *quinoas*. This southern component, according Wilson (ibid.), has the highest biosystematic variation level of *quinoa*, and Wilson found it impossible to discriminate further sub-types in his analysis.

More recently, Bertero, Del Castillo and collaborators studied quinoa variability from a genetic perspective (Bertero et al. 2004; Del Castillo 2008; Del Castillo et al. 2006, 2008). Bertero et al. (2004) identified four genotypic groups of quinoa on the basis of their genotypic-by-environment interaction: G1, inter-Andean valley varieties; G2, Peruvian Plateau varieties; G3, Bolivian Plateau varieties and G4, sea-level central Chilean varieties. Del Castillo et al. (2008) mention that quinoa genetic variability is also expressed by the diversity of colors of the stems, inflorescences and grains; shape and size of the inflorescences; proteins presence; saponin content and the presence of oxalate crystals in their leaves. The analysis of genetic markers (RAPD) of four populations of Bolivian cultivated quinoa (coming from the Plateau, saline areas and inter-Andean valleys) demonstrated that there are both intra- and inter-population variation, which distinguish three groups: (1) Plateau quinoas (divided in northern and central Plateau), (2) valley quinoas and (3) saltflat quinoas (Del Castillo et al. 2006, 2008). According to Del Castillo (2008), this genetic differentiation can be interpreted as a result of the adaptive potential of quinoa populations being directed during or after domestication towards diverse agro-ecological regions isolated not only by geographical factors but also by climatic and physical barriers.

Quinoa grains have high-quality proteins (12% to 16%) constituted by water-soluble albumins and globulins with high levels of digestibility (80%). They also have high proportions of essential amino acids, Omega 3, 6, and 9 fatty acids, vitamins, and minerals, such as calcium and iron. Its carbohydrate content is mainly organized as starch (50–60%) small grains of spherical to polygonal shape, disposed to forming oblong aggregates and located in the perisperm. Hevia et al. (2001) show that gelatinisation of these grains occurs between 55°C and 65°C depending on the types and quantities of other substances present in the perisperm, e.g. sugars, proteins, lipids, acids and water which can slow down or inhibit gel formation. The content of free sugars in the grain is 6.2%, and total fiber is 7.8% (Cusack 1984; Mujica and Jacobsen 2006; Repo-Carrasco et al. 2003; Romo et al. 2006). Although the grains are the most commonly consumed part of the plant, the leaves are sometimes used in salads when still fresh or in porridges when already dried. The leaves, stems and grain are also used in medicine mainly because of their anti-inflammatory and analgesic properties (Romo et al. 2006).

Quinoa grains have steroidal compounds (saponins) that are in fact glycosides that have a bitter taste, form foam in water solution and have toxic effects (haemolytic power) (Romo et al. 2006; Vera et al. 2001). These substances protect the grain against birds, rodents and insects during the maturation stage and storage period (Vera et al. 2001) but need to be removed before human consumption. There is a debate around where the saponins are found in the grain. Different authors have proposed that they are placed in the pericarp (Romo et al. 2006), in the episperm (Vera et al. 2001) or even in the perisperm (Planchuelo 1975), but recent analysis through microscopic fluorescence showed that saponins are in situ in the grain, in the cellular walls of the pericarp (López Fernández 2008). Quinoas vary in their saponin content between 0.06% and 5.1%, depending on ecotype and on environmental factors (Fontúbel 2003; Vera et al. 2001; Romo et al. 2006). While Junge (1973 in Tagle and Planella 2002:40) in previous decades considered “bitter” those grains with 3.4–3.9% of saponin content, recent studies divided in “bitter” and “sweet” quinoas those with more and less than 0.11% of saponins, respectively (Landauer and Avendaño 2001). Carrillo (1927:57), based on ethnographic information, and Cardozo and Tapia (1979:177) concur in the fact that there is a relationship between white-smaller grains and sweet quinoa and large grains and bitter quinoa. The direct positive correlation between the saponin content and the increment of grain size has been confirmed by recent studies (Fontúbel 2003). Also, Gandarillas (1967) said that in the Bolivian Plateau, quinoas commonly denominated as “without saponins” are concentrated in the southern part of the Titicaca lake and have small to intermediate size grains and that quinoas with the highest saponin content are focused on the southern part of the Oruro and Potosí Departments and have large grains.

Saltflat quinoa is considered to have the highest saponin content of the Tapia's mentioned groups (Tapia 1982).

In sum, the more bitter the quinoa, the more difficult it is to reduce saponin to a minimal content not prejudicial for consumption. As we argue below, postharvest practices described in this paper are related with pericarp extraction and subsequent washing up of the grains. They involve different types and sequences of activities, which are included in what people call "mejorado de los granos" (grain enhancement) that make the grains apt to consumption. These activities also vary depending on the kind of meal that people intend to prepare. Although today, *quinoa* consumption has extended into the European and North American market, Bolivia is the largest producer and exporter of the world (Nieto and Valdivia 2001; Tapia 2000). The increase in the scale of production has led Bolivian farmers to use modern techniques for preparing the grain to eat, especially those concerning saponin extraction using machines for removing the pericarp. This situation is causing the loss of knowledge about traditional processing methods, which presently are only used by old people in a few communities, like Villa Candelaria.

An ethnoarchaeology of quinoa processing

The community

Villa Candelaria (Province of Nor Lípez, Department of Potosí, Bolivia, Figs. 1 and 2) is located near the southern shores of Salar de Uyuni, in the southern Andean high plateau or "Altiplano". With altitudes above 3,650 m asl, very low temperatures (ranging from −13°/3°C to 20°/28°C depending on the season) and annual precipitations below 300 mm and concentrated between December and March, this area presents very hostile conditions for farming.

Villa Candelaria comprises between 30 and 40 quechua-speaking households. Most households cultivate *quinoa*

