

The possible influence of post-harvest objectives on *Cucurbita maxima* subspecies *maxima* and subspecies *andreana* evolution under cultivation at the Argentinean Northwest: an archaeological example

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Abstract This paper investigates the possible links between postharvest activities and methods of plant husbandry or management of *Cucurbita maxima* ssp. *maxima* and *C. maxima* ssp. *andreana* in the prehispanic Argentinean Northwest area. Microscopic methods were used to assess the micromorphological characteristics of modern specimens of South American *Cucurbita* and *Lagenaria* species to obtain diagnostic anatomical traits. These traits were then used as criteria for identifying archaeological Cucurbitaceae rind remains from domestic to funerary contexts of the Pampa Grande archaeological site (1720±50 BP, cal. 259–433 AD). Following the taxonomic identification of the archaeological plant remains, they were further assessed for signs of human selection or possible cultivation, including: rind thickness, qualitative characters (lobbing, wartiness and colour) and postharvest traits (artificial shape, charring, staining and decoration of sherds). The results indicate the presence of *Lagenaria siceraria* together with spontaneous, intermediate and domestic *C. maxima* morphotypes. Different subspecies *maxima* morphotypes were recognized: those intended as food, having thin pericarps to facilitate consumption and those intended also as food, but as containers too, as in *Lagenaria*, in which the rinds are thickened and lignified. The latter morphotype may possibly represent a strategy of postharvest intensification, but not through new processing techniques, but through the development of landraces with a longer fruit shelf life, resulting from changing husbandry criteria to selective pressures over cultivated stands.

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Introduction

The aim of this paper is to examine the relationship between postharvest activities and plant management or husbandry practices, in the prehispanic Argentinean Northwest area (ANA), for two species: *Cucurbita maxima* Duchesne ex Lam. ssp. *maxima* and *C. maxima* Duchesne ex Lam. ssp. *andreana* (Naud.) A.I. Filov. Based on the archaeobotanical analyses of Cucurbitaceae rind remains from the Pampa Grande archaeological site, this study is focused on the influence of post-harvest on the evolution of both subspecies under cultivation. It will be argued that post-harvest factors were among the selective pressures on the evolution of domesticated plant forms, morphotypes and/or landraces. In addition, *Lagenaria siceraria* (Molina) Standl. (bottle gourd) will be discussed because, in present-day and ancient South American societies, its uses and associated management practices under cultivation are usually very close to those of *C. maxima*.

Postharvest system and management/husbandry practices

The term post-harvest (or postharvest) is adopted from agronomy where it represents a specialised branch of agronomy focused on the physiology of economically useful plants for the purpose of assessing the conditions, technology and information that are necessary to prevent loss of quality, quantity and nutrients after harvesting (Wills et al. 1998). The aim of post-harvest research is to increase abundance through decreasing losses of quality and

quantity. In the field of archaeology, Yen (1980) introduced the concept of “postharvest intensification” which he defined as activities that transform raw plants into storable crops and activities that convert a single plant resource into different foods. Wollstonecroft (2007) recently introduced the term “postharvest system” to encapsulate the “skills, knowledge, technology and coordination of labour that are necessary to convert raw plants into edible products and/or preserve them as storable yields, and/or promote the availability of nutrients” (Wollstonecroft 2007: 25). She expanded on Yen’s (1980) definition of postharvest intensification including “(1) all food processing activities that promote increased abundance, e.g. activities which render inedible plants edible, increase their shelf life and/or promote the bioaccessibility and bioavailability of nutrients; (2) transformation of the production system, brought about by increases in post-harvest labour, technology and knowledge” (Wollstonecroft 2007: 25). Consumption is a third scope, alongside preharvest (clearing and tilling the land, planting, tending) and postharvest, that directs the production system because it determines what is needed and the form in which it must be consumed (Capparelli and Lema 2011). Preferences of the consumers themselves dictate what is good to eat or to use and how, when and where it must be presented. Consumers may be individuals, particular social sectors within a society or other societies (or social units inside of it) with whom trade or exchange is established. It is argued here that it is consumer preferences in the form of cultural selection that drive the domestication process. This process includes the transformation of wild plants into morphologically distinct crops and the later development of landraces,¹ which are the result of husbandry practices, changes in genetic frequencies, mutations and the appearance of different morphotypes, among other phenomena. It is further argued here that some criteria for cultivation and selection would have been decided during the postharvest stages, when techniques of processing, transport, preservation, detoxification or storage are applied and certain characters of plant organs are found to be the most useful. In other words, during postharvest plants would have been examined and selected according to changed postharvest requirements which, ultimately, fulfil consumption requirements (Capparelli and Lema 2011).

Adjustments also occur in postharvest practices depending on the technology, knowledge and tools available. Transformations in the postharvest system can induce changes in the overall production system because they

require readjustments over routine subsistence practices, which in turn may affect labour organisation and social organization, among others (Wollstonecroft 2007). These major effects of postharvest practices upon production will occur in the case of plant products that have a major role in the production system or that where minor products but, thanks to postharvest intensification, achieved a more important role in the production system. (Note: postharvest also refers to economically useful plants that are not edible, e.g. plants used for shelter, clothing and medicine).

***C. maxima* and *L. siceraria*: husbandry and utilization in South America**

Cucurbita is an American genus with three South American domesticated taxa (*Cucurbita ficifolia* Bouché, *Cucurbita moschata* Duchesne and *C. maxima* ssp. *maxima*) and two non-cultivated or spontaneous taxa (*C. ecuadorensis* Cutler & Whitaker and *C. maxima* ssp. *andreana* (Naud.) A.I. Filov) (Whitaker and Cutler 1968).

C. maxima ssp. *andreana* is considered to be the ancestor of *C. maxima* ssp. *maxima* given the morphological and genetic evidence (Nee 1990, Sanjur et al. 2002), despite some authors belief that both subspecies derived from a hypothetical common ancestor (Willson et al. 1992). Both taxa are interfertile and for this reason—together with ecological, morphological and physiological ones—most modern *C. maxima* ssp. *andreana* populations are considered as weedy forms of the ancestral wild form (Lema 2009). Recent findings of *C. maxima* ssp. *andreana* populations in eastern Peru and Bolivia (Andres and Nee 2005; Valega Rosas et al. 2004) indicate that this taxa has a much wider distribution than was believed, and these populations may help in filling the disjunction between the modern area of concentration of most subspecies *andreana* populations in the east central Argentina and the assumed domestication area of subspecies *maxima* along the eastern slopes of the Andes, between Bolivia and Argentina. Besides, no archaeological remains of *C. maxima* ssp. *andreana* have been identified until now. This paper reports the first certain taxonomic recognition of archaeological rind remains belonging to this taxon.

C. maxima ssp. *andreana* fruits are highly diverse in size (6 to 21.5 cm in height and 5 to 9.5 in diameter²) and shape, occurring as ovoid, oblong, globoid, pear-shaped,

¹ Landrace is a morphologically distinct population of a crop, which have a degree of genetic integrity maintained in part by natural selection and in part by human selection; is a local population showing the most desirable performance for specific traits or local adaptations maintained as populations rather than pure line cultivars (Sthapit et al. 2000)

² These sizes comprise all the mentioned measurements for *C. maxima* ssp. *andreana* in the bibliography and herbarium registers. Considering that they include some large fruits, some of them are likely to be the result of hybridization with ssp. *maxima* (Lema 2009). Ashworth (1997) states that ssp. *andreana* fruits have 71.63±2.86 mm. in height and 67.80±2.27 mm. in diameter, ranges of measurement that are more frequent in fruits of this taxa.

spherical or depressed; even a single plant can bear both ovoid and globose fruits (Ashworth 1997, Martínez Crovetto in Burkart 1974; Millán 1945). They have smooth surfaces and their colour goes from clear green to clear yellow (depending on the degree of maturation of the fruit) with clear longitudinal striations (Ashworth and Galetto 2001; Martínez Crovetto in Burkart 1974; Millán 1945; Lira Saade 1995).

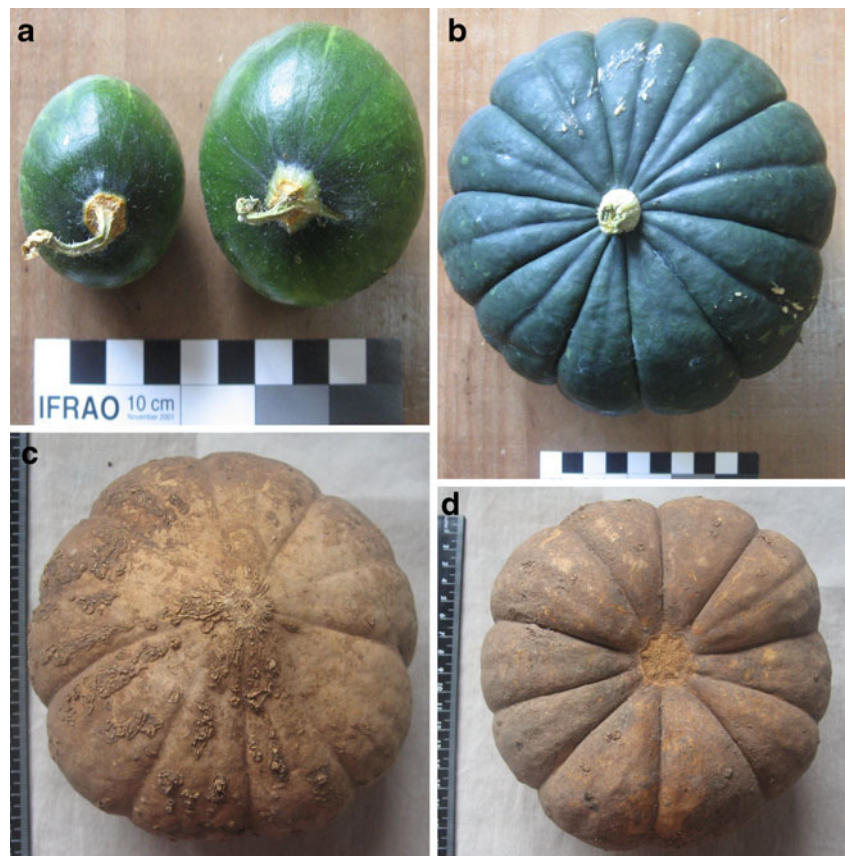
C. maxima ssp. *maxima* is one of the most diverse of the domesticated species within this genus. There are presently approximately 52 cultivars, each differing in morphological traits (colour, shape, wartiness, size and lobbing, among others) as well as agronomical characters (annual cycle, productivity and adaptive plasticity) (Lira Saade 1995). Among the most well-known cultivars or horticultural groups are: Hubbard, Banana, Buttercup, Acorn, Winter Crookneck and Boston Marrow (Decker Walters and Walters 2000; Whitaker and Jagger 1937; Whitaker and Bohn 1950). In Argentina there are two local landraces: *C. maxima* ssp. *maxima* cv. *zapallito* (Carrière) Millán and *C. maxima* ssp. *maxima* cv. *zipinka* Millán (Millán 1947). The Zapallito landrace (Fig. 1a, b) is mentioned by travellers of the XVIII century among the crops cultivated by the aboriginal populations of the Chaco area of Argentina and later in Chile and the Argentinean Northwest (Lema 2009).

This landrace is characterized by having a bushy habit (as opposed to a climbing habit found in the majority of Cucurbitaceae), early maturation and small, globose (sometimes turban-shaped or slightly lobed) and green fruits (sometimes with stripes). The fruits are consumed immature, including their smooth rind which is thin (2 mm thickness when immature) and palatable, but hardens into an inedible thick form during ripening (Contardi 1939; López-Anido et al. 2003; Millán 1945; Millán 1947).

Millán (1947) describes Zipinka landrace fruits (Fig. 1c, d) as lobed, with a more- or less-pronounced apex, a rind colour that varies between yellowish and various shades of green, a smooth-surface (sometimes with warts) and a notably thick rind which develops within a few days after the fruit starts to ripen. The thick rind makes them durable, but they are not edible when immature as Zapallito fruits. This cultivar occurs as both, bushy and climbing plants and its distribution—since the XIX century—covers the Argentinean Northwest (Millán 1947).