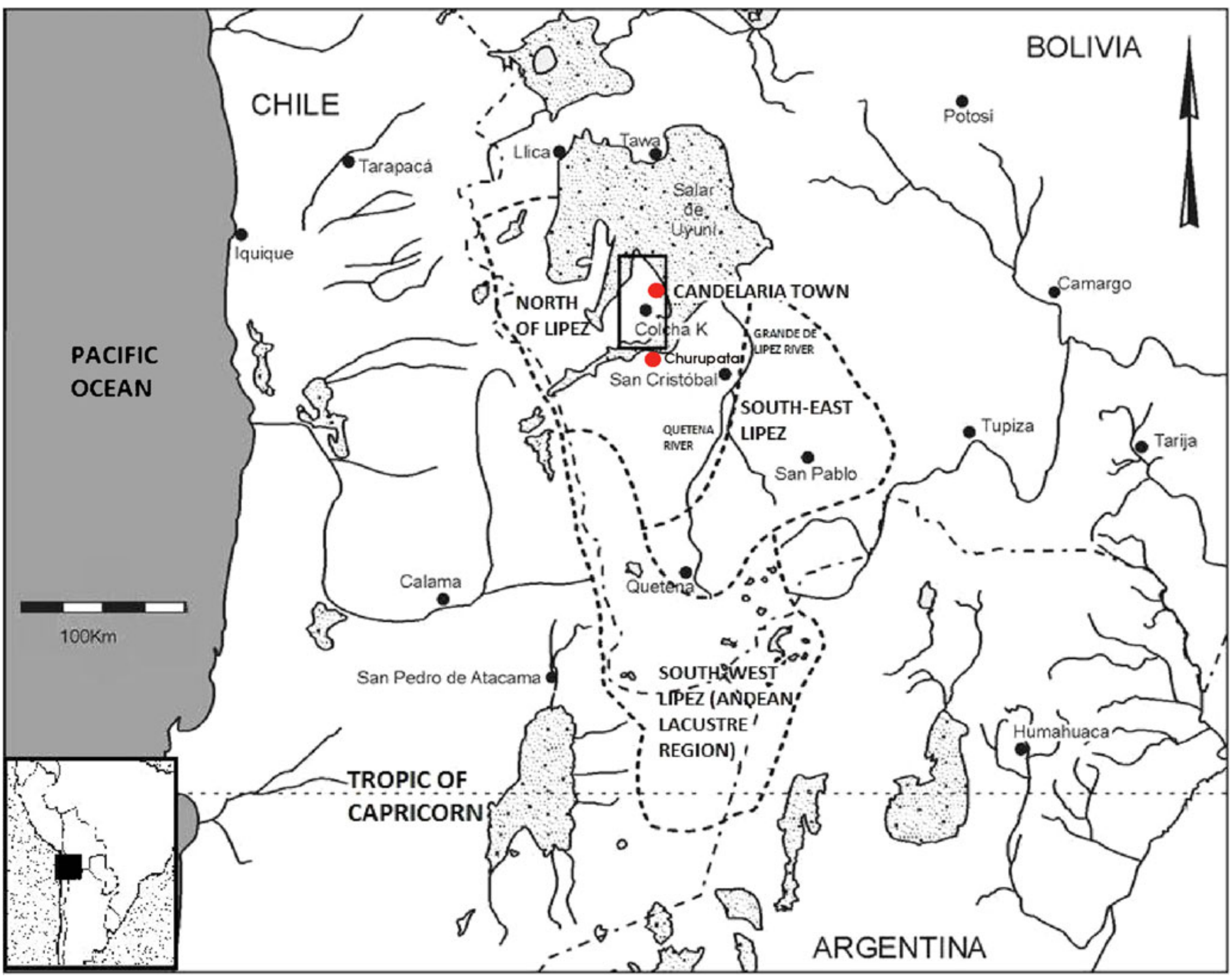

Fig. 1 Study area: Northern Lípez, Potosí. Bolivia. Location of Villa Candelaria modern town and Churupata archaeological site (*red points*)

Fig. 2 General view of Villa Candelaria modern town

and potatoes not only for their own consumption but they also sell them in urban markets directly or through middle-persons. Some families also breed llamas and donkeys. Parts of the inhabitants are permanent residents, while others only live in the community during the period of cultivation and harvest. People also cultivate European legumes for family consumption, such as broad bean (*Vicia faba*), and cereals, such as barley (*Hordeum vulgare*), mainly in small-irrigated plots.

The forms of production and consumption of quinoa practiced in farmer communities like Villa Candelaria seem to be very old or "traditional", as indicated by their similarity with descriptions found in ethnohistorical sources (López and Capparelli 2008). According to Tapia (1982, 2000), Bertero et al. (2004) and Del Castillo et al. (2006, 2008) classifications of *quinoa*, that one cultivated in our study area belongs to the groups of the Plateau (above 400 mm of annual precipitation) and to the Saltflat *quinoa* (below 400 mm of annual precipitation). In terms of the classification of Wilson (1988a, b), it belongs to the southern component of the Andean quinoa. People of Villa Candelaria cultivated mostly quinoa of white-transluscent episperm, which can present white, yellow, pink, red or orange pericarp; also "pasancalla" *quinoa* (with brownish episperm and pericarp) is grown, but less frequently. *C. quinoa* var. *melanospermun* grows as a weed in Villa Candelaria farmers's lands, it is recognized by the people for their smaller black grains and is called by them *ajara*.

While 80% of the domestic units of Villa Candelaria grow the quinoa in flat lands ("pampa") placed in the neighbourhoods of the town, which were given to them from the government 50 years ago, the other 20% of the inhabitants preserve their old tradition of cultivating quinoa on the hill "cerro", where agro ecological conditions are most suitable for this crop. These hills are 6–8 km away from the town, and people used to do a return journey every day in the epoch of the *quinoa* growing cycle. Otherwise, they improvise in the field a basic hut called *anta*, where they can pass the night, especially in times of harvest, where more people and harder work is required (Guagliardo 2008).

Methods

Eight women, living in different households of Villa Candelaria, aged between 50 and 70 years old were interviewed during several field trips conducted from 2007 to 2009. These women shared with us their knowledge on grain-processing practices acquired from their parents and/or grandparents. Open and semi-structured interviews, as well as direct and participant observation, were applied (Martin 1995; Cotton 1996). Information was collected through digital recordings (MP3), field notes and photographs.

During participant observation, all our informants gave us subsamples of grains from each processing stage of the three different types of grain enhancement (see below for a description). One litre of quinoa grains (equivalent to 650 g) of pink and white pericarp, both with white-translucent episperm, were used by the interviewers to undertake each kind of grain enhancement. These samples were analyzed in order to define morphological and quantitative indicators that could allow the recognition of different types and stages of processing in the archaeobotanical record. Each sample of grains was scanned under both stereoscopic and incident light microscopes. Several qualitative characteristics were registered, such as presence/absence of perigonium and pericarp, evidences of parching in terms of brown colouring of pericarp and episperm, loss of embryos, among others. Percentages of each feature in a whole sample were obtained by extrapolation of values counted for 150 grains. Since archaeobotanical macro-remains are commonly charred, experimental charring was conducted. Four sets of 20 quinoa grains each (unprocessed and prepared to be consuming as whole seed, soup and *pitu*) were burned in an open fire during 5 min in an experimental domestic hearth at an average temperature of 350–400°C. Temperature was measured by means of a thermometer and a thermocouple. Another two sets of 10 grains each were charred in a muffle furnace at 400°C, one in oxidizing and the other in reducing atmosphere.

Results

As mentioned before, quinoa grains have to be exposed to several treatments prior to consumption. These treatments are comprised within what our informants called "mejorado de los granos" (grain enhancement or improvement). Their main purpose is to reduce as far as possible the presence of saponins in the grain. The types of grain enhancement vary depending on the meal that people want to prepare. People divide them in three general groups, each of which involves different activities in a characteristic sequence (Fig. 3). These activities take place in different locus of the domestic space (Fig. 4). The grains for enhancement are taken from large storage bags made of wool (today nylon is also used) kept in special storage rooms. These sacks (Fig. 5a) contain grains that have been already threshed and cleaned in the cultivation plots right after the harvest and then transported by donkeys to the domestic area for storage (see Lopez 2010 for more detail on quinoa post-harvest processing from the stage of harvesting the panicles to that of bulk storage).

Enhancement types of quinoa

1. Quinoa to be eaten as whole seed or grain

   This is called, in Spanish, quinoa for graneado (also *pissara* in Quichua, see Cevallos Tovar 1945:17). This kind of *quinoa* can be boiled and eaten alone (like rice) or in porridge mixed with other vegetables. Ground into flour this *quinoa* can be used to prepare *mukuna* (a special kind of bread). The activities involved in grain enhancement for this kind of use include parching, treading, winnowing, washing, rubbing, and drying (Fig. 3). Firstly, *quinoa* is parched by heat in an outdoor hearth exclusively used to process food. The grains are placed on a metal frying pan called *ankanabatía* (they used clay pots in the past but changed to metal ones which heat more quickly) and are stirred with a straw brush called *p'iji* (Fig. 5b). After 3 min of parching the grains acquire a light brown colour, and in this way, the pericarp becomes brittle so it can be easily removed by treading. The embryo shows almost no distortion after parching. The *quinoa* is then poured in the *saruna* for treading. The *saruna* is a circular, mobile stone basin similar to a mortar.[3] The size of it may vary but the diameter of the cavity is always around 45 cm, so the feet of a person can fit inside and move (Fig. 5c). The *saruna* is filled up to three fourths of its volume; if less *quinoa* is trodden at a time, the grains can be broken and, therefore, unsuited for its preparation as whole seed. Grains are trodden while they are still hot because the pericarp separates more easily in this way. This treatment concludes when the grains are covered by a white powder (the fragments of the pericarp). Each set of grains already tread are temporarily placed over a wool blanket (*awayo*) extended next to the *saruna*. A first winnowing is then needed. To do that, the *quinoa* is poured from a height of 40–80 cm on the *awayo* when gentle breeze blows (Fig. 5d). Winnowing takes place in open areas, where the wind intensity is considered appropriate, approximately 50 m away from the house in the cases we observed. Treading and winnowing are repeated once again, and then the grains are ready for rinsing and rubbing. Rinsing is done in a bucket or a dish (today made from plastic or metal) filled with water; the *quinoa* is stirred gently with the hands to let the little stones that could be mixed with the *quinoa* settle at the bottom of the bucket (Fig. 5e). The water is drained into the irrigation ditch that runs along the centre of the courtyard (see Fig. 4). The grains are then moved to another container with a piece of cloth spread inside (Fig. 5f). The *quinoa* is wrapped with this fabric and this improvised "bag" is rubbed between the hands. Rinsing helps to dissolve the saponins and take them away, while rubbing helps to erode the remaining fragments of pericarp from the grains. Rinsing and rubbing are repeated until no foam appears and the water is no longer white but transparent. Finally, the grains are sun dried on an *awayo* spread on the ground in the courtyard (Fig. 5g). Once dried, the *quinoa* is winnowed one more time before storing it in little bags in the kitchen, where it is ready to be used at any time (Fig. 5h).

2. Quinoa to be eaten in soups

   People call it *quinoa* for "sopa" (in Spanish; or *pescke* in Quichua, see Cevallos Tovar 1945:17). Soups and stews are prepared with them by boiling *quinoa* with other vegetables and, occasionally, meat. These kinds of grains can be used also to prepare drinks. Grain enhancement for this kind of *quinoa* is similar to the treatment described for whole seeds (see Fig. 3). But, parching for soup takes less time (2 min) than that of whole seed *quinoa*. Another difference is that during the second treading, a ground mineral called *poq'era* is added to the grains in the saruna. *Poq'era*, which is extracted from the nearby mountains, intensifies the friction among the grains.

3. Quinoa to be eaten as pitu

   In Quichua, people give the name "*pitu*" (or "*p'ito*", see Bruno 2008) to a kind of toasted *quinoa* refined flour, which does not require further processes of cooking, and is consumed with water and sugar. During this kind of grain enhancement there are several episode of parching (see Fig. 3) The first parching is

[3] It is interesting to mention that, as occurs in other parts of the NW of Argentina with the mortars (see Capparelli and Lema 2011), the modern people of the Bolivian Altiplano look for *sarunas* in the archaeological sites, instead of making the artefact themselves.

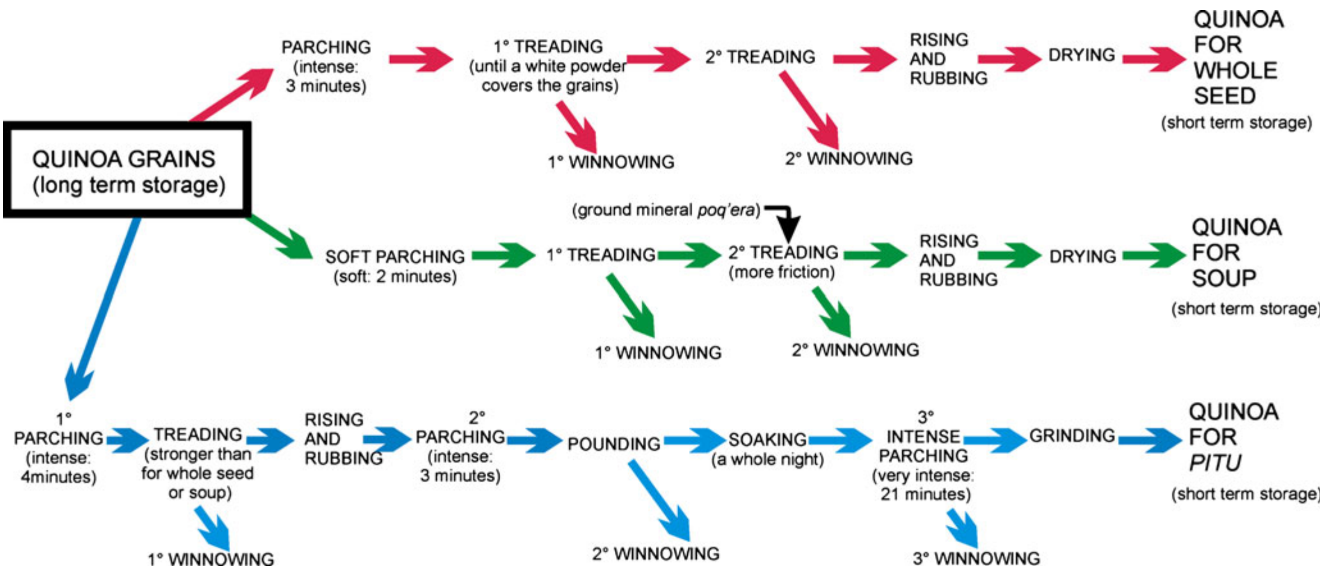

Fig. 3 Sequence of practices involved in the enhancement of quinoa for whole grain, soup and *pitu* (see text for more detail) following Hillman (1981) models for wheat. See also Tables 2 and 3 for a description of archaeobotanical analysis of samples from each stage. The duration of the heating period refers in all cases to 650 g of quinoa grains

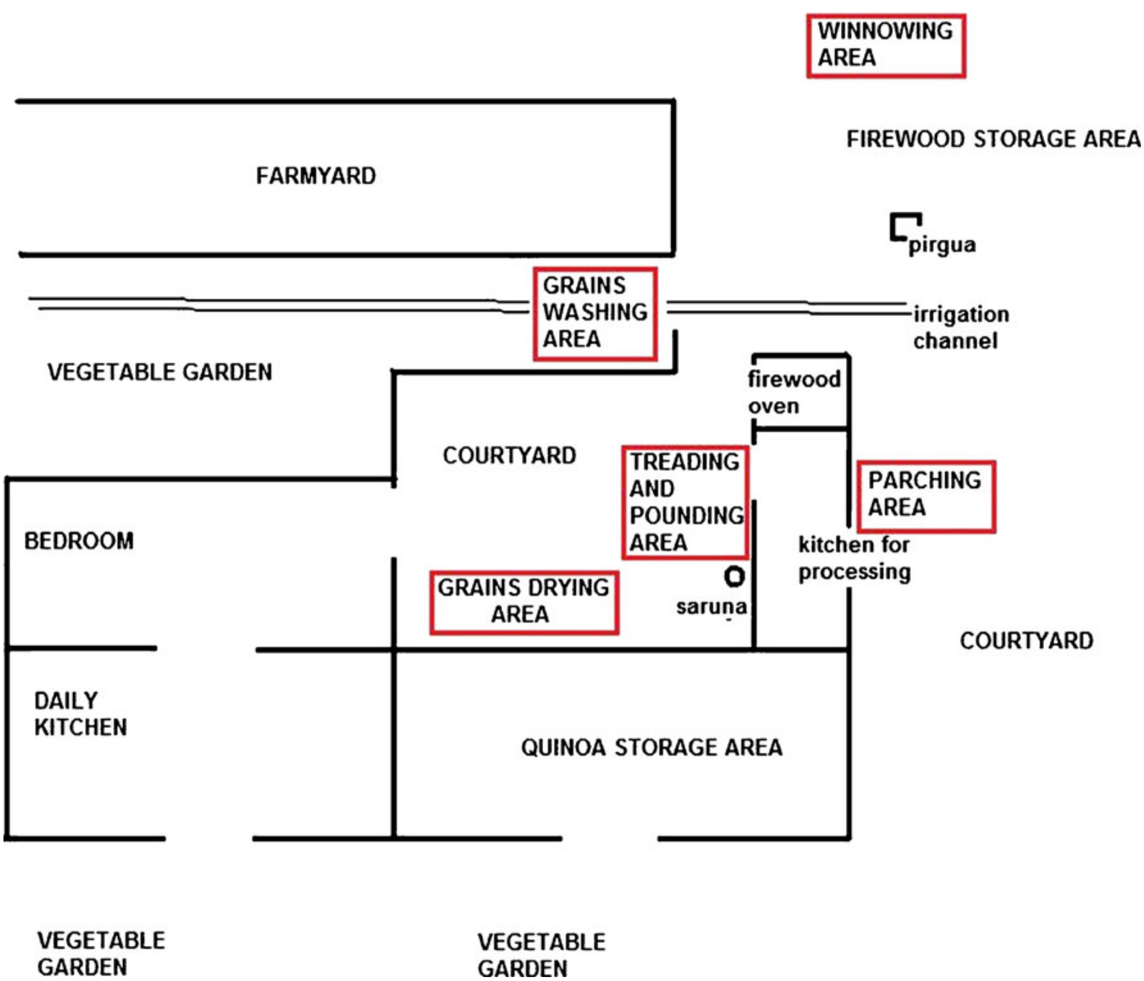

Fig. 4 Spatial distribution of main components of the household and the locations where post-harvest practices for enhancement of *quinoa* grains take place