The *Lagenaria* genus includes five wild species from Tropical Africa to the cultivated specie *L. siceraria* (Molina) Standl., which is an annual plant distributed in tropical regions worldwide (Teppner 2004). Modern American populations of this last species belong to subspecies *siceraria*, but recent DNA analysis of *L. siceraria* archaeo-

Fig. 1 Local landraces from Argentina; **a–b** *Cucurbita maxima* ssp. *maxima* cv. *zapallito* in immature (**a**) and mature (**b**) states; **c–d** *C. maxima* ssp. *maxima* cv. *zipinka*



logical remains (ca. 8000 BP) from North to South America show their relationship with the Asian genotype (Erickson et al. 2005). In fact, Erickson et al. (2005) argue that this domesticated crops arrived to America with first peopling of the continent. Fruits of *L. siceraria* are highly diverse in shape and size, but the rinds are always smooth and without lobes or warts; they are diverse in colour but usually brown to bordeaux when mature (Teppner 2004).

Among both modern and ancient societies of South America, postharvest activities for both *Cucurbita* and *Lagenaria* are aimed at the consumption of seeds, flowers, buds, tender shoot tips, leaves, immature fruits (with or without detoxification, depending on the variety) or the pulp (mesocarp) of ripened fruits; another common use of the rinds is as containers or as raw materials to make other objects (Decker Walters and Walters 2000; Lira Saade 1995; Millán 1946; Teppner 2004; Whitaker and Bohn 1950). Modern aboriginal populations of Argentina usually use mature *L. siceraria* fruits to make different artefacts, making the use of *Cucurbita* rinds less frequent (Table 1). *Cucurbita* seeds are the most nutritious part of the plant, with high levels of oil and protein; they also have medicinal applications as a diuretic, antipyretic and to expel gastrointestinal parasites (Decker Walters and Walters 2000; Lira Saade 1995). Today, whole parched seeds are eaten in several South American countries, usually discarding the testa after having bitten the seed, also seeds are ground to make different dishes (Lira Saade 1995). Fruit pulp can be dried to store it, in the case of *C. maxima* ssp. *maxima* (the richest species in terms of vitamins) flesh quality generally holds up best when dehydrated and then reconstituted (Decker Walters and Walters 2000). By contrast, ethnobotanical and ethnographic reports for Argentina shows the absence of the consumption of *L. siceraria* seeds (Table 1).

Archaeological records reveal the presence of *L. siceraria* since the oldest human occupations in Argentina (ca. 10000 BP), and the presence of postharvest traits since the middle Holocene (Table 2; Fig. 2(1)). Remains of this species are frequent in archaeological sites of all cultural periods, usually represented by rind remains, being seeds extremely unusual. The most ancient record of *Cucurbita* sp. consists in phytoliths identified on grinding tools recovered in archaeological contexts dated ca. 4000 BP, seed remains of *C. maxima* ssp. *maxima*, *C. moschata* and *C. ficifolia* begin to be frequent from the Formative period (Table 2; Fig. 2).

Besides archaeobotanical remains, at the ANA were found phytomorphic vessels and polished stone artefacts representing lobed *Cucurbita* fruits (Fig. 3a–c), some of them corresponding to possible *C. moschata* considering the representation of its peduncle distinctly flared at the fruit end (Fig. 3d) (Lema 2009). These pieces correspond to the earliest stages of the Formative period (200 BC–200 AD) and

suggest the use of *Cucurbita* fruits as containers among the first ANA farmers (Lema 2009).

In the Big North area of Chile, several findings of modified *Cucurbita* fruits also reveal their ancient use as containers. Some of this fruits were found with remains of dyes (Focacci 1974; Rivera et al. 1974) or vegetal flours (Santoro 1980) in their interior. Some were decorated and others halved, with charred areas (Dauselberg 1974). All were recovered in sites considered as transitional between the costal tradition and the early agricultural tradition, ranging between 1000 and 1600 BC (Lema 2009). Several Cucurbitaceae findings were made in funerary contexts as part of the remains which accompanied burials of mummies in both Chile and Argentina.

Cucurbita evolution under domestication

Cultivated stands of *Cucurbita* are characterized by high morphological and anatomical diversity, probably due to multiple selection criteria and frequent interbreeding with wild or weedy forms (Decker Walters and Walters 2000; Lira Saade 1995). Wild *Cucurbita* are adapted to thriving in disturbed sites of natural or human origin (Decker Walters and Walters 2000), a characteristic that permitted them to survive near human settlements (Asch and Asch 1978; Whitaker and Bemis 1975). Wild gourds were probably good candidates for experimentation and casual cultivation because they are highly visible, their populations can be easily manipulated and they have relatively high production rates (Cowan 1997). The main obstacle that ancient people had to overcome was the elimination of cucurbitacins, which are toxic oxygenated tetracyclic triterpenes that make the leaves, roots and fruits bitter (Decker Walters and Walters 2000).

The cucurbitacins are known to be present in the fruit flesh of wild gourds (Cowan 1997; Cowan and Smith 1993; Decker Walters and Walters 2000; Lira Saade 1995; Nee 1990; Purseglove 1968 in Piperno and Pearsall 1998; Robinson and Decker-Walters 1997 in Bisognin 2002); some researchers argue that the seeds also have this toxic component, in either the cotyledons (Sharma and Hall 1971 in Robinson et al. 1976) or testa (Hart 2004). Detoxification activities, by boiling or parching the *C. maxima* ssp. *andreana* fruits, are reported for aboriginal and rural communities of the Argentinean pampas (Brücher 1989; Millán 1968; Lira Saade 1995, see Table 1). Experimental assays reported by Hart (2004) for *Cucurbita pepo* L. ssp. *ovifera* (L.) D. S. Decker var. *ozarkana* (Scheele) D.S. Decker, resulted in detoxification of the seeds after submerging or boiling them several times in water with ashes, a process that is enhanced if seeds have been ground. Nee (1990) and Cowan and Smith (1993) argue that the

Table 1 Ethnographically and historically reported uses for Cucurbitaceae in Argentinean local communities

Ethnic group	Location	Taxa-organ	Uses	Reference
Tobas Wichis	Chaco area	<i>Lagenaria siceraria</i> Fruits	Containers for honey, to store water for a few hours or to prepare, ferment and store drinks	Sosa Veron 1948 Arenas 2003
Not specified	Chaco area	<i>L. siceraria</i> Fruits with long and narrow necks	Containers to store seeds. The opening at the neck is typically stoppered with a cob and the whole container put into a net bag for transportation	Sosa Veron 1948
Matarás	Chaco area	<i>L. siceraria</i> ^a Fruit	Consumed immature, used to contain liquids when mature	Jolis (1762, 1767) in Torres et al. 2007
Not specified	Chaco area	<i>L. siceraria</i> Fruit	Made into bowls or spoons halving them along their longitudinal or transverse sections, their borders are rounded and decorated and the surface is usually painted or seared	Sosa Veron 1948
Tobas Wichis	Chaco area	<i>L. siceraria</i> Fruit	Halved fruits to drink <i>Ilex paraguayensis</i> infusion, to make dishes, spoons to drink, or dishes to soak fruits	Arenas 2003
Rural communities	Uruguay	<i>L. siceraria</i> fruits (rudereral populations) ^a Fruit	As containers, detoxified by several washings	Millán 1945
Abipones Tobas Wichis	Chaco area	<i>L. siceraria</i> Fruit	Made into rattles piercing one end of the gourd to empty the contents, and into which seeds are subsequently placed, the opening is then closed with a wooden handle. Shamanic artefact, used to ward off evil spirits	Sosa Veron 1948 Dobrizhoffer 1968 [1783–1784] Arenas 2003
Tobas Wichis	Chaco area	<i>Cucurbita maxima</i> ssp. <i>maxima</i> (landrace of thick pericarp)	Halved fruit dehydrated by placing it among hot ashes or under the sun, then stored for several months. For consumption they are boiled	Arenas 2003
Wichis	Chaco area	<i>Cucurbita moschata</i> Fruits <i>Cucurbita</i> sp. Landrace of thick pericarp Fruit	Halved fruits are placed among hot ashes until the fruit pulp is cooked, the fruit then retrieved, allowed to cool and then eaten, the rind is discarded or used as a container	Mirta Santoni pers. com.
Tobas Wichis	Chaco area	<i>C. maxima</i> ssp. <i>maxima</i> seeds	Roasted and pounded for consumption	Arenas 2003
Charrúas, Puelches, Tehuelches and rural communities	Pampa area	<i>C. maxima</i> ssp. <i>andreaea</i> ^a Fruit	Fruits consumed after detoxification by placing them among hot ashes	Millán 1968, Brücher 1989
Tobas Wichis	Chaco area	<i>C. maxima</i> ssp. <i>maxima</i> <i>C. moschata</i> Fruits	Fruits are cut and boiled or cooked among hot ashes	Arenas 2003
Tobas Wichis	Chaco area	<i>C. maxima</i> ssp. <i>maxima</i> Fruits	Entire fruits cooked in pit ovens	Arenas 2003

^a Taxonomic identification suggested after analysing written records (see Lema 2009 for more details)

Table 2 Archaeological Cucurbitaceae remains from Argentina

Period	Area	Archaeological site chronology	Taxonomic identification remain type
Early Holocene (10000–6000 BP)	Northwest	Huachichocana III (layer E3) [1] 9340±120–8670±550BP	<i>Lagenaria siceraria</i> rind fragments
Middle Holocene (6000–3000 BP)	Northwest	Quebrada Seca 3 [2] 4930±110; 4410±60BP	<i>Cucurbita</i> sp. phytoliths in grinding artefacts.
Late Archaic		Punta de la Peña 4 [2] 4060±90; 3820±100BP	<i>Cucurbita</i> sp. phytoliths in grinding artefacts.
		Peñas Chicas 1.3 [2] 3680±50BP	<i>Cucurbita</i> sp. phytoliths in grinding artefacts.
		Cueva Cacao 1 A [2] 3000BP	Rattle made with a <i>Lagenaria siceraria</i> fruit
		Inca Cueva-c 7 [3] 4080BP	<i>Lagenaria siceraria</i> rind fragments. Some decorated with incisions, one with remains of a red pigment in its internal face.
Late Holocene (3000–150 BP) Formative (2500–1000 BP)	Northwest	Cueva de los Corrales [4] 2060±200BP	<i>Cucurbita</i> sp. rind fragment
		Puente del Diablo [5]	<i>Cucurbita maxima</i> aff. ssp. <i>maxima</i> seeds
		Costa de Reyes [6] 224±105 AD	<i>C. maxima</i> seeds
		La Poma [7]	<i>C. maxima</i> seeds
		Alamito [8] 250 BC a 450 AD	<i>Cucurbita</i> sp.
		Cerro El Dique [9] 240±50 AD	Gourd
		Potrero Grande [10] 260±50 AD	Gourd
		Loma sobre Puente río La Viña. Site 1 [11] 460–730 AD	<i>C. maxima</i> aff. ssp. <i>maxima</i> Charred seeds
		Punta de la Peña 9 [2] ca. 1400 BP	<i>Cucurbita</i> sp. phytoliths in grinding artefacts.
		Punta Colorada [12] Site 3 720±85 AD	Squash seeds
		Cuesta de Zapata [13] 737±85 AD	<i>C. maxima</i>
		Los Viscos [14]	<i>C. maxima</i> and <i>Cucurbita moschata</i> seeds, peduncles and rind fragments
		Pampa Grande [15] 1720±50 BP cal. 259–433 AD	<i>C. maxima</i> ssp. <i>maxima</i> seeds, peduncles and rind fragments. <i>C. maxima</i> ssp. <i>andreaeana</i> rind fragments
			<i>Cucurbita</i> sp. rind fragments <i>C. ficifolia</i> peduncle
			<i>C. maxima</i>
			Squash
			<i>Cucurbita</i> sp. seeds
			squash
			squash
			<i>C. maxima</i> . seeds, peduncles and rind fragments.
			<i>C. maxima</i> var. <i>turbaniformis</i> rind fragments
			<i>C. maxima</i> seeds, rind fragments and entire fruits with openings (one containing 2.200 gr of <i>Chenopodium quinoa</i> seeds)
			<i>C. moschata</i> peduncle and rind fragment
			<i>C. maxima</i> fruit
			<i>C. maxima</i> seeds and rind fragments
			Rind fragments of squash
	Midwest	Cueva del Toro [16]	
		Cueva Ponontrchue o Pájaro bobo [17] 2010±40 BP	
		Gruta del Indio del Rincón del Atuel [18] 2200–1900 BP	
		Reparo de las pinturas rojas [19] ca. 1600 BP	
		Agua de la mula-1 [20] 1600–1000 BP	
		Punta del Barro Dump heap N°2 [21] 350–400 AD	
		Los Morrillos [22] 0–375 AD	
		Los Morrillos [22] 280–375 AD	
		Vega de los Pingos [23]	
		Agua de la Tinaja [24] 1360±70 BP	
		Las Tinajas [25] 1360±60 BP	

Late Holocene (3000–150 BP) Late period (1000–500 BP)	Northwest	Agua de Los Caballos-1 [26] 1200 BP Sarahuico [27] 710±70 BP Doncellas [28] Los Amarillos [29] 1200–1420 AD Jueña [30] 1335 AD Santa Rosa de Tastil [31] 1362–1439 AD Morhuasi [32] Arroyo Tala Cañada I [33] from 984–1024 AD to 1028–1219 AD	Squash Cucurbitaceae seeds <i>C. maxima</i> fruit <i>Cucurbita ficifolia</i> seeds <i>Cucurbita</i> sp seeds Gourd Gourd
Late Holocene (3000–150 BP) Inka period (500–400 BP)	Northwest	CPun39 [34] Huachichocana III (layer C) [1] El Shincal Inka–Hispanic aboriginal period [35]	<i>Cucurbita</i> sp. phytoliths in soil samples from an ancient crop field <i>Cucurbita</i> sp. phytoliths in ceramic sherds <i>C. maxima</i> seeds <i>C. maxima</i> ssp. <i>maxima</i> seed and <i>Cucurbita</i> sp. peduncle, charred
Late Holocene (3000–150 BP) Hispanic-aboriginal period (400–300 BP)	Midwest	El Shincal Inka- Hispanic aboriginal period [35] Epuñlan Grande [36]	<i>Cucurbita</i> sp. charred seed <i>C. maxima</i> aff. ssp. <i>andreaana</i>

Only the most ancient remains of *Lagenaria siceraria* are included. Taxonomic identifications transcribed as reported in original papers or according to recent analysis (for references, see Lema 2009). All dates proceed from indirect radiocarbon datings not calibrated, except Pampa Grande date. All are dry remains except those signaled as charred. Bracketed numbers correspond to references for Fig. 2

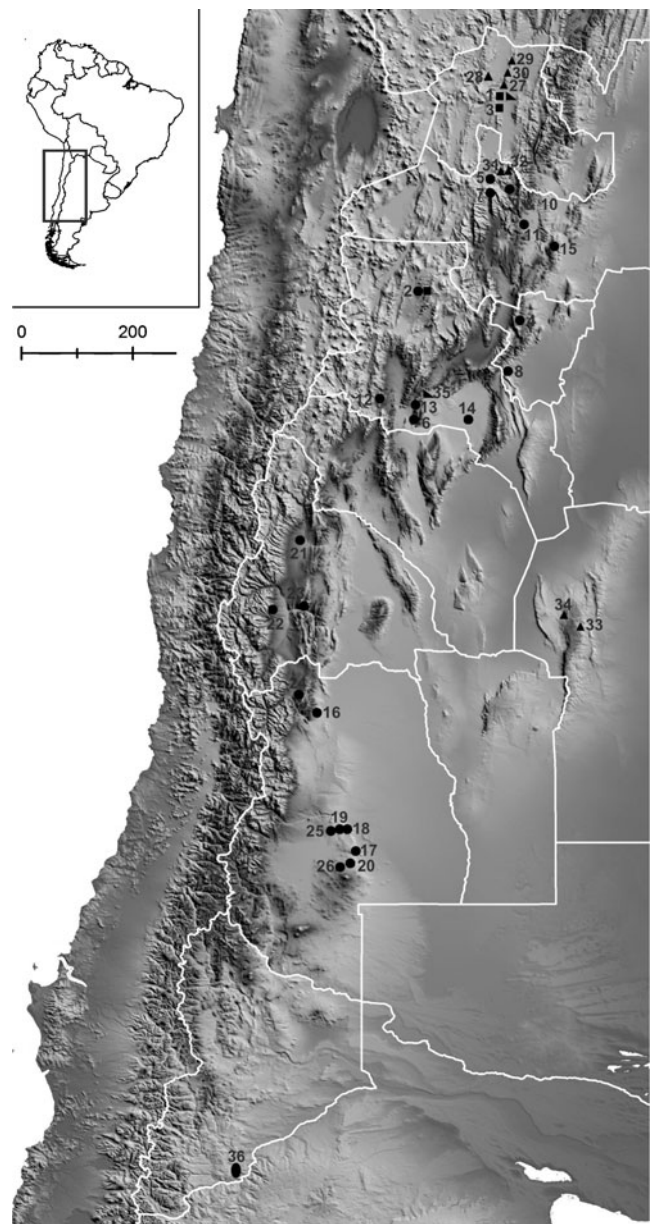
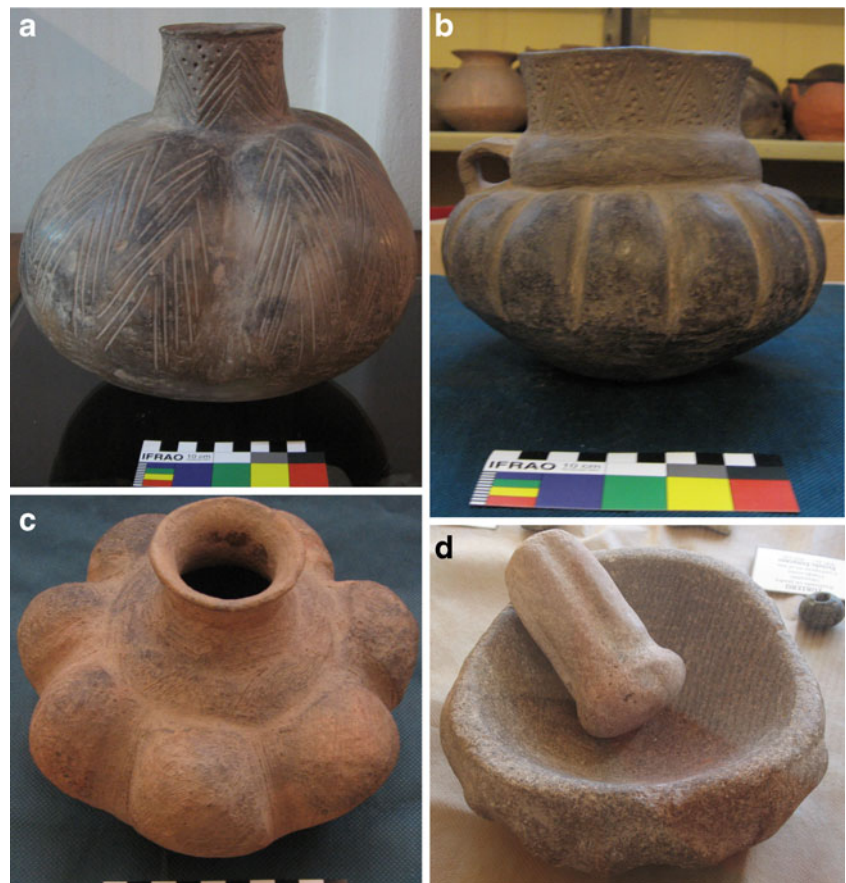


Fig. 2 Map showing archaeological findings of Cucurbitaceae remains in Argentina. Shading indicate altitudinal differences. Chronological references: squares for early and middle Holocene sites (10000–3000 BP); circles for Formative sites (2500–1000 BP); equilateral triangle for Late Period sites (1000–500 BP); obtuse triangles for Inka sites (500–400 BP); ovals for Hispanic-aboriginal period (400–300 BP). References for archaeological sites in Table 2

seeds need to be detoxified because the cucurbitacins are present in the placental tissue, which is virtually impossible to remove from the seed coat. Detoxification is considered unnecessary in cases where the seeds are used for medicinal applications e.g., as purgative, vermifuge or abortifacient (Valderas 2000).

Reasons to explain why ancient people domesticated wild *Cucurbita* include i) for their edible seeds (Whitaker

Fig. 3 Modelling of *Cucurbita* in archaeological pieces from the Argentinean Northwest Area corresponding to the Formative period; **a–c** lobed *Cucurbita* fruits modelled in pottery; **d** mortar pestle (polished stone) representing a *Cucurbita moshata* peduncle



and Bemis 1975; Cowan 1997; Cowan and Smith 1993; Nee 1990; Robinson and Decker-Walters 1997 in Bisognin 2002); ii) for their fruit (consumed after detoxification) (Bisognin 2002; Decker Walters and Walters 2000); and iii) to use their rinds as containers (Piperno and Pearsall 1998). The last two explanations are usually regarded as secondary to seed consumption because the seeds of gourds are tasty and nutritious (Decker Walters and Walters 2000; Lira Saade 1995; Nee 1990) as well as storable. Among wild and domesticated *Cucurbita*, seeds of subspecies *andreana* have the highest oil content: ~61% in 100 g (dry wt), having palmitic, oleic and linoleic types (Carreras et al. 1989; Lira Saade 1995). The argument that wild gourds were first selected to use their rinds as vessels, rattles or fishing floats has been rejected by some authors (e.g. Cowan 1997 based arguments that the fruits are too small and shells too brittle and because there is no evidence of rind fragments from Archaic archaeological sites in USA having been used as containers). Modern use of wild fruits as containers in North America is mentioned by Cutler and Whitaker (1961) and Lira Saade (1995). In Peru today Ashaninkas Indians use the rind of dry *C. maxima* ssp. *andreana* fruit to make handicrafts to sell to tourists (Valega Rosas et al. 2004). Significantly, the rind of this subspecies can only be used as a raw material for

manufacturing objects if appropriate postharvest techniques are used: in cases where the fruit is opened fresh and the pulp extracted to let the rind dry, the fruit walls curl back on themselves; conversely, if the entire fruit is allowed to dry, the mesocarp is reabsorbed and rind does not roll (Lema 2009). Although this last alternative turns the rind rather brittle, it is the most useful in order to use the rind as container, fishing float or to make artefacts.

Evolutionary changes that are visible in domesticated gourds included the production of bigger seeds and/or fruits, both characters apparently linked (Piperno et al. 2000; Smith 1997), non bitter and more starchy less fibrous flesh, loss of seed dormancy, fruits that are more diverse in shape and colour and fruits with softer rinds (Bisognin 2002; Decker Walters and Walters 2000). According to Piperno et al. (2002:10923), “*Cucurbita* evolution under domestication involved a selection for softer, nonlignified rinds [...] although lignified rinds are still common in some domesticated varieties”. Because the lignified fruit preserves longer, people probably selected for this feature as a way to produce a type of gourd with an enhanced storage life. Lignin is also a mean of defense against herbivory and fungal diseases, having as well implications in the archaeological identification of Cucurbitaceae because phytoliths are more abundant in lignified fruits. Both

breeding goals (edible fruits with a thin rind, as well as more durable fruits, with a thicker rind) are recognized by Bisognin (2002) together with a selection for early maturation and resistance to insects and diseases for Cucurbits in general, and by Decker Walters and Walters (2000) for *C. maxima* ssp. *maxima* in particular.

Materials and method

Pampa Grande archaeological site

The archaeobotanical remains analysed in this paper were recovered after excavations directed by Dr. Alberto Rex González during the 1970s in an archaeological locality called Pampa Grande. The locality is situated in the eastern slopes of the Andes at the piedmont zone, the meeting place of the highlands (prepuna and puna) and lowlands (Fig. 2(15)). Pampa Grande is a group of seven caves (the biggest ones called Los Aparejos and El Litro and minor ones identified by numbers) situated in gorges over fluvial terraces at the Las Pirguas mountains, between 2,500 and 3,000 m. asl, in the open forest and grassland areas of the *Yunga* biotope (Oller et al. 1984–1985). Summer temperatures are warm and humid while cold, dry winters, with heavy snows. This makes access to the caves impossible between May and October (Oller et al. 1984–1985).

During the Formative period people appear to have used the caves for domestic and funerary purposes; no structures have been found in the areas near the caves (Baldini et al. 1998, 2003; Lema 2009). High quantities of animal bone remains, ceramic, textile and basketry pieces were recovered from these caves, together with more than 80 human remains (Baffi and Torres 1996; González 1972). Funerary modalities inside the caves include direct burials, cremation, entombment in stone enclosures and burials inside funerary urns for both adults and sub adults, together or not (Baldini and Baffi 1996).