Fig. 5 **a**–**h** Modern *quinoa* enhancement practices to be consume as whole seed. **a** Long-term bulk storage of non enhanced quinoa; **b** parching; **c** treading in the *saruna*; **d** winnowing; **e**, **f** rinsing and rubbing; **g** sun drying; **h** short-term storage of enhanced quinoa

done in the same manner as for whole seed, except that in this case it takes 25% more time (4 min). Treading is also more intense than in *quinoa* for whole seed or soup. After treading, it is necessary to do a first winnowing, and then the rinsing and rubbing, all in the same manner described before. A second parching of 3 min is done at this stage, then grains are strongly pounded with a stone pestle in the same *saruna* used previously for treading (Fig. 6a, b). A second winnowing is done. After that, grains are soaked in cold water over a whole night until they swell. Soaking is done in a container with a piece of cloth spread inside similarly of that used for rinsing (Fig. 6c). According to Doña Elvira Cayo, if grains are soaked in hot water, they need less time (only about 2 h). A third parching is done after soaking; this parching lasts more time than the others (21 min) and requires the use of a long stick for stirring in order to protect the hands from the hot vapour produced during the parching (Fig. 6d). A third winnowing is done then, leaving the grains ready for grinding. Grinding is done today in a European style mill, but people say that in the past a *q'ona* (a ground stone basin with a stone pestle) was used.

All the different kind of *quinoas* cultivated in Villa Candelaria may be indistinctly processed into any of these grain enhancement types, except for the *pasancalla*. This kind of *quinoa* is enhanced just like quinoa for soup. Enhanced *pasancalla* grains are used to

Fig. 6 **a**–**d** Modern *quinoa* enhancement practices to be consume as *pitu*. **a**, **b** Pounding in the *saruna*, **c** soaking, **d** 3rd (last) parching

prepare *pipoca* (pop-*quinoa*), but also they can be ground into a flour, which, due to its characteristic flavour, is used only to prepare sweet meals.

Sample analysis

A sample of *quinoa* was morphologically and quantitatively analysed after each stage of processing (Figs. 7a–l and 8a–j). This analysis revealed that *quinoa* for whole seed (Fig. 7a, c, e, g, i and k) differs from that for soup (Fig. 7b, d, f, h, j, l) from the beginning of the processing because of the initial intense parching carried out in the former (see Fig. 7a and b). This results in more grains with parching evidence[4] after the first stage of processing (62% vs 28%, respectively, Table 2, first column). As a consequence of intense parching, pericarp becomes brittle and less adhered to the seed and takes a brownish colour. Parching make pericarp to be extracted easily during the following steps, and none of the specimens of *quinoa* for whole seed preserved its complete pericarp in the last stages of processing (Fig. 7c, g and k). Parching evidence (in terms of the presence of brown pericarp) is reduced almost to a quarter (14%) of the initial values (62%) in the final stages of processing of *quinoa* for whole seed. This reduction occurs because brown coloured pericarp is removed. However, this 14% is still high, if it is compared to the 1% of *quinoa* for soup (Table 2, fourth column). This high proportion of specimens that are still brown may be because longer parching also riched the episperm and not just the pericarp. By contrast, *quinoa* for soup, which is parched less, has a less brittle and brown-coloured pericarp (Table 2, fourth column). Perisperm of *quinoa* grains used as whole seed or ready to prepare soups have a flourlike appearance and a very white colour, which is especially obvious in those which have lost their pericarps (Fig. 7k and l).

The embryo is the other part which is affected in several grains by treading and rubbing, especially in *quinoa* processed for whole seed or soup. Their winnowed residues are commonly constituted mainly by embryos, and by some deteriorated grains (Fig. 7e, f, i and j). This feature is consistent with the percentages of grains that lost their embryos in the last stage of grain processing for both kinds of preparations (41% and 17% of grains without embryos in *quinoa* for whole seed and soup, respectively).

Grains to be eaten as *pitu* (Fig. 8a–j) combine characteristics of the two other types, such as high quantity of grains browned by parching and high percentages of preservation of part of the pericarp after the first treading (Table 3, second column; Fig. 8c). However, as grains are exposed here to three stages of parching, the last one of long duration, all of the grains show traces of parching (i.e. browning) by the last stages of processing (see Table 3, sixth column). Despite this more intense parching, a relatively high number (25%) of the grains preserve part of the pericarp in the final stage. It is thought that the relative high number of grains preserving part of the pericarp may be because treading and pounding of grains for *pitu* was done more softly than in the other enhancement types. This might be also the reason for the higher persistence of the embryos in *quinoa* for *pitu* (see below). Soaking, the penultimate step to obtain *quinoa* for *pitu*, dissolves remnant saponins of the pericarp. In grains

[4] We refer to "parched grains" or "parching evidence" external evidences of heating, which can be recognized by the presence of patches of light to dark brown pericarp or episperm.

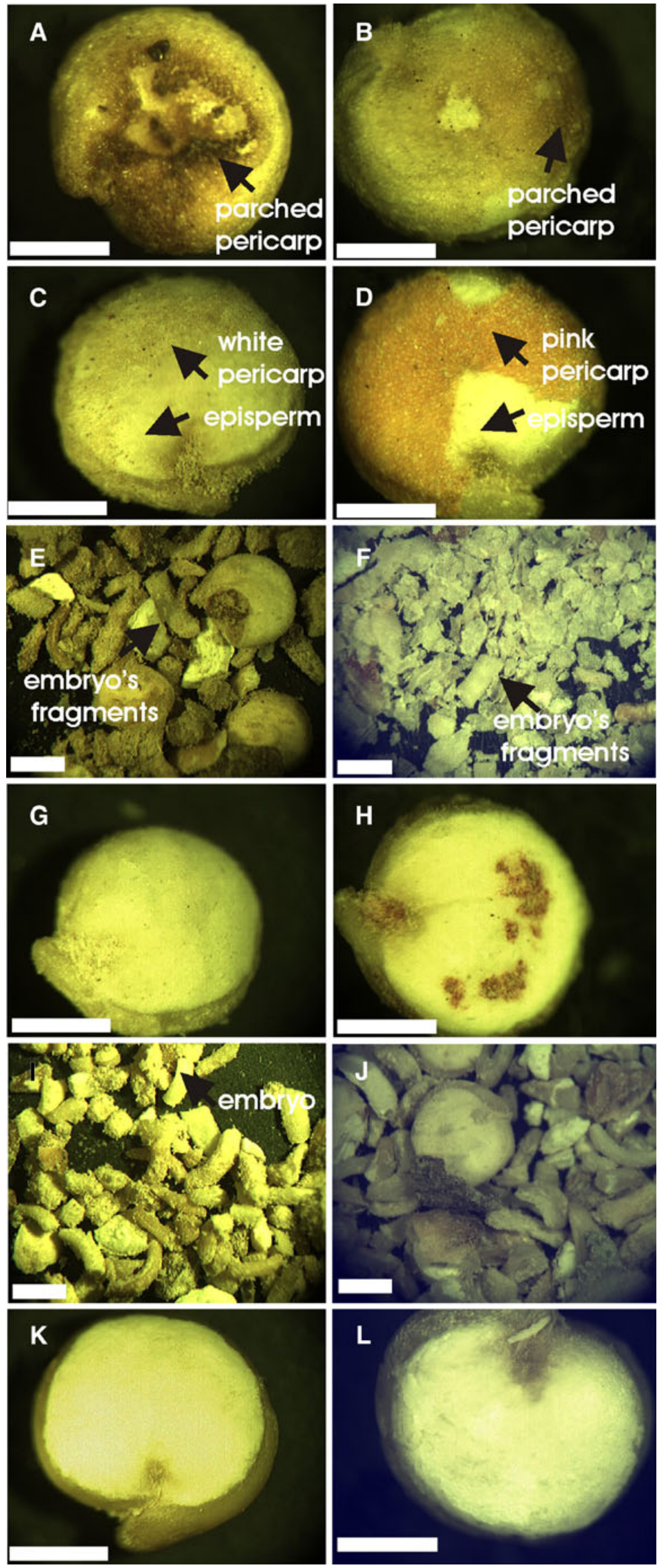

Fig. 7 **a**–**l** *Quinoa* grains after different stages of processing for whole seed (*left column*) and soup (*right column*). **a**, **b** After parching. **c**, **d** After first treading. **c** *Quinoa* of white pericarp, **d** *Quinoa* of pink pericarp, **e**, **f** 1st winnowing residue, **g**, **h** after 2nd treading, **i**, **j** 2nd winnowing residues, **k**, **l**, grain ready to be consumed as whole seed and soup, respectively. *Scale*=1 mm