The archaeobotanical assemblages are exceptionally well preserved, being unique for the geographic area in which the caves are situated; moreover the quantity of plant remains is particularly high compared with other sites from the ANA. The diversity of domesticated species is high, including *Phaseolus lunatus* L., *P. vulgaris* L. and eight landraces of *Zea mays* L. Other cultivated species include *Smilax* sp. *sonchifolium* (Poeppig & Endl.) H. Robinson, *Phaseolus* sp. and *Arachis* sp. Wild local resources were also recovered including *Prosopis* sp., *Geoffroea decorticans* (Hook. & Arn.) Burkart, and *Zyzyphus mistol* Griseb. (Miente Alzogaray and Cámara Hernández 1996; Pochettino 1985; Zardini 1991). The plant remains were hand-picked, having been found in situ during excavations; flotation and fine sieving were not applied. Palynological analysis of camelid

dung revealed the presence of weeds such as *Plantago* sp. (D'Antoni, 2008). Other species, probably representing the same time period, were found in funerary vessels unearthed during previous excavations including: *Chenopodium quinoa* Willd., *Chenopodium* sp., *Amaranthus* sp., *A. caudatus* L. var. *leucospermus* Thell., *A. caudatus* L. var. *alopecurus* Moq., *Z. mays* and *P. vulgaris* (González 1972; Hunziker 1943). Some of the seeds identified as *Chenopodium* sp. and *Amaranthus* sp. have black testa and a sub-acute border identical to weedy/wild forms of both genera (Hunziker 1943).

Whitaker (1983) remarked on diversity of *C. maxima* ssp. *maxima* landraces present in these caves and noted the care with which its fruits rinds, and also *L. siceraria* ones, were threaded onto strings. He also suggested the presence of *C. maxima* ssp. *andreaana* based on one slim piece of rind (Tarragó 1980; Whitaker, unpublished manuscript).

Today the Pampa Grande archaeological collection is situated at the La Plata Museum (LPM), Department of Archaeology. Documentation of the excavation is fragmentary and some information about the archaeological contexts and recovery techniques is missing. After studying the collection, Cucurbitaceae dry rind fragments ($N=95$), peduncles ($N=11$) and seeds ($N=11$) were recorded in samples belonging to different caves representing both residential and funerary contexts (Lema 2009). Through morphological and anatomical approaches the seeds were identified as *C. maxima* ssp. *maxima* ($N=10$) and *Cucurbita* aff. *maxima* ssp. *maxima* or aff. *moschata* ($N=1$), peduncles were identified as *C. ficifolia* ($N=1$), *L. siceraria* ($N=1$) and *C. maxima* ssp. *maxima* ($N=9$) (Lema 2009). Among subspecies *maxima* peduncles, six specimens were found to have basal diameter measurements that are half way between measurements registered in modern *C. maxima* ssp. *andreaana* peduncles and those registered in modern subspecies *maxima* landraces, and three specimens have same sizes as peduncles of the Zapallito landrace (Lema 2009). All these remains have morphological features that correspond to mature organs.

Rind analysis

Domesticated *Cucurbita* (especially *C. maxima* ssp. *maxima* and *C. pepo*) have six layers of tissues in the pericarp (according to Winton and Winton 1935 and Hayward 1953, both following Barber 1909). The epicarp or epidermis consists in a layer of cells with thick walls disposed in palisade, the hypodermis is constituted by several layers of isodiametric thick walled cells with scarce intercellular spaces, the outer mesocarp has stone cells and the middle and inner mesocarps have parenchyma cells with starch grains the former and sieve tubes and vascular bundles the latter. These layers of parenchyma are constituted by thin walled cells with lots of pits which absorb liquid very

slowly (León 1987). The different sections of the mesocarp have variable quantity of layers with cells that get bigger from the outer to the inner mesocarp. Finally, the endocarp is a thin membranous tissue added to the seeds surfaces.

According to Piperno et al. (2002), *C. maxima* ssp. *maxima* and *C. moschata* may or may not have stone cells, depending on the degree to which the fruit is lignified, characteristics that are the outcome of different human selection criteria. The presence of stone cells in the external mesocarp produces a hard rind which resists degradation (Winton and Winton 1935). Only lignified fruits have phytoliths in the most external layer of stone cells in an area called “phytolith forming zone [...] located in the interface of the hypodermis and the sclerenchymatized outer mesocarp” (Piperno et al. 2002:10923). Formation of phytoliths is governed by a single gene (*Hr*) which codifies lignification and phytolith production in *Cucurbita* (Piperno 2008). Moderate fruit lignification is due to the probably incomplete dominance of the *Hr* locus, which is reflected in a diminution of stone cells layers (Piperno et al. 2002). Also environmental factors are linked to the presence of moderately silicified phytoliths and to differences in phytolith sizes, since a single *Cucurbita* taxon can generate phytoliths of different sizes depending on the environmental conditions in which it was grown (Bozarth 1987). Phytolith size and shape are used as diagnostic criteria for taxonomic recognition and to distinguish wild from domesticated forms (Piperno 2008; Piperno and Pearsall 1998; Piperno et al. 2000; Piperno and Stothert 2008). According to Piperno (2008) in all wild *Cucurbita* the *Hr* gene causes the deposition of a thick layer of stone cells and phytoliths. Also, Piperno and Pearsall (1998) detected a strong positive correlation between the increase of fruit and seeds sizes and the size of the phytoliths, since the latter have more space to grow in larger fruits.

Finally, changes in rind thickness and in qualitative traits such as lobbing, colour and wartiness have been used as reliable signals of the presence of domesticated Cucurbits in archaeological contexts from North America (Cowan 1997; Cowan and Smith 1993; Smith 2000). Rind thickness has also been used to establish the presence of domesticated *L. siceraria* (Erickson et al. 2005; Fuller et al. 2010).

Therefore in order to identify archaeological rind fragments, morphological and micromorphological (anatomical) criteria -using both qualitative and quantitative features- were developed using modern specimens. Reference collection was constituted with samples of those taxa reported in archaeological sites from the ANA: *C. maxima* ssp. *maxima* (one fruit corresponding to a non-lignified cultivar sold in a Buenos Aires market and another fruit of the landrace Zipinka with lignified rind collected in a Catamarca rural community), *C. maxima* ssp. *andreana* (six fruits belonging to different plant populations from Buenos

Aires province), *C. ficifolia* (one fruit from Mendoza province), *C. moschata* (a non-lignified fruit sold in a Buenos Aires market) and *L. siceraria* (one fruit collected in a urban residence from Buenos Aires). Since lignified fruits of *C. moschata* were not available, references in Piperno et al. (2002) for its anatomical traits were considered. The emphasis over *C. maxima* ssp. *andreana* fruits is due to the lack of information about this subspecies. For this reason, and with the objective to establish a baseline for non-cultivated populations of *C. maxima*, shape and size of fruits and rind thickness were registered in reference samples following Cowan and Smith (1993). Measurements were taken with a TESA digital calliper and its accompanying software. Anatomical observations and measurements were made in transversal sections of the pericarps employing a fotonic microscope with transmitted and incident light and also with SEM (JSM-JEOL 6360 LV).

In some cases before observing cross sections of pericarps using transmitted light a decolouration with sodium hypochlorite (50%) was made. Microscopic measurements were taken from images recorded with a Motic Image Plus 2.0 web camera attached to the microscope and its measuring software. Measurements were also calculated from SEM images using the programme Image Tool 3.0. Classification and description of the tissues was made following Winton and Winton (1935) and Hayward (1953). Epicarp/epidermis, hypodermis and mesocarp were considered since these tissues are the ones preserved in archaeological rinds.

After trying to reassemble all the Cucurbitaceae rind fragments present in Pampa Grande archaeological collection, a sample of 95 fragments were selected for micromorphological analysis considering those that could not be reassembled with other fragments, and selecting only one in the case of those that could be reassembled. Taxonomic determination of this archaeological sample was achieved comparing their anatomical traits with the diagnostic ones determined for each taxa in modern samples. Quantitative and qualitative micromorphological analysis were also carried out employing a transmitted and incident light microscope and SEM. Qualitative characters of the pericarp (colour, superficial texture, consistence, rolling, presence of warts and lobbing) together with characters caused by postharvest activities (modifications made to the pericarp in order to shape it, presence of holes, thermo-alteration, charring and soot) and thickness were registered for each rind fragment once it was taxonomically identified. To estimate thickness, three to five measurements were taken on each fragment and then averaged, since this trait varies along a fragment according to the area of the fruit where it belongs and also due to differential degradation. Comparing thickness values was done after microscopical analysis in order to evaluate the representation of the different pericarp

Table 3 Diagnostic anatomical traits of pericarps belonging to South American *Cucurbita* taxa and *Lagenaria siceraria*

Taxa	Epicarp (Epidermis)	Hypodermis	Phytoliths	Outer mesocarp	Middle mesocarp	Inner mesocarp
<i>Cucurbita maxima</i> ssp. <i>andreaea</i> (Fig. 4d–f)	Quadrangular cells with thick walls and mild depressions in their external face	Circular cells in a heterogeneous disposition. More than 10 layers	Present. With a radial disposition of cells around them	Flattened stone cells with straight walls, isodiametric or transversally elongated homogeneous disposition	Cells with thick walls whose size is bigger than those of the outer mesocarp	Big cells with thin walls, with a lax disposition. Presence of vascular bundles (with spiral thickenings) and sieve tubes
<i>C. maxima</i> ssp. <i>maxima</i> non-lignified	Quadrangular cells with thick walls and accentuated depressions in their external face	Between 5 and 6 layers	Absent	Cells with thin walls progressively bigger (from the outer to the inner mesocarp). Homogeneous disposition. Abundant starch grains in the inner mesocarp		
<i>C. maxima</i> ssp. <i>maxima</i> cv. <i>zipinka</i> lignified	Quadrangular cells with thick walls and accentuated depressions in their external face	Between 5 and 6 layers	Present. With a radial disposition of cells around them	Faceted and isodiametric stone cells	Elongated or isodiametric circular cells with thin walls which are progressively bigger. Homogeneous disposition. Sieve tubes in the inner mesocarp	
<i>C. moschata</i> non-lignified	Rectangular cells	Several layers, more than in <i>C. maxima</i> ssp. <i>maxima</i>	Absent	Cells with thin walls which are progressively bigger. Homogeneous disposition. Inner mesocarp with vascular bundles, sieve tubes and starch grains		
<i>C. moschata</i> lignified	Rectangular cells	Between 5 and 6 layers	Present. With a radial disposition of cells around them	Stone cells radially elongated Homogeneous disposition	–	–
<i>Cucurbita ficifolia</i>	Rectangular cells	Between 5 and 6 layers	Present. With a radial disposition of cells around them	Heavily thickened stone cells. The external ones are circular and the internal ones have straight walls and are transversally elongated. Homogeneous disposition	Faceted sub circular cells with thickened walls	Faceted sub circular cells with thin walls
<i>L. siceraria</i>	Indistinguishable layers, usually absent		Present	Stone cells with diverse morphology (usually long and narrow). Heterogeneous disposition	Elongated cells with thin walls and starch grains	Irregular and lax cells. Vascular bundles with spiral thickenings

One fruit was analysed in each case and for lignified fruits of *C. moschata*, characters were described after Piperno et al. 2002. Cells of the outer mesocarp can be radially or transversally elongated in respect to the axis of the fruit which goes from the peduncle to the corolla

Table 4 Shape, size and pericarp thickness registered in six modern fruits from different *Cucurbita maxima* ssp. *andreaana* populations situated in Buenos Aires province (Argentina)

Fruits	A	B	Shape (MaxHght/MaxDia)	1	2	3	4	5
1	51.79	53.78	0.96	1.39	5.22	1.59	3.83	2.13
2	56.7	57.54	0.99	1.66	5.97	1.79	4.85	2.58
3	–	–	–	1.32	–	–	–	–
4	59.29	58.34	1.02	0.95	5.6	0.96	3.6	2.23
5	–	–	–	1.24	–	–	–	–
6	–	–	–	1.1	3.97	1.61	–	–
MEAN				1.28	5.19	1.49	4.09	2.31
STD				0.25	0.87	0.36	0.67	0.24
CV				19.22	16.74	24.40	16.25	10.21
MIN				0.95	3.97	0.96	3.60	2.13
MAX				1.66	5.97	1.79	4.85	2.58

A maximum fruit height, *B* maximum fruit diameter, *I* thickness at maximum fruit diameter (five measurements were taken in each fruit), 2 peduncle “knob” thickness (one measurement per fruit), 3 thickness adjacent to peduncle “knob” (two measurements per fruit), 4 corolla or blossom, “knob” thickness (one measurement per fruit), 5 thickness adjacent to corolla “knob” (2 measurements per fruit). All measurements in millimetre. *STD* standard deviation, *CV* coefficient of variation; *MIN* minimal value; *MAX* maximum value

sections and tissues on each fragment, since comparison can only be made among samples which have similar preservation conditions.

In order to observe phytoliths in archaeological fragments of pericarps, a chemical digestion of the tissues must be done (Bozarth 1987). Since preservation of these archaeobotanical macro remains was preferred, phytoliths included in the tissues of both modern and archaeological pericarps of *C. maxima* ssp. *maxima* and subspecies *andreaana* were measured. Considering that the same methodological criterion was applied in reference (modern) and ancient pericarp samples, results of both can be compared with each other. Two measurements were taken on each phytolith, in those cases where only the cavity left by a detached phytolith was present together with the absence of hypodermis and

epidermis, only one measurement was registered. Archaeobotanical samples consisted in 13 pericarps where 20 phytoliths were measured; modern samples consisted in one *C. maxima* ssp. *andreaana* and one *C. maxima* ssp. *maxima* cv *zipinka* rind, making six phytolith measurements in each case.

Results

Reference collection

Micromorphological analysis allowed the differentiation of *Cucurbita* species and subspecies through mostly qualitative traits. Anatomical diagnostic characters for modern samples of *Cucurbita* spp. and *L. siceraria* are presented in Table 3.

Table 5 Phytoliths (*N*=6) size measured in modern rinds of *Cucurbita maxima* ssp. *andreaana* and *C. maxima* ssp. *maxima*

	<i>C. maxima</i> ssp. <i>andreaana</i>		<i>C. maxima</i> ssp. <i>maxima</i> cv. <i>zipinka</i>	
	Diameter 1	Diameter 2	Diameter 1	Diameter 2
	31.5	47.5	90.4	–
	37.1	41	71.5	–
	57.3	50	50.6	49.8
	59.7	75.4	50.5	52
	53.2	49.2	66.9	70.1
	60.6	62.6	74.2	60.3
MEAN	52.09		63.63	
STD	12.13		13.43	
CV	23.28		21.10	
MIN	31.5		49.80	
MAX	75.4		90.40	

STD standard deviation, *CV* coefficient of variation, *MIN* minimal value, *MAX* maximum value

Table 6 *Cucurbita* pericarp remains from Pampa Grande

Pericarp	Cave and context	Colour	Surface	General aspect	Thickness (mm)	Taxonomic identification	Association	Postharvest characters
C5 (f) (Fig. 4a–c)	Los Aparejos. Domestic	Light yellow	Smooth	Rolled	0.95	<i>Cucurbita maxima</i> ssp. <i>andreaana</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> peduncle and pericarp (C6a) and <i>Lagenaria</i> sp. pericarp (C6 b, Table 5)	
C5 (d) (Fig. 6c)	Los Aparejos. Domestic	Light brown	Smooth		1	<i>C. maxima</i> ssp. <i>andreaana</i>	Idem C5 (f)	
C5 (b)	Los Aparejos. Domestic	Light yellow	Smooth	Rolled	1.08	<i>C. maxima</i> aff. <i>C. maxima</i>	Idem C5 (f)	
C9 (b)	Los Aparejos. Domestic.	Light yellow	Smooth	Rolled	1.40	ssp. <i>andreaana</i> <i>C. maxima</i> aff.	Associated with a slightly lobed pericarp of <i>C. maxima</i> ssp. <i>maxima</i> (C9 a)	
C5 (e)	Los Aparejos. Domestic	Light yellow	Smooth	Rolled	1.52	ssp. <i>andreaana</i> <i>C. maxima</i> ssp.	Idem C5 (f)	
089(a) (Fig. 6b)	Los Aparejos. Domestic	Light brown	Smooth	Compact	1.73	<i>C. maxima</i> ssp. <i>andreaana</i>	Associated with <i>Prosopis</i> sp. endocarps, <i>Geoffroea decorticans</i> endocarps, <i>Phaseolus</i> sp. pods, a <i>Zea mays</i> cob, <i>Arachis</i> sp. pods and <i>Cucurbita</i> sp. (070) and two <i>C. maxima</i> ssp. <i>maxima</i> pericarps (089 b and c).	
C5 (a)	Los Aparejos Domestic	Light yellow	Smooth	Rolled	1.80	<i>C. maxima</i> aff. <i>C. maxima</i>	Idem C5 (f)	
C1 (b)	Los Aparejos Domestic	Light brown	Smooth		1.83	ssp. <i>andreaana</i> <i>C. maxima</i> aff.		
C11 (b)	Los Aparejos. Funerary	Ochre yellowish	Smooth	Rolled	1.85	<i>C. maxima</i> aff. <i>C. maxima</i>	Associated with <i>C. maxima</i> pericarp (C11 a)	
C5 (c)	Los Aparejos Domestic	Light yellow	Smooth	Rolled	1.86	ssp. <i>andreaana</i> <i>C. maxima</i> ssp.	Idem C5 (f)	
067(b)	No data	Yellow	Smooth, lobed	Compact, slightly lignified	2.08	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Z. mays</i> bracts, <i>Phaseolus</i> sp. pods, <i>Arachis</i> sp. pods and two <i>C. maxima</i> ssp. <i>maxima</i> pericarps (067 a, c)	
I/II (c)	Los Aparejos. Funerary	Light brown	Smooth	Compact	2.10	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with two fragments of <i>C. maxima</i> ssp. <i>maxima</i> pericarps (I/II a and b)	
8h	Los Aparejos. Funerary	Light ochre	Smooth	Compact	2.11	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Z. mays</i> kernels, <i>Phaseolus vulgaris</i> seeds and <i>Prosopis</i> sp. endocarps	
I/5 (a)	Los Aparejos. Domestic or Funerary	Light ochre	Smooth	Compact	2.38	<i>Cucurbita</i> sp.	Associated with <i>C. maxima</i> ssp. <i>maxima</i> (I/5 b) and <i>L. siceraria</i> (I/5 Table 7) pericarp <i>Prosopis</i> sp. endocarps, <i>Geoffroea decorticans</i> endocarps, <i>Z. mays</i> bracts and cobs, <i>P. vulgaris</i> . seeds	
C1 (c)	Los Aparejos. Domestic	Ochre yellowish	Smooth		2.38	<i>C. maxima</i> ssp. <i>andreaana</i>	Associated with <i>C. maxima</i> aff. ssp. <i>andreaana</i> (C1 b) and <i>C.</i>	

Table 6 (continued)

Pericarp	Cave and context	Colour	Surface	General aspect	Thickness (mm)	Taxonomic identification	Association	Postharvest characters
I/5 (b)	Los Aparejos. Domestic	Light ochre	Smooth	Compact, corky	2.40	<i>C. maxima</i> ssp. <i>maxima</i>	<i>maxima</i> ssp. <i>maxima</i> (C1 d) pericarps Idem I/5 (a)	
I/II (b)	Los Aparejos. Funerary	Light brown	Smooth	Compact, slightly to non-lignified	2.40	<i>C. maxima</i> ssp. <i>maxima</i>	Idem I/II (c)	Thermal alteration in external and internal faces, mesocarp stained red
C15 (b)	Los Aparejos. Domestic	Light brown	Smooth		2.56	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> seed and pericarp (C15 a)	
89	Los Aparejos. Domestic	Light ochre	Smooth	Compact	2.61	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>P. vulgaris</i> seeds, a <i>C. maxima</i> ssp. <i>maxima</i> peduncle, <i>Prosopis</i> sp. and <i>Geoffroea decorticans</i> endocarps, <i>Z. mays</i> cob and kernel	
C18 (d)	No data, possible funerary context	Ochre yellowish	With warts and slightly lobed		2.62	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with four <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C18 a–e) and <i>L. siceraria</i> pericarps (Lag-7, Table 7)	
C10 (c)	El Litro Domestic	Brown yellowish	Smooth	Lignified	2.76	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with two <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C10 a and b) and <i>L. siceraria</i> pericarps (C10d, Table 7)	
092/6	El Litro Domestic	Ashy with darker veins	Smooth	Compact slightly lignified	2.86	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with a <i>Z. mays</i> cob and <i>L. siceraria</i> pericarp (092/12, Table 7)	
C11 (a)	Los Aparejos Funerary	Light yellow	Smooth	Compact, corky, lignified	3	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C11 (b)	
C6 (a)	Los Aparejos Domestic	Light brown reddish	Rough		3.06	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C5 (f)	
C3 (b)	El Litro Domestic	Ochre yellowish	With warts		3.08	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> peduncle and pericarp (C3a) and <i>L. siceraria</i> pericarps (Lag-2, Table 7)	
10 (a) (Fig. 8b, c)	Los Aparejos Domestic	Light brown	Smooth	Compact lignified	3.15	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> pericarp (C10b), <i>Prosopis</i> sp., <i>Geoffroea decorticans</i> and <i>Zizypus mistol</i> endocarps	Charred in one extreme in external and internal faces
I/II (a)	Los Aparejos Funerary	Light yellow	Smooth	Corky	3.20	<i>C. maxima</i> ssp. <i>maxima</i>	<i>P. vulgaris</i> seeds and <i>Z. mays</i> cobs and kernels Idem I/II (c)	
C13 (d)	El Litro Domestic	Ochre yellowish	Rough	Corky	3.38	<i>Cucurbita</i> sp.	Associated with <i>C. maxima</i> ssp. <i>maxima</i> peduncle and <i>L. siceraria</i> pericarps (C13 and Lag-3, Table 7)	
10 (b)	Los Aparejos Domestic	Light brown	Smooth	Compact, lignified	3.41	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C10 (a)	Rounded edges

C3 (a)	El Litro Domestic	Ochre yellowish	Rough	Lignified	3.51	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> peduncle and pericarp (C3 a)	Thermal alteration
070	Los Aparejos Domestic	Ashy	Smooth, lobed	Compact	3.59	<i>Cucurbita</i> sp.	Idem 089 (a)	
067(c)	No data	Light ochre	Lobed, with warts	Compact, corky, lignified	3.72	<i>C. maxima</i> ssp. <i>maxima</i>	Idem 067 (b)	
C17 (Fig. 8a)	Los Aparejos Domestic	Ochre yellowish	Lobed, with warts.	Compact, lignified	3.98	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Z. mays</i> cob and <i>Prosopis</i> sp. endocarps.	Straight border with a hole next to it
C18 (e)	No data, possible funerary context	Ochre yellowish	Slightly lobed, with warts	Lignified	3.99	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with four <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C18 a–d)	
C10 (b)	El Litro Domestic	Light brown	Smooth		4.12	<i>Cucurbita</i> sp.	Associated with two <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C10 a and c)	
C4 (a)	Los Aparejos Domestic	Light brown	Small warts		4.22	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with three <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C4 b–d)	
C2	Los Aparejos Domestic	Ochre yellowish	Smooth, lobed	Compact, lignified	4.24	<i>C. maxima</i> ssp. <i>maxima</i>		
C4 (c)	Los Aparejos Domestic	Light brown-ashy	Rough, lobed	Lignified	4.24	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C4 a	
C12 (b)	Cave II Funerary	Ochre yellowish	Rough, lobed		4.40	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> pericarp (C12 a) and peduncle	
089 (b)	Los Aparejos Domestic	Yellow	Smooth, lobed	Compact, corky, lignified	4.53	<i>C. maxima</i> ssp. <i>maxima</i>	Idem 089 (a)	
089 (c)	Los Aparejos Domestic	Yellow	Smooth, lobed	Compact, corky, lignified	4.64	<i>C. maxima</i> ssp. <i>maxima</i>	Idem 089 (a)	
C18 (a)	No data, possible funerary context	Ochre yellowish	Slightly lobed, with warts		4.67	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with four <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C18 b–e) and <i>L. siceraria</i> pericarps (Lag-7)	
C15 (a)	Los Aparejos Domestic	Ochre yellowish	With warts	Slightly lignified.	4.76	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> seed and pericarp (C15 b)	Internal face with signs of thermal alteration and charring
C12 (a)	Cave II Funerary	Ochre yellowish	Lobed, with small warts		4.80	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C12 (b)	
C14 (b)	Los Aparejos Domestic	Ochre	Smooth, slightly lobed	Lignified.	4.84	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>L. siceraria</i> pericarp (C14 a, Table 7)	
I/10 (c)	Los Aparejos Domestic	Yellow	Smooth, lobed	Compact, corky, heavily lignified	5.07	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Lagenaria</i> sp. pericarp (I/10, Table 7), <i>Geoffroea decorticans</i> endocarps, <i>Phaseolus</i> sp. pods and seeds, <i>Z. mays</i> cobs and bracts	
I/3	Los Aparejos Domestic	Yellow	Smooth, slightly lobed	Compact, corky, slightly lignified	5.08	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>P. vulgaris</i> seeds, <i>Z. mays</i> cob and <i>Geoffroea decorticans</i> endocarps	
067 (a)	No data	Light and dark brown	Smooth	Compact, lignified	5.17	<i>C. maxima</i> ssp. <i>maxima</i>	Idem 067 (b)	
084	Los Aparejos Domestic	Light brown	Smooth, lobed	Compact, lignified	5.23	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Z. mays</i> cob	
C7 (b)	Los Aparejos Domestic	Ochre yellowish	Smooth		5.24	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> ssp. <i>maxima</i> pericarp (C7 a)	
C8	Los Aparejos Domestic	Light yellow	Rough	Lignified	5.32	<i>C. maxima</i> ssp. <i>maxima</i>		
C4 (b)	Los Aparejos Domestic	Light brown	Rough	Compact	5.32	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C4 a	