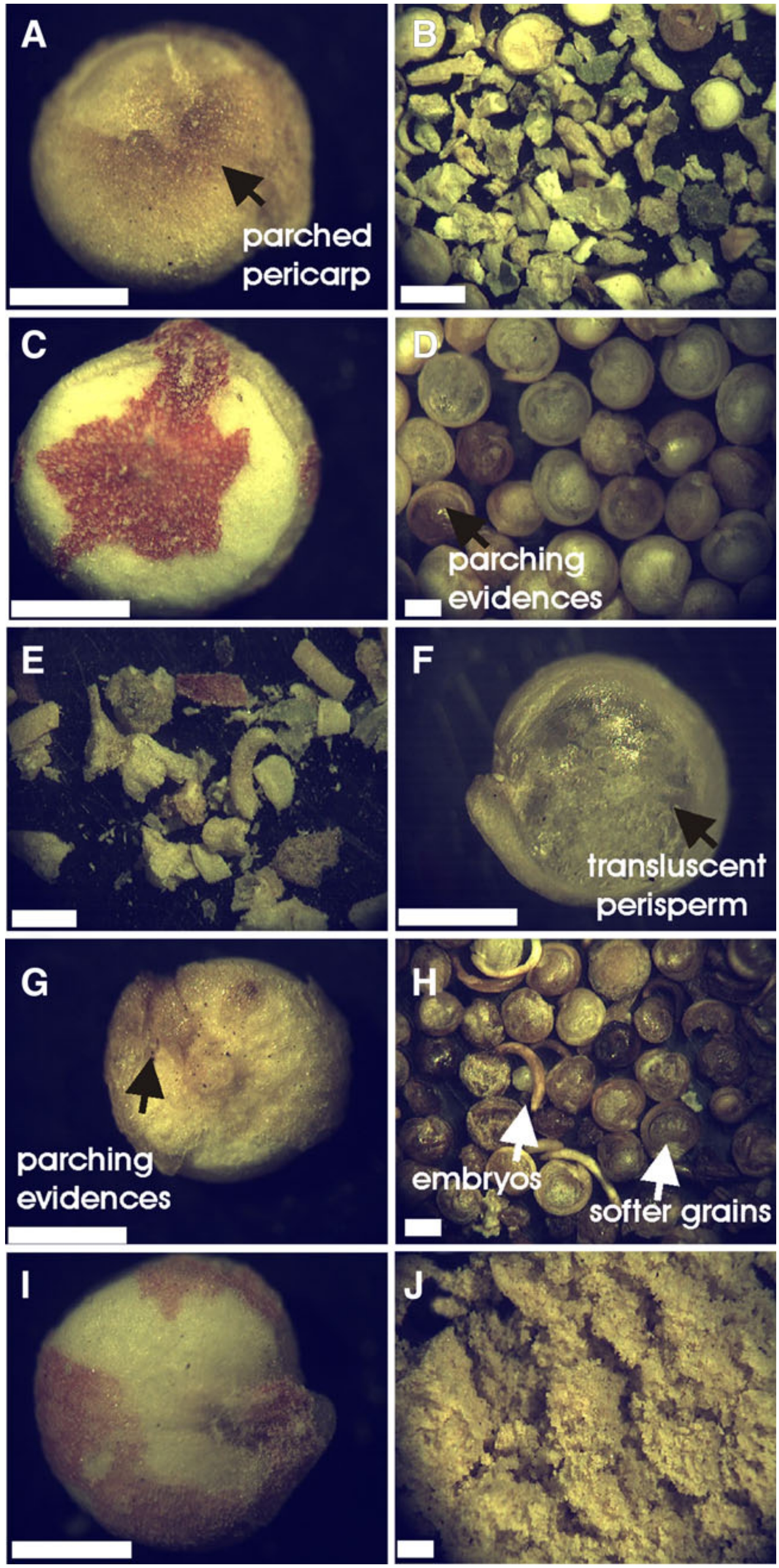

Fig. 8 **a**–**j** *Quinoa* grains after different stages of processing for *pitu*. **a** After 1st parching; **c** after 1st treading; **e** 1st winnowing residues; **g** after 2nd parching; **i** after pounding; **b** 2nd winnowing residues; **d** after soaking; **f** after 3rd parching, grain ready to make *pitu*; **h** 3rd winnowing; **j** *pitu* flour elaborated after ginding. *Scale*=1 mm

Table 2 *Quinoa* to be consumed as whole seed and as soup: micromorphology of the grains after each processing activity

	Parching	1st treading	2nd treading	Rinsing and rubbing
Whole seed	100% of the grains with complete pericarp, some of them also with perigonium.	73% of the grains with complete pericarp or part of it.	28% of the grains with complete pericarp or part of it.	18% with part of the pericarp (none of them with complete pericarp)
		27% of the grains without pericarp.	72 without pericarp.	82 without pericarp (10% with injured spermoderm).
	62% of the grains with brown colour parching evidence (in some of them parched pericarp separates from the seed and fold, see Fig. 7a)	50% with brown colour parching evidence	50% with brown colour parching evidence.	14% with brown colour parching evidence.
	0% of the grains without embryo	17% of the grains without embryo	35% of the grains without embryo	41% of the grains without embryo
Soup	100% with complete pericarp or part of it (5% with perigonium).	74% of the grains with complete pericarp or part of it.	70% with complete pericarp or part of it.	35% with complete pericarp or part of it.
		25% without pericarp.	30% without pericarp.	65% without pericarp (24% of them with injured spermoderm).
	28% with brown colour parching evidence (in some of them parched pericarp separates from the seed and fold, see Fig. 7b)	2% with brown colour parching evidence.	1% with brown colour parching evidence	1% with brown colour parching evidence.
	0% of the grains without embryo	17% of the grains without embryo	16% of the grains without embryo	17% of the grains without embryo

Table 3 *Quinoa* to be eaten as *pitu*

1st Parching	Treading	Rinsing and rubbing	2nd Parching	Pounding	Soaking and 3rd parching
8% of the grains with perigonium.	8% of the grains with perigonium.	6% of the grains with perigonium.	3% of the grains with perigonium.		
92% of the grains with complete pericarp or part of it.	91% of the grains with complete pericarp or part of it.	65% of the grains with complete pericarp or part of it.	60% of the grains with complete pericarp or part of it.	40% of the grains with complete pericarp or part of it.	0% of the grains with complete pericarp and 25% of the grains with part of pericarp.
	1% of the grains without pericarp.	35% of the grains without pericarp.	40% of the grains without pericarp.	60% of the grains without pericarp.	75% of the grains without pericarp (some of them with testa separated from the episperm and wrinkled or folded).
62% of the grains with brown colour parching evidence (in some of them parched pericarp separates from the seed and fold, see Fig. 8a)	26% with brown colour parching evidence.	42% with brown colour parching evidence.	53% with brown colour parching evidence.	34% with brown colour parching evidence.	100% of the grains with brown colour parching evidence (a sign that grain is "ready to grind") and with vitreous/pearl appearance.
0% of the grains without embryo	4% of the grains without embryo	5% of the grains without embryo	7% of the grains without embryo	7% of the grains without embryo	7% of the grains without embryo

Micromorphology of the grains after each processing activity that have lost their pericarp, soaking contributes also to the separation of the testa from the rest of the seed, and some specimens have wrinkled or folded testa after soaking similarly to what occur in legumes seeds such as *Prosopis* (see Capparelli and Lema 2011). Soaking grains for *pitu* also results in a diagnostic translucent (vitreous/pearly) appearance (Fig. 8d and f) different from the white flour-like appearance of *quinoa* for whole seed or soup (Fig. 7k and l, respectively). It is interesting to note that the portion of the sample that is removed by winnowing during grain processing for *pitu* does not have a large quantity of embryo fragments. Instead, entire or fragmented soft grains occur in the winnowing by-product (Fig. 8e and h). This feature is consistent with the low percentages of grains without embryos (7%) in the last stage of *pitu* preparation (Table 3, sixth column).