Table 6 (continued)

Pericarp	Cave and context	Colour	Surface	General aspect	Thickness (mm)	Taxonomic identification	Association	Postharvest characters
092/19	Domestic El Litro Domestic	Light ochre	Smooth, lobed	Compact, lignified	5.38	<i>maxima</i> <i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>Z. mays</i> cob	
C9 (a)	Los Aparejos Domestic	Light yellow	Rough, slightly lobed	Lignified	5.44	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C9 (b)	
C1 (d)	Los Aparejos Domestic	Light brown	Smooth	Lignified	5.59	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with <i>C. maxima</i> aff. ssp. <i>andreana</i> (C1 b) and <i>C. maxima</i> ssp. <i>andreana</i> (C1 c) pericarps	
C10 (a)	El Litro Domestic	Ochre-yellowish	Smooth, lobed		5.62	<i>Cucurbita</i> sp.	Associated with two <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C10 a, b)	
C4 (d)	Los Aparejos Domestic	Light brown-ashy	Rough	Lignified	6	<i>C. maxima</i> ssp. <i>maxima</i>	Idem C4 a	
C7 (a) (Fig. 6a)	Los Aparejos Domestic	Light yellow	Smooth, lobed	Compact, conky	6.26	<i>Cucurbita</i> sp.	Idem C7 b	
C18 (c)	No data, possible funerary context	Ochre-yellow	Slightly lobed, with warts		6.37	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with four <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C18 a–e)	
C18 (b)	No data, possible funerary context	Ochre-yellowish	Slightly lobed, with small warts	Compact, conky	6.64	<i>C. maxima</i> ssp. <i>maxima</i>	Associated with four <i>C. maxima</i> ssp. <i>maxima</i> pericarps (C18 a–e)	

The table shows remains from the pericarps with lesser thickness (up) to those with major thickness (down)

Biometrical morphological analysis of modern *C. maxima* ssp. *andreana* fruits are presented in Table 4. Depending on the area of the fruit, pericarp thickness can be different in this subspecies, augmenting in the areas of the peduncle and corolla due to a noticeable increase in subepidermal tissue. The general mean rind thickness of all the measurements taken at the six fruits is 1.85 mm (range, 0.79–5.97 mm) with a standard deviation of 1.2 and a very high CV (65.15). Quantitative diagnostic traits of phytoliths for both *C. maxima* subspecies are presented in Table 5.

Pampa Grande rinds

Taxonomic identification after anatomical analysis indicates that 60 rind fragments can be assigned to the genus *Cucurbita* and 35 to *L. siceraria*. All the analysed *Cucurbita* sp. and *L. siceraria* rinds (Tables 6 and 7) have all the tissues of the pericarp, except for the inner mesocarp, therefore thickness can be compared among them.

Samples identified as *C. maxima* ssp. *andreana* ($N=6$) (Fig. 4a–c) or subspecies *affinis* ($N=5$) have an average thickness (1.58 mm), a range (0.95–2.38 mm) and a CV (27.9) more than the ones registered in the fruits walls of modern samples of this taxa (Table 4). *C. maxima* ssp. *maxima* pericarps ($N=43$) have a thickness range between 2.08 and 6.64 mm (average, 4.09; CV, 30.63), therefore there is an overlapping area between archaeological samples of both *C. maxima* subspecies, which goes from 2.08 to 2.38 mm (Fig. 5). Finally, the thickness range (2.38–6.26; average, 4.23; CV, 34.47) of pericarps identified as *Cucurbita* sp. ($N=6$) is similar to the domesticated subspecies.

Remains of subspecies *andreana* pericarps have smooth surfaces and light yellow, light brown or ochre yellowish colour (Table 6), with some of them rolled. Rinds whose thickness fall in the overlapping area represent intermediate morphotypes in the expression of rind characters (Decker and Wilson 1986), they have smooth surfaces without warts—only one rind is lobed—epicarp colours are yellow, light ochre or light brown and some sherds are moderately lignified.

The highest diversity in qualitative traits was found among *C. maxima* ssp. *maxima* pericarps with a thickness range between 2.40 and 6.64 mm. There are smooth lobed fruits ($N=12$), with warts ($N=3$), smooth and unlobed ($N=13$), rough ($N=6$), rough lobed ($N=3$) and lobed with warts ($N=8$) and colours can be yellow, ochre, light brown, light brown reddish or ashy, dark brown, light yellow, ochre yellowish, brown yellowish and ashy with or without darker striations. *Cucurbita* sp. and ssp. *maxima* rinds were classified as lignified or not (Table 6) according to the presence and quantity of stone cells and phytoliths, being all rind fragments thicker than 3 mm lignified.

Table 7 *Lagenaria siceraria* pericarp remains from Pampa Grande

Pericarp	Cave and context	Thickness	Association	Postharvest characters
Lag-7 (a)	No data, possible domestic	1.78	Idem C18 (Table 6)	Straight border
Lag-7 (d)	No data, possible domestic	1.81	Idem Lag-7 (a)	Border with small holes
W29	Cave II, possible domestic	2	No data	Enclosed were founded crumpled dry leaves, twisted sedge leaves and remains of small cords
C13 (c)	El Litro. Domestic	2.08	Idem C13 d (Table 6)	Border with small holes and buttonhole with vegetable fibers passing through it
Lag-7 (e) (Fig. 7g)	No data, possible domestic	2.08	Idem Lag-7 (a)	
Lag-2 (d)	El Litro. Domestic	2.12	Idem C3 b and a (Table 6)	Border with small holes
C16	El Litro. Domestic	2.14	Associated with <i>Arachis</i> sp. pods, <i>Geoffroea decorticans</i> endocarps and <i>P. vulgaris</i> seeds	
Lag-7(c)	No data, possible domestic	2.15	Idem Lag-7 (a)	Border with small holes
I/10 (b)	Los Aparejos. Domestic	2.20	Idem I/10 (c) (Table 6)	
Lag-7(b) (Fig. 7f)	No data, possible domestic	2.24	Idem Lag-7 (a)	Border with small holes with a tinny string linking them
Lag-1(a)	Los Aparejos. Domestic	2.31	No vegetable remains associated	Small hole with string remains and a buttonhole with vegetable fibers passing through it
C13 (a)	El Litro. Domestic	2.38	Idem C13 d (Table 6) and c	
067 (Fig. 7e)	No data	2.41		Buttonhole next to a border
Lag-7(f)	No data, possible domestic	2.43	Idem Lag-7 (a)	Border with small holes with vegetable fibers passing through them
I/5	Los Aparejos. Domestic	2.49	Idem I/5 (a) and (b) (Table 6)	
071(b) (Fig. 7c)	Cave IV, possible domestic	2.49	Associated with wooden arrow shafts	
C4 (e)	Los Aparejos. Domestic	2.54	Associated with <i>P. vulgaris</i> seeds and pods and <i>Prosopis</i> sp. and <i>G. decorticans</i> endocarps	
Lag-1(b)	Los Aparejos. Domestic	2.63	No vegetable remains associated	
C19 (a)	El Litro, possible domestic	2.65	No vegetable remains associated	
C19 (b)	El Litro, possible domestic	2.72	No vegetable remains associated	
092/12	El Litro. Domestic	2.79	Idem 092/6 (Table 6)	
W45	El Litro, possible domestic	2.8	No vegetable remains associated	
Lag-3	El Litro. Domestic	2.84	Idem C13 (a)	
C6 (b)	Los Aparejos. Domestic	2.88	Idem C5 (a–f) and C6 (a) (Table 6)	
Lag-7(g)	No data, possible domestic	2.94	Idem Lag-7 (a)	
C14 (a)	Los Aparejos. Domestic	2.96	Idem C14 (b) (Table 6)	
Lag-2 (c)	El Litro. Domestic	3.11	Idem C3 (b and a) (Table 6) and Lag-2 (d)	
I/10 (a)	Los Aparejos. Domestic	3.17	Idem I/10 (b and c) (Table 6)	
B 085 (a)	Cave III. Domestic	3.21	Associated with <i>Zea mays</i> cob, <i>Arachis</i> sp. pod, <i>P. vulgaris</i> seeds and pods, <i>Prosopis</i> sp.	

Table 7 (continued)

Pericarp	Cave and context	Thickness	Association	Postharvest characters
B 085 (b)	Cave III. Domestic	3.35	endocarps, <i>C. aff. maxima</i> ssp. <i>maxima</i> or <i>moschata</i> seed.	
SD 22	El Litro. Funerary	3.38	Idem 085 (a)	
W28	Cave V. Funerary	3.40	Associated with <i>Z. mays</i> cob	
C10 (d)	El Litro. Domestic	3.60	No vegetable remains associated	
Lag-6	Cave V. Domestic	3.60	Idem C10 (a, b and c) (Table 6)	
Lag-2 (b)	El Litro. Domestic	3.67	No vegetable remains associated	
Lag-2 (a)	El Litro. Domestic	4.23	Idem C3 (b and a) (Table 6) and Lag. 2 (d and c)	
071 (a) (Fig. 7a, b)	Cave IV, possible domestic	4.35	Idem C3 (b and a) (Table 6) and Lag. 2 (b, c and d)	Halved fruit with straight borders. Small holes next to the border with remains of a red string passing through them and then knotted
C13 (b)	El Litro. Domestic	4.52	Idem C13 d (Table 6) and a and c	
W39	Probably Cave II, funerary	–	No vegetable remains associated	

The table shows remains from the pericarps with lesser thickness (up) to those with major thickness (down). In “Pericarp” column those remains indicated with the initial W correspond to remains mentioned by Whitaker (unpublished manuscript), but not found in the archaeological LPM collection

All *L. siceraria* pericarps have uniform colours which can be dark brown or bordeaux and in a few cases light brown (Table 7). There is only one case (Lag. 7, Fig. 7f) with white dots, a character which is regulated in *Lagenaria* by a single pair of genes (Robinson et al. 1976). Thickness is highly variable with a general median of 2.81 mm (range, 1.78–4.52 mm) and a CV of 24.89. Therefore several remains have intermediate values between those recognized for wild cucurbitaceae in general (less than 2 mm) and those registered in domesticated bottle gourds from archaeological sites in America (more than 3 mm) (Erickson et al. 2005, Fuller et al. 2010)

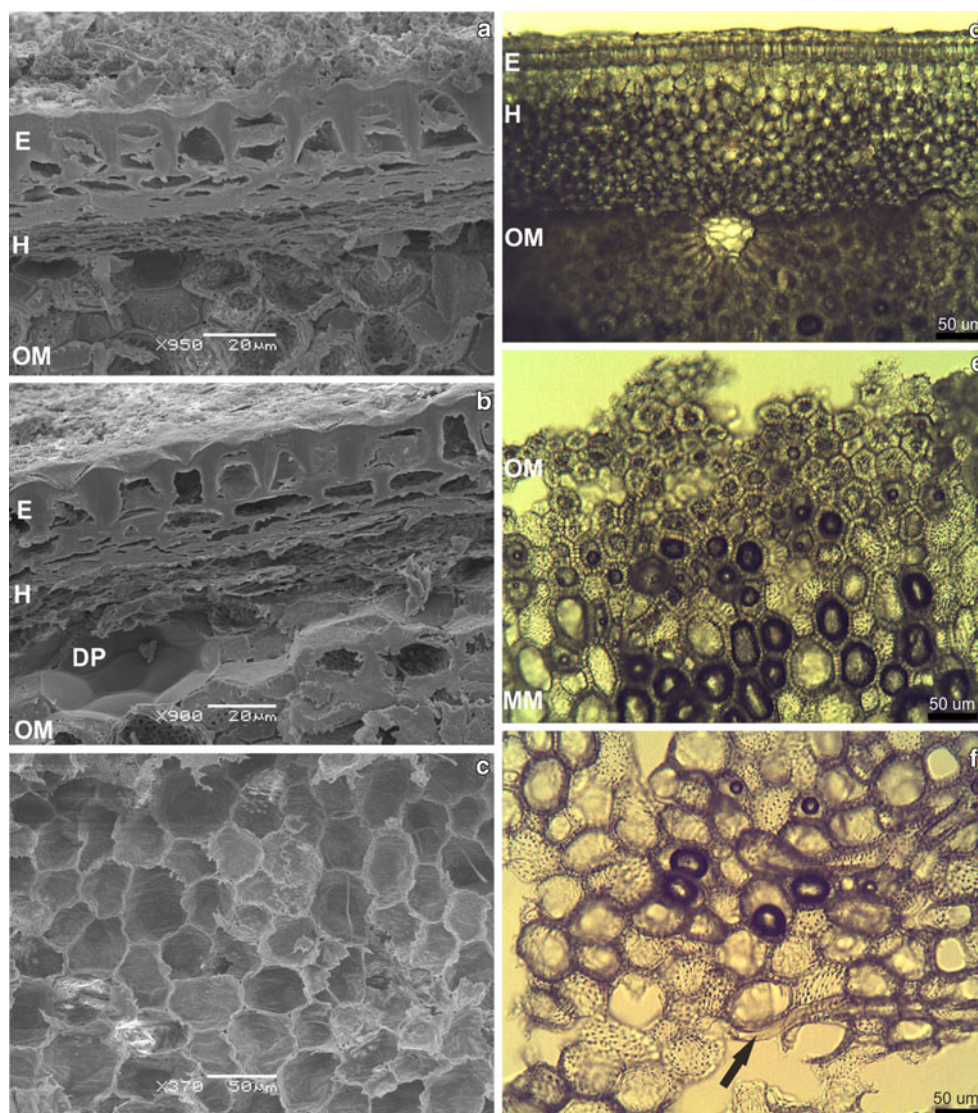
Twenty phytoliths present in archaeological pericarps were analysed (Table 8; Fig. 6). *C. maxima* ssp. *maxima* and *Cucurbita* sp. archaeological phytoliths (Table 9; Fig. 6a, b) have ranges (28.2–82.8 and 34.7–85.2 µm, respectively) less than modern *C. maxima* ssp. *maxima* phytoliths and CV values (24.61 and 24.41, respectively) similar to modern *C. maxima* ssp. *andreana* phytoliths (Table 5). In the case of *C. maxima* ssp. *andreana* pericarps (Table 9; Fig. 6c) phytoliths have a range (15.3–74.9) similar to modern ones, but a greater CV (41.18) than that registered in reference collection (Table 5).

Post-harvest modification of rinds

Among characters linked with postharvest activities, Whitaker, unpublished manuscript mentions an entire *L. siceraria* pear-shaped fruit (W29/Lag-5) (Fig. 7d) found in cavern II, with an opening cut in one of its sides, enclosed were found crumpled dry leaves, twisted sedge leaves and remains of small cords. Whitaker (unpublished manuscript, 1983) also mentions a halved *L. siceraria* fruit (W28) found inside a funerary urn in Cave V and remains of a bottle shaped fruit (W39) probably recovered in a funerary context.

Among *L. siceraria* pericarps analysed in this paper the Lag-7 (a–f) (Table 7; Fig. 7f, g) remains not only represent the only ones with white spots, but they have a straight border under which several small holes are aligned, which are equidistant. In some fragments a very tinny string links these holes passing over the border; in others a buttonhole is present, with some vegetable fibers passing through it. In Lag-7 (b), an “inverted scallop” decorative technique is used. A string was passed through the pericarp probably with a small needle since the holes have the same diameter as the string. Rind 067 (Table 7; Fig. 7e) also has a small hole with remains of a string and a buttonhole of around 1 cm length with grass fibres passing through it. The same is true of rind 071 (Table 7), fragment *b* (Fig. 7c), which has a straight border with holes next to it and remains of vegetal fibres in a manner similar to Lag-7; fragment *a* (Fig. 7a, b) is part of the base of a fruit which was halved

Fig. 4 Transversal sections of *Cucurbita maxima* ssp. *andreana* rinds; **a–c** Pampa Grande C5f rind; **d–f** modern reference rind; in **(f)**, the *arrow* indicates the presence of a sieve tube. *E* epicarp, *H* hypodermis, *OM* outer mesocarp, *MM* middle mesocarp, *DP* area left by a detached phytolith



through the axis going from the peduncle to the corolla, below the edge there are several holes and remains of a string stained red which after passing through two holes was tied up the inner side of the fruit. This probably was a

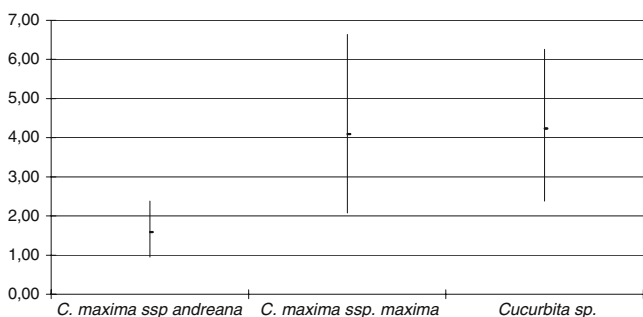


Fig. 5 Pampa Grande Cucurbita rinds thickness according to their taxonomic identification

device made in order to suspend the fruit used as a container.

All the identified characters linked with postharvest activities are present in *Cucurbita* sp. or *C. maxima* ssp. *maxima* pericarps thicker than 2.4 mm, most of them lignified. Four pericarps have signals of thermal alteration, charring or soot deposit on both external and internal faces (Table 6; Fig. 8b, c). An interesting case is the J'/II(b) specimen, which has the area of the mesocarp stained red (Table 6). This could be the result of the absorption of some liquid of this colour by the parenchyma cells of the mesocarp, thanks to their thin walls with lots of pits (León 1987). Another interesting case is fragment C17 (Table 6; Fig. 8a) which has a hole of 7 mm diameter next to a rounded border; it could have been used to pass string through it in order to suspend the fruit, as in the case of fragment 071 of *L. siceraria*. The idea that the holes in some Cucurbitaceae pericarps from Pampa Grande repre-

Table 8 Phytolith measurements of 20 Pampa Grande pericarps

Pericarp	Taxa	Diameter 1	Diameter 2
C5 d	<i>C. maxima</i> ssp. <i>andreaana</i>	53.7	45.1
C9 b	<i>C. maxima</i> aff. ssp. <i>andreaana</i>	74.9	46.5
C11 b	<i>C. maxima</i> aff. ssp. <i>andreaana</i>	43.4	15.3
C11 b	<i>C. maxima</i> aff. ssp. <i>andreaana</i>	48.4	24.2
C3 a	<i>C. maxima</i> ssp. <i>maxima</i>	53.2	61.5
C3 b	<i>C. maxima</i> ssp. <i>maxima</i>	44.4	52.5
C18 e	<i>C. maxima</i> ssp. <i>maxima</i>	77	47.6
C10 b	<i>Cucurbita</i> sp.	7.4	71.7
C10 b	<i>Cucurbita</i> sp.	37.1	63.1
C10 b	<i>Cucurbita</i> sp.	70.5	60.5
C10 b	<i>Cucurbita</i> sp.	43.3	63.5
C10 b	<i>Cucurbita</i> sp.	53.2	73.8
C10 b	<i>Cucurbita</i> sp.	34.7	50
089 (c)	<i>C. maxima</i> ssp. <i>maxima</i>	56.5	82.8
C15 a	<i>C. maxima</i> ssp. <i>maxima</i>	52	52
C7 b	<i>C. maxima</i> ssp. <i>maxima</i>	28.2	53.3
C9 a	<i>C. maxima</i> ssp. <i>maxima</i>	71.3	52.4
C7 a	<i>Cucurbita</i> sp.	63.7	82
C7 a	<i>Cucurbita</i> sp.	53.2	69.7
C7 a	<i>Cucurbita</i> sp.	48.4	85.2

All measurements in micrometres

sent a modification linked to suspending the fruit used as a receptacle is reinforced by the fact that some ceramic sherds of this site also have the same holes next to their border, which still have remains of strings in them.

Pericarp remains of *C. maxima* ssp. *andreaana* (or *affinis*) and those whose thickness is in the overlapping area have not got signs of modification due to use and were found exclusively in Los Aparejos cave, in residential and funerary contexts (Table 6). Remains C5 (a–e) were associated to a *C. maxima* ssp. *maxima* rind and peduncle (Table 6), this last one corresponds to a mature fruit, is fibrous instead of corky and has small basal diameter, making these last traits similar to those of modern Zapallito landrace peduncles (Lema 2009). A similar association was registered in C9 (b), 089, C11 (b) and C1 (b) remains found in the same archaeological context with lobed and smooth *C. maxima* ssp. *maxima* rinds, C1 (b) was also associated with a rind whose thickness is in the overlapping range. The other sherds also situated in the overlapping area are associated to other *C. maxima* ssp. *maxima* thicker rinds.

Rinds of subspecies *maxima* were recovered in several caves (Los Aparejos, El Litro and Cavern II) (Table 6); fruits with thick or thin walls were found in both, domestic and funerary contexts (Table 6). Distribution of *L. siceraria* findings is broader than in the case of *Cucurbita*. Besides Los Aparejos and El Litro shelters, rinds were also found in

caves III, IV and V. In these last minor caves no *Cucurbita* remains were recovered, although in Cave II only *C. maxima* ssp. *maxima* rinds are present. Even pericarps of both genres were in some cases arranged together (see Lag-7 and C18, Tables 6 and 7).

The results of the ubiquity analysis show that there is no difference in archaeological contexts according to taxonomical assignment or degree of association to husbandry practices among Cucurbitaceae rind remains in Pampa Grande. Spontaneous, domesticated and intermediate forms share the same contexts. *Lagenaria* and intermediate *C. maxima* morphotype are more common in funerary contexts, however, and subspecies *maxima* and subspecies *andreaana* are more frequent in domestic ones (Figs. 9 and 10).

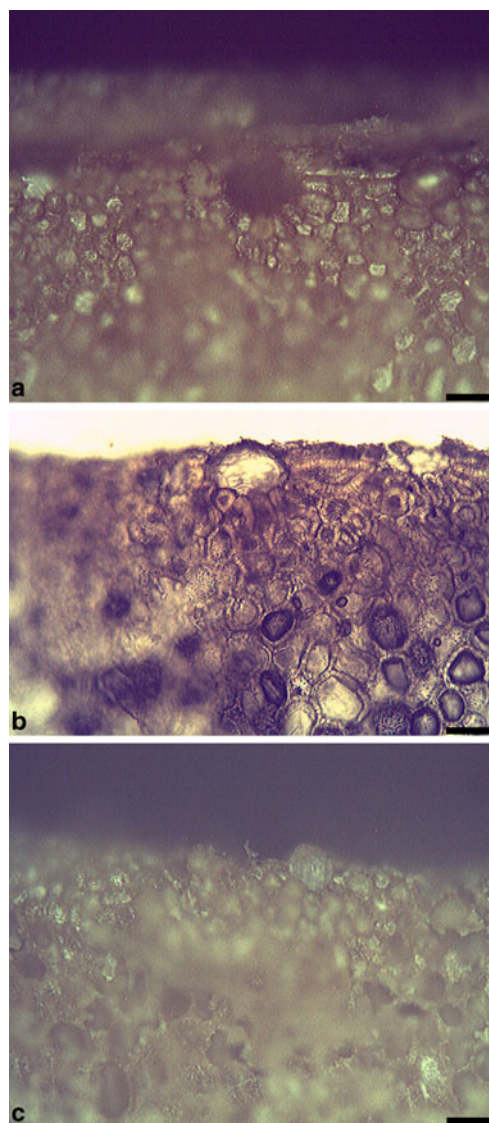


Fig. 6 Phytoliths included in Pampa Grande rinds; **a** *Cucurbita* sp. (C7a); **b** *Cucurbita maxima* ssp. *maxima* (089); **c** *C. maxima* ssp. *andreaana* (C5d); scale bar, 50 μ m

Table 9 Phytoliths measurements from the Pampa Grande site according to their taxonomical identifications

	<i>Cucurbita maxima</i> ssp. <i>andreana</i>	<i>C. maxima</i> ssp. <i>maxima</i>	<i>Cucurbita</i> sp.
Measurements	53.7	53.2	79.4
	74.9	44.4	37.1
	43.4	77	70.5
	48.4	56.5	43.3
	45.1	52	53.2
	46.5	28.2	34.7
	24.2	71.3	63.7
	15.3	61.5	53.2
		52.5	48.4
		47.6	71.7
		82.8	63.1
		52	60.5
		53.3	63.5
		52.4	73.8
			50
			82
			69.7
			85.2
Mean	43.94	56.05	61.28
STD	18.09	13.80	14.96
CV	41.18	24.61	24.41
MIN	15.3	28.20	34.70
MAX	74.9	82.80	85.20

All measurements in micrometres

STD standard deviation, CV coefficient of variation, MIN minimal value, MAX maximum value

Discussion

Chronology of Pampa Grande caves is not well defined yet; motifs and designs of pottery and basketry, funerary modalities and other cultural remains suggest that ancient use of these shelters correspond to the Formative period (Baldini et al. 1998; 2003; Gonzáles 1972). Rinds assigned to *C. maxima* ssp. *andreana* (C5) were dated by AMS obtaining a result, of 259–433 cal. AD (1720±50 BP) which corresponds to the inferred cultural period (Lema 2009). Although more AMS dates are desirable, we can assume that all Cucurbitacea remains are contemporary in this site. These remains had the same contexts of use and discard, including rind fragments of subspecies *andreana*, subspecies *maxima*, *Cucurbita* sp. and those in the overlap category, all associated in the same archaeological contexts, usually together with bottle gourd remains. Despite small differences in ubiquity of these shells, all share the same physical spaces in the world of the living and of the dead. In Pampa Grande funerary contexts it is common to find

plant parts and also bones of animals accompanying human remains (Lema 2009). Also weed forms of *Chenopodium* sp. and *Amaranthus* sp. were found inside a funerary urn (Hunziker 1943). The exception is *Phaseolus vulgaris*, which included remains of var. *aborigineus* Burkart (wild) and intermediate morphotypes recovered only in domestic contexts and those of var. *vulgaris* (domesticated) found in both residential and funerary ones (Lema 2010).