In sum, a high percentage (65% to 82%) of grains without pericarp is a general feature common to the final stages of the preparation of *quinoas* for whole seed, soup or *pitu*. The presence of high quantities of such grains can be used for distinguishing *quinoas* with grain enhancement from both modern ethnographic, as well as in desiccated archaeological samples (it applies also to charred archaeobotanical samples, see the issue "experimental charring" below). In addition, the presence of partial or complete pericarp, together with other useful diagnostic features may be useful to differentiate each specific kind of grain enhancement, as per the following key:

a. all the grains with vitreous or translucent and pearly appearance and parching evidence, most but not all the grains without pericarp, most grains with their embryos (some of them with wrinkled or folded testa)……………………………………*quinoa* for *pitu*
   (aa) grains without vitreous or translucent and pearly appearance, instead, a flourlike very white appearance is observed in peeled grains…………………………………………………………*quinoa* for whole seed or for soup
b. presence of a few grains with complete pericarp, 17% of the grains without embryo, almost no parching evidence (1%)……………………………*quinoa* for soup
   (bb) none of the grains with complete pericarp, half of them without embryo, 14% of the grains with parching evidence………………………………………………………*quinoa* for whole seed or soup

In an archaeobotanical assemblage, however, grains with complete or partial pericarp might be less diagnostic than the other features, because it would be difficult to distinguish if they might represent the deposition of unprocessed grains.

Experimental charring During charring, it was observed that some *quinoa* grains may pop and others do not. If the *quinoa* pops, the perisperm is usually exposed and becomes very soft. These grains are not useful for identifying the post-harvest activities described here. Grains that do not pop are diagnostic; they maintain much of their qualitative morphology after charring. For example, all the grains with complete pericarp and embryo in the initial condition preserved their pericarp and embryo after carbonization, which means that the lack of pericarp and/or embryo in charred remains can be attributed mostly to processing activities. Non-processed grains charred with an experimental hearth had similar behaviour to those charred in a muffle furnace with an oxidizing atmosphere (i.e. no variation in diameter and 45% to 54% increase in thickness), while those charred in a muffle furnace with a reducing atmosphere had almost no variation in both measures (Table 4). Enhanced grains showed different responses after charring. Grains for whole seed and soup have shrinkage of their diameter (from 5.8% to 8.3%), but thickness had different responses: grains for whole seed show no change and those for soup increase 11%. Grains for *pitu* increase both their diameter (8.3%) and their thickness (46%; Table 5).

Translucent grains of *quinoa* for *pitu* can be distinguished after charring because they still have a silky texture, smoother and more brilliant than the other two

Table 4 Average of the percentages of changes in diameter and thickness of *quinoa* grains after charring by means of an experimental hearth and muffle furnace

Method	Non-processed grains	Feature	Before charring	After charring	Change %
Experimental hearth	n=20	Diameter	2.40 mm	2.40 mm	0%
		Thickness	1.24 mm	1.80 mm	+45.1%
Muffle furnace	400°C (oxidizing atmosphere) n=10	Diameter	2.50 mm	2.50 mm	0%
		Thickness	1.30 mm	2 mm	+53.8%
	400°C (reducing atmosphere) n=10	Diameter	2.40 mm	2.40 mm	0%
		Thickness	1.35 mm	1.40 mm	+3.7%

Material: white quinoa from Doña Elvira of Villa Candelaria town

Table 5 Percentages of changes in diameter and thickness of *quinoa* grains, after charring by means of an experimental hearth

Non-processed grains (n=20)	Enhanced grains (n=20 for each type)						
	Enhancement type	Feature	Enhanced grains before charring	Change % with respect to non-processed grains	Enhanced grains after charring	Change % with respect to non-charred enhanced grain	Change % with respect to non-processed grains
Diameter 2,40 mm	Whole seed	Diameter	2,21 mm	−0.8%	2,26 mm	+2.26%	−5.80%
		Thickness	1,22 mm	−1.6%	1,24 mm	+1.6%	0%
	Soup	Diameter	2,21 mm	−7.9%	2,20 mm	−0.45%	−8.30%
Thickness 1,24 mm		Thickness	1,14 mm	−8.1%	1,38 mm	+21.05%	+11.3%
	Pitu	Diameter	2,43 mm	+1.3%	2,6 mm	+6.99%	+8.30%
		Thickness	1,29 mm	+4%	1,81 mm	+40.3%	+46%

Values for each enhancement type, charred and non-charred, are averages of a same set of grains; while values for non-processed grains are averages of a different set of grains. Material: white *quinoa* from Doña Elvira of Villa Candelaria town

types (see Fig. 9a and b). However, these grains become much softer and more fragile than those of *quinoa* for whole seed or soup. Therefore, post depositional factors may affect *quinoa* for *pitu* more severely than the others, what may result in a sub-representation of these kinds of grains. It was also observed that the perisperm of *quinoa* for *pitu* is easily destroyed when it is charred under more intense processes of carbonization, retaining only the annular embryos of the grain.

Finally, it is worth mentioning that these diagnostic characters are useful in the case of accidental charring occurred in hearths used for cooking *quinoa* meals. This is because in these cases *quinoa* reaches the fire already processed. In contrast, *quinoa* grains accidentally charred during parching at an initial (in the case of grain/soup/*pitu*) or also intermediate (in the case of *pitu*) stage of processing, frequently keep their pericarp complete. In these cases, it is more difficult to distinguish between the different types of enhancements from archaeological *quinoa* assemblages.

An archaeological case study: quinoa remains from preliminary excavations at Churupata

Churupata (Fig. 10a–c) is a fortified village (252 m length× 160 m width) placed on the East facing side of a hill. It is located 3 km away from the town of Villa Candelaria, at 3,750 m asl. Its geographical coordinates are 67°37.415′ W and 20°39.299′ S. It dates to the Late Regional Developments Period (1250–1450 A.D.) and was probably abandoned during the fifteenth century, when the Inkas expanded over the southern Andes and conquered the Plateau people. The earlier Regional Developments Period (900–1250 A.D.) is a time of dramatic reorganization marked by a gradual disintegration of macro-regional structures related to the Tiwanaku formation. This is a time of increasing levels of intergroup violence accomplished by a long-term cycle of drought that peaks during the late phase of the period. In contrast, the late phase of the period is characterized by a tendency toward a rapid population aggregation and political integration among communities. This involved not only contrasts of size and internal complexity among settlements but also the differential distribution of public areas or "plazas" that become a well-defined component of site structures (Nielsen 2008: 216). In the case of Churupata archaeological site, one central "plaza" was recognized, together with more than a hundred of rectangular rooms made from one simple stone wall and a stone perimeter wall (Fig. 10b). Each room has an entrance with an air deflector (Fig. 10c), which is a wall that protects the hearth from strong air fluxes. The occupation of the site appeared to have been permanent

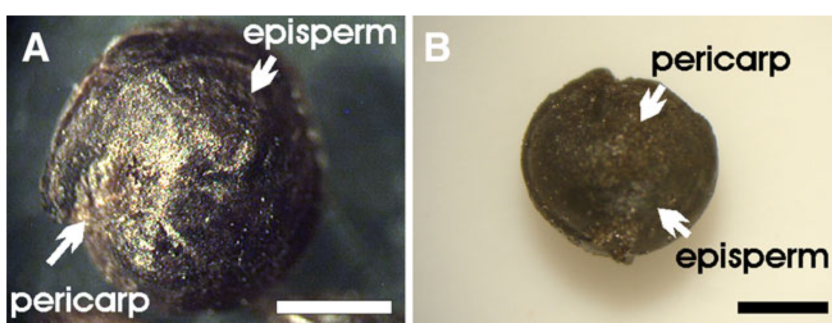

Fig. 9 **a**, **b** Experimental charring of *quinoa* grains. **a** For *pitu*. **b** For whole seed/soup. *Scale*=1 mm

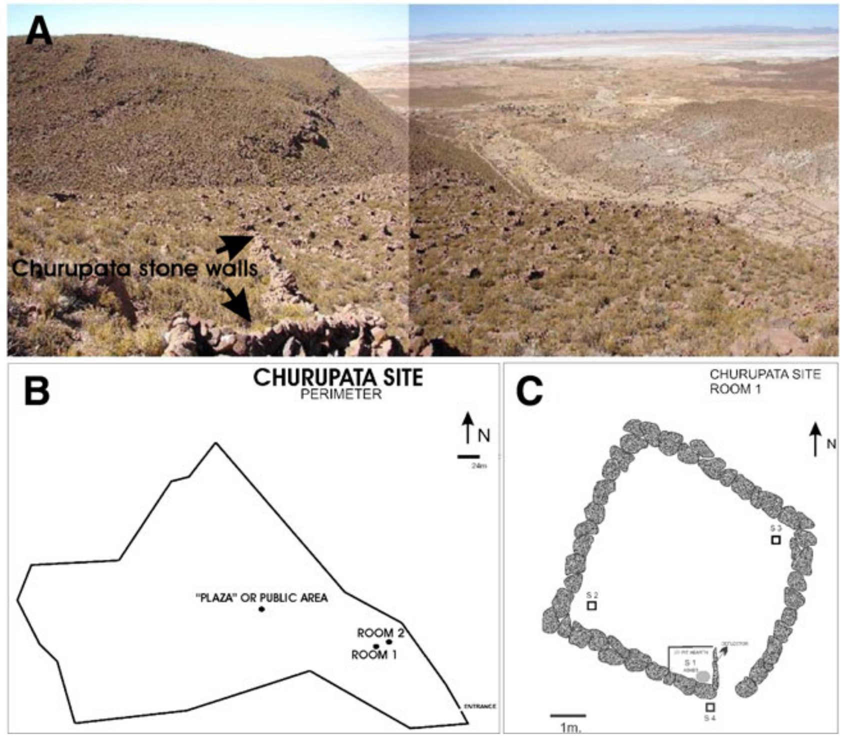

Fig. 10 **a**–**c** The pre-Inka archaeological site of Churupata. **a** Panoramic view of Churupata landscape and some of its stone walls; **b** Churupata perimeter showing approx. location of the "plaza", rooms 1 and 2 (a complete map of the site is being done and will be published in the future). **c** Room 1 showing location of the archaeobotanical samples. S1 sample, comprised between the deflector and the southern building wall shows the pit hearth from where Churupata grains were recovered

but for short periods, which is a characteristic of the defensive sites of the Bolivian Plateau (Nielsen 2002).

Several lines of evidence indicate that the economy of the North Lipez region during the Regional Developments Period (ca. 900–1400 A.D.) was based on a combination of llama herding with dry farming of micro-thermic crops, such as *quinoa* and potatoes (Nielsen 1998). The settlements of this period, then, offer a good opportunity for testing the potential of the ethnoarchaeological observations presented above for identifying post-harvest treatments and modes of enhancement of *quinoa*.

During a preliminary phase of research at the site, a test sample of 120×78 cm (S1) was excavated inside a room, next to the air deflector (it is shown in Fig. 10c by the S1 trapezoidal area limited by the air deflector on the right and the southern wall of the room at the bottom). The excavation encountered the bedrock 15 cm below the present surface. The deposit rendered a single level of occupation with a shallow pit hearth with charcoal and carpological archaeobotanical remains on the top, and ashes on the bottom (Fig. 10c), as well as associated ceramics of Mallku style (Arellano and Berberián 1981) and animal bones. All the sediment recovered from this excavation area was dry-screened through two sieves of 0.97- and 0.41-mm mesh in order to recover as many macro-botanical remains as possible. Three additional columnar samples of 20× 20 cm and 15 cm deep were excavated; two of them in the corners of the room (S2-3 in Fig. 10c) and one outside (S4 in Fig. 10c), but no cultural remains were found in them.

Both sediment fractions (>0.97 and 0.97–0.41 mm) from S1 were examined under stereoscopic microscope. The only carpological macrobotanical remains found were 48 grains of domesticated *C. quinoa* of lenticular shape, truncate edges, and a diameter average of 2.20 mm. The specimens recovered (Fig. 11a–d) share the following characteristics: (1) they are carbonized; thus, details such as parching/not parching cannot be evaluated; (2) only 50% are entire grains with or without pericarp, the remaining 50% are half grains and isolated cotyledons, a preservation condition that can be attributed to post-depositional processes; (3) 92% of the entire grains lack of pericarp, 6% have only patches of pericarp and 2% showed scratches in the pericarp; (4) they are bigger in size than fresh grains, some of them were popped; (5) most of them has an opaque texture and do not show the pearl/silky aspect typical of the post-soaking effect (Fig. 11b–d).

It is known that charred archaeobotanical material, although systematically recovered, represent only a minute fraction on the range of plants used by ancient people in a site and that its assemblages are most likely to result from routine practices representing different charring events (Stevens 2003:71). We can recognize in this sample post-harvest practices related to grain enhancement, especially through the presence of a high proportion of grains without pericarp. Specifically, we can infer the preparation of *quinoa* for whole seed or soup, given the opaque texture characteristic of most of the grains recovered. The absence of *pitu* may be due to the fragility

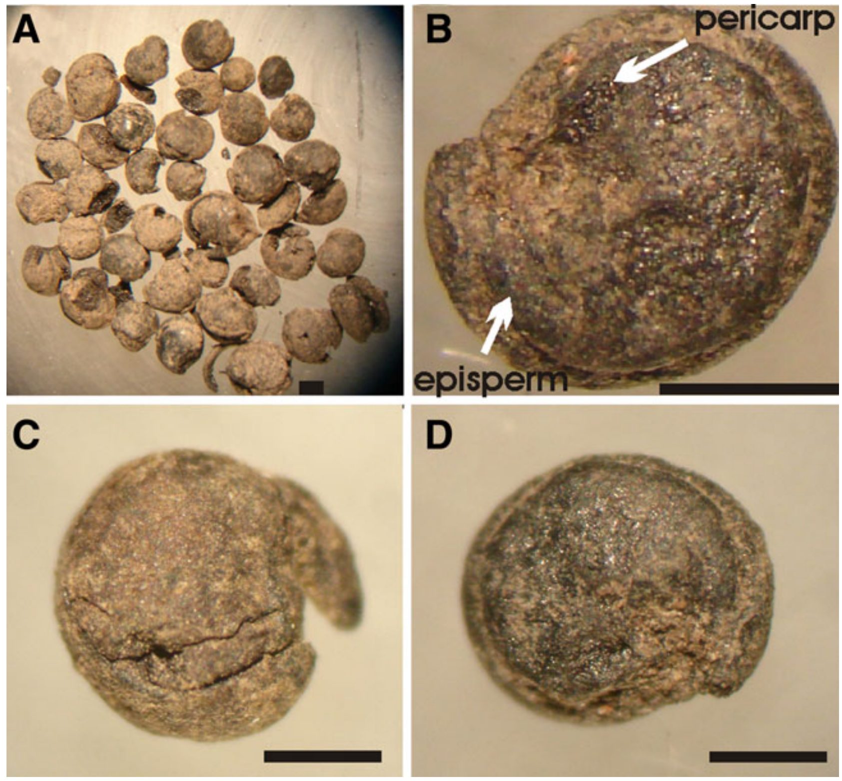

Fig. 11 **a**–**d** Charred archaeological *quinoa* grains recovered at Churupata site remains. **a** View of the group. **c**–**d** Individual specimens with less than 50% of pericarp

that these grains showed when exposed to fire. The high percentage of grains without pericarp as compared to those with scratched pericarp indicates that their grain enhancement finished. Thus accidental charring probably resulted from routine daily practices of *quinoa* cooking rather than from parching events developed during the grain enhancement process. Grain enhancement activities surely did take place within the Churupata site but probably in other structures. This idea is supported by the presence of a *saruna* in room 2 (see Fig. 10b for the location of room 2), an area that may have been used at least for treading and pounding activities.

Discussion and conclusions

Quinoas vary in their saponin content depending on ecotype and on environmental factors (Fontúbel 2003; Vera et al. 2001). This variation notwithstanding, most *quinoas* require post-harvest treatments to reduce saponins prior to human consumption. Bibliography based on ethnobotanical data of other places where *quinoa* is cultivated, commonly refers to processes of enhancement of the grains simpler than those registered in Lípez, Bolivia. According to Bruno (2008),[5] for example, farmers in the Titicaca area do not carry out parching, treading or pounding of the grains; rinsing and rubbing (and sometimes also the exposition to the sun) are sufficient to prepare *quinoa* for consumption. Similar situations are described by Carrillo (1927:52) in the Plateau, by Tagle and Planella (2002:41) in Central Chile with *quinoas* produced at sea level ("sea level" group), by our own research in San Juan Mayo (3,200 m asl; Southern Plateau border) (López and Capparelli sine data) and also by Heiser (1985:88) and Repo-Carrasco et al. (2003). It is thought that traditional grain enhancement practices probably vary according to saponin content, so the activities involved can be different if distinct *quinoa* landraces were involved in different production areas. Unfortunately, in the few cases where enhancement of the grains is described, researchers rarely specify the kind of landrace that people consumed in each of their study area. However, it is likely that sweeter *quinoas* (with fewer saponins) were used in the cases when repeated rinsing was enough to make *quinoa* palatable. On the contrary, the long and complex processing chain involved in grain enhancement recorded in Lipez may be related to a higher amount of saponins of the local varieties, although further analysis is needed in terms of measuring saponin content of our studied *quinoa* types (which we are planned to be carried out in the future). As noted above, Tapia (1982) reports that *quinoa*s from salty areas, such as those of our study region, have higher amounts of saponins than those from other soil conditions. Apart from the implications that climate may have had on

[5] Unfortunately, Bruno (2008) does not specify the kind of landrace/ecotype that people consume in her study area.

favouring bitter *quinoa*s in our study region, farmers might also have preferred them in order to minimize cultivation and storage risks, including insect, rodent and bird predation, against which bitterness is a good defense (see Morlon 1983 in Cusack 1984). Given the variability in *quinoa* bitterness, it is important to take into account the types of *quinoa* consumed in specific cases and perhaps other environmental factors that may condition saponin content, in order to interpret what macrobotanical analysis of grains may imply in terms of enhancement or cooking practices in archaeological cases. For example, parching, treading and pounding, a characteristic of post-harvest enhancement of the Lípez *quinoas* analyzed here, may not be necessary in the treatment of sweeter ecotypes.

In the Andes, *quinoa* is most commonly eaten as whole seed or as soup. The consumption as *pitu* seems to be more characteristic to the Plateau.[6] The *pitu* flour is mixed with water to form a thick paste, which provides a large amount of calories that are rapidly assimilated. Presently, *pitu* is eaten in Lipez as a quick “snack” during harvest time and in the long-distance llama caravan journeys to Eastern valleys (Nielsen 2001). Around the Titicaca lake an edible powder called *p’ito*, which is usually made out of *kañawa* (*Chenopodium pallidicaule*) or barley, is mentioned by Bruno (2008:220) to be prepared from ground and toasted *ajara* (free-living *C. quinoa*) in times of famine. To the best of our knowledge, *pitu* is rarely prepared by people who grow sweet *quinoas*. Ethnoarchaeological data regarding grain enhancement practices related to *pitu* preparation could help to test the validity of these differences in the past.

There are also other implications of consuming *quinoa* from different enhancement processes. For example, it is known that one of the main advantages of *quinoa* grains is the high proportion of proteins, which have several constitutive essential amino acids (see data compilation in Tagle and Planella 2002:37). *Quinoa* proteins are located in the endosperm and the embryo (Prego et al. 1998). However, as recorded above, the loss of embryos during processing is relatively high, except for *pitu* preparation. Despite this nutritional advantage of *pitu*, this form of enhancement may cause a reduction of *quinoa* amino acids because of the long exposition of grains to heating (see Cardozo and Tapia 1979). As can be seen, the consumption of *quinoa*, enhanced under one or the other type of processing, may have had a differential impact on nutrient bioaccesibility (in terms of Wollstonecroft et al. 2008).

Grains that are to be processed for enhancement are taken from large wool bags kept in special storage rooms placed in the domestic area. These sacks (Fig. 5a) contain grains that have been threshed already in the cultivation plots. Field activities (see Lopez 2010), after harvest by uprooting, include treading on the panicles to separate them from the stems and to initiate threshing, and then pounding and rubbing of the panicles, coarse sieving, winnowing and fine sieving, in order to obtain clean grains free of the rachis and leave parts of the inflorescence. However, on a few occasions, it was observed that people store partially threshed grains in the domestic area, leaving winnowing and fine sieving stages to be carried out in the courtyard of the domestic area. They justified the storage of partially threshed grains as due to time constraints, such as saying that the sun was setting or that they had to hurry to do other things in the town. Therefore, the domestic space, which may generally reflect at Lípez grain enhancement and meal preparing practices, might occasionally present remains of activities related to final threshing. For example, partly and totally threshed, non-enhanced quinoa grains were recovered from storage contexts of other two archaeological sites as Cueva del Diablo and Lojo respectively (see Lopez 2010). This is consistent with Stevens (2003) archaeobotanical analysis of several southern Britain sites in the point that storage practices may have a special relevance to distinguish between different patterns of organization of agricultural labour. But also, ethnoarchaeological data of quinoa presented here shows another feature, which is two stages of storage. On the one hand, bulk and long term storage in larger wool bags placed in special storage rooms was used for non-enhanced grains. While on the other hand, small and short term storage in wool bags commonly placed in the kitchens involved storage of enhanced grains. As was shown by the present results, these two stages of storage can be differentiated by the predominance of grains with complete pericarp or grains without pericarp, respectively. While the first ones can be stored for several years (up to 4 years, sometimes), aided by the presence of saponins that protect them from rodents and other pests, enhanced grains have a short shelf life due to the lost of the protective saponins. As farmers consume quinoa as whole seed or soup every day, grains have to be enhanced periodically in order to have short-term stores of *quinoa* ready for daily cooking. In the case of the Churupata site context analysed here, the presence of charred enhanced grains near the pith hearth allow us to infer that accidental charring probably resulted from routine daily practices of *quinoa* cooking and that these grains can come from a short-term type of storage probably placed inside the same room 1 building. This kind of storage pattern was observed, for example, at room 1 of Bajo Lacaya Bolivian site (see Nielsen and Berberián 2008, Fig. 5), where a storage area was recognized by the presence of ceramic characteristic pots.

[6] In central Chile, Tagle and Planella (2002:43) mention that quinoa toasted flour is used to prepare the *ulpo*, a non-alcoholic beverage. Whether this flour is or is not similar to the Bolivian *pitu,* is still unknown, because of a lack of details about its preparation.

In sum, ethnoarchaeological and arcaheobotanical data allows us to recognize a double-storage pattern (long-term vs. short-term) in the past. It could also reveal different forms of relationship among field activities and domestic storage, post-harvest treatment, and consumption, perhaps patterns that have no present-day analogue. Particularly, the use of traditional technologies of grain enhancement in Lipez supports the definition of different types of treatment geared toward various forms of consumption, each one with distinctive archaeological traces that can be identified through the analysis of macrobotanical remains. Our case study from Churupata indicates that these correlates can be effectively applied to the interpretation of archaeological contexts, while suggesting further avenues for research.

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