In relation to intermediate *C. maxima* rind remains we cannot assume that they constitute a different landrace since they are very few. They could represent a fortuitous event, fruits of a single plant, a single fruit or even an “accident”, maybe resulting from hybridization between subspecies *andreana* to subspecies *maxima* (a weed of type II, according to De Wet and Harlan 1975), an escape from cultivation (weed type III, De Wet and Harlan 1975), or a small cultivated population under certain husbandry practices different to those applied to other *C. maxima* ssp. *maxima* or *Cucurbita* sp. morphotypes. Probably husbandry practices allowed crosses between the sympatric populations of spontaneous, weedy and domesticated forms, a practice recorded in modern peasant communities of Mexico for gourds stands (Altieri and Merrick 1987). The problem of cucurbitacins could be dealt with through detoxification strategies, or use of plant parts for medical purposes. Hybrid populations are also a common source of diversity from which farmers can obtain new landraces (Decker Walters and Walters 2000) or resistance to diseases (Altieri and Merrick 1987). Some shells of this intermediate morphotype are moderately lignified, which could be the result of hybridization and a subsequent incomplete dominance of the *Hr* locus. Interbreeding in ancient stands could also explain the characters exhibited by the Pampa Grande *C. maxima* ssp. *andreana* rind remains, which have traits present in modern fruits of this subspecies (pericarps rolled with smooth surfaces and different shades of yellow and light brown colours), but belonging to more variable populations than modern ones as phytoliths and quantitative analyses suggest. Differences in the region from which modern reference samples came versus that of the archaeological specimens must be considered also (cf. Bozarth 1987, on detection of environmental influence in phytoliths size).

Rind thickness is also correlated with cultivation in *L. siceraria*, having some Pampa Grande rinds intermediate thickness values. Since there is no true wild *Lagenaria* populations detected in America (Erickson et al. 2005) we can interpret this in-between values as belonging to a feral population. In this sense, subsequent crosses between cultivated and feral populations could explain the high CV values shown by the archaeological remains. Hence, taking Cucurbitaceae rind analysis into account we can assume that wild-weed-crop complexes (Alcorn 1995; Altieri and Merrick

Fig. 7 Pampa Grande *Lagenaria siceraria* rinds with postharvest traits; **a** rind 071a with holes and remains of a string stained red; **b** rind 071 with a string tied up in the inner side of the fruit (*arrow*); **c** rind 071b with a straight border and holes next to it having remains of vegetal fibres; **d** Lag-5 entire broken fruit; **e** rind 067 with a buttonhole and grass fibres passing through it; **f** Lag-7 (b) rind with white spots and a straight border with strings linking holes through an “inverted scallop” decorative technique; **g** Lag-7 (e) rind with a buttonhole and vegetable fibres passing through it



1987; Beebe et al. 1997; Piperno and Pearsall 1998) were present in ancient times at Pampa Grande.

Despite allowing interbreeding, selective pressures exerted by Pampa Grande inhabitants also resulted in different *C. maxima* ssp. *maxima* landraces. According with Whitaker (unpublished manuscript) pericarps of Cave II (C12 a and b) correspond to a halved fruit similar to a modern “Banana” cultivar, and in his opinion in Pampa Grande “material similar to modern cultivars had commenced to appear, e.g.: Hubbard types, Turban types,

Banana types, and perhaps others” (Whitaker 1983: 583). Among these last ones we can suggest Zapallito and/or Zipinka landraces. At Pampa Grande, rinds of domesticated ssp. *maxima* are the most diverse in both qualitative and quantitative traits, a tendency also detected by Smith (2000) in archaeobotanical rind remains of *C. pepo*. Despite of this diversity, there are two distinct morphotypes, probably representing two different landraces. One morphotype is constituted by thick and lignified rind remains, similar to those of Zipinka landrace. All the postharvest traits detected

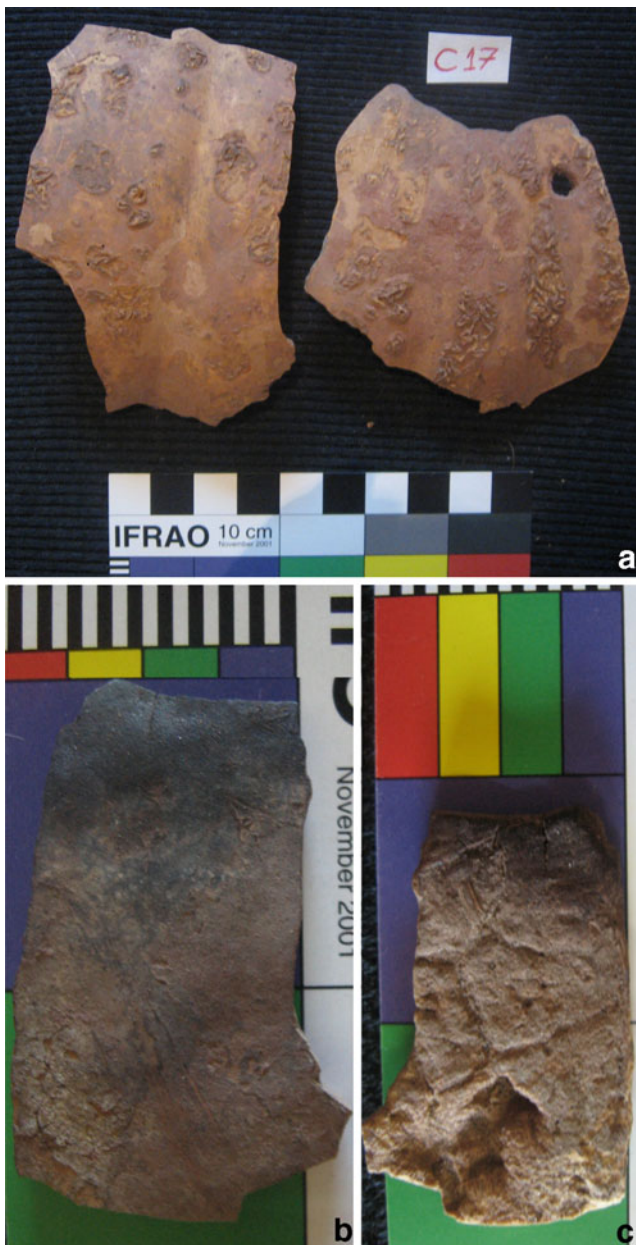


Fig. 8 Pampa Grande *Cucurbita maxima* spp. *maxima* rinds with postharvest traits; **a** C17 with a rounded border and a hole next to it; **b–c** 10 a with an extreme charred in external (**b**) and internal (**c**) faces

in *Cucurbita* rinds fragments of Pampa Grande site are present in this kind of rind, pointing to their use as containers in a similar way that those of bottle gourds. In this sense both taxa could have been part of an association in past times similar to modern folk “complexes”, since they are “species that share [...] morphological [...] characteristics, as well as uses” (Balick 1996: 60). It is possible that *L. siceraria* fruits could not be exposed to fire (no ethnographic, ethnohistorical or ethnobotanical references were found to indicate that this can be done) in the same way that the thick-shelled *Cucurbita* could, which is

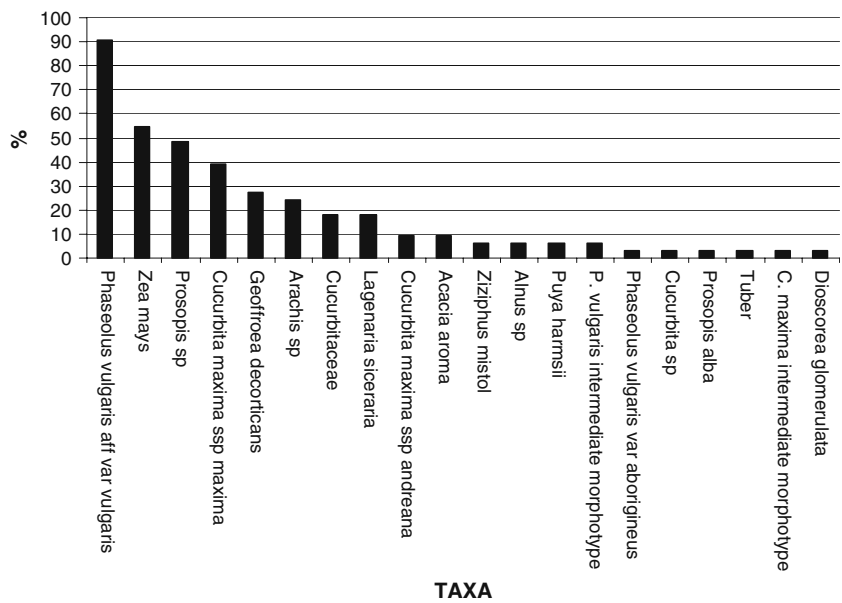
indicated by the charring and thermal alteration of the internal and external faces of some thick pericarps remains identified as subspecies *maxima*. Charring and soot deposits could be the result of cooking the fruits for their consumption, used for cooking other preparations in their interior or to dehydrate the fruits in order to store them. According to these evidences this thick-shelled morphotype is representing a landrace whose fruit flesh was probably eaten and their rind worked into containers. Archaeological records at the North of Chile and Argentinean Midwest belonging to the Formative period point to the use of *Cucurbita* rinds as containers to store seeds, flour, liquid or staining substances. A similar use is suggested at the ANA by phytomorphs vessels of this same period representing *Cucurbita* lobed fruits. Pericarp remains of Pampa Grande confirm the presence of lobed thick walled rinds used as containers during the Formative of the ANA.

The other *Cucurbita* morphotype with thin rind could be a different landrace linked to fruit consumption as in modern commercial cultivars. *C. maxima* ssp. *maxima* seeds recovered in domestic contexts at these shelters do not show signs of seed consumption (as per Cox and van der Veen 2008) and could represent seeds stored to be sowed. This opens the possibility that if there were landraces developed to consume their fruits when immature—such as happens with modern Zapallito landrace, whose presence is suggested by some peduncles of Pampa Grande—some fruits could have been left to reach full maturation in order to have mature seeds for the next sowing season. If this was the case, fruits with thick and hard rinds could represent this kind of landrace, which usually develop a woody texture when mature (Millán 1947).

The analysis developed in this paper also changes the interpretation stated by Whitaker in reference to these same Pampa Grande findings: “The esteem in which gourds were held is supported by the fact that several fractured containers were patched by using plant fibres (probably a grass) or a leather thong” (Whitaker 1983: 583). The presence of strings passing through holes or buttonholes is linked with the suspension of the gourd containers or with their decoration and not with patching them. Despite the fact that artefacts made of gourds were not repaired in Pampa Grande, they were appreciated and beautified.

No *L. siceraria* seeds were recovered at these shelters, this kind of record has usually been interpreted as the result of the consumption of *Lagenaria* seeds (Cutler and Whitaker 1961) which, as we previously established, is not the case for Argentina. The absence of seeds and the finding of a single peduncle of *L. siceraria* in the shelters could indicate that this taxon was subject to different processing techniques than those applied to *Cucurbita*. Probably *Lagenaria* fruits were emptied outside the caves because neither its flesh nor its seeds were consumed.

Fig. 9 Ubiquity of plant remains in domestic contexts at Pampa Grande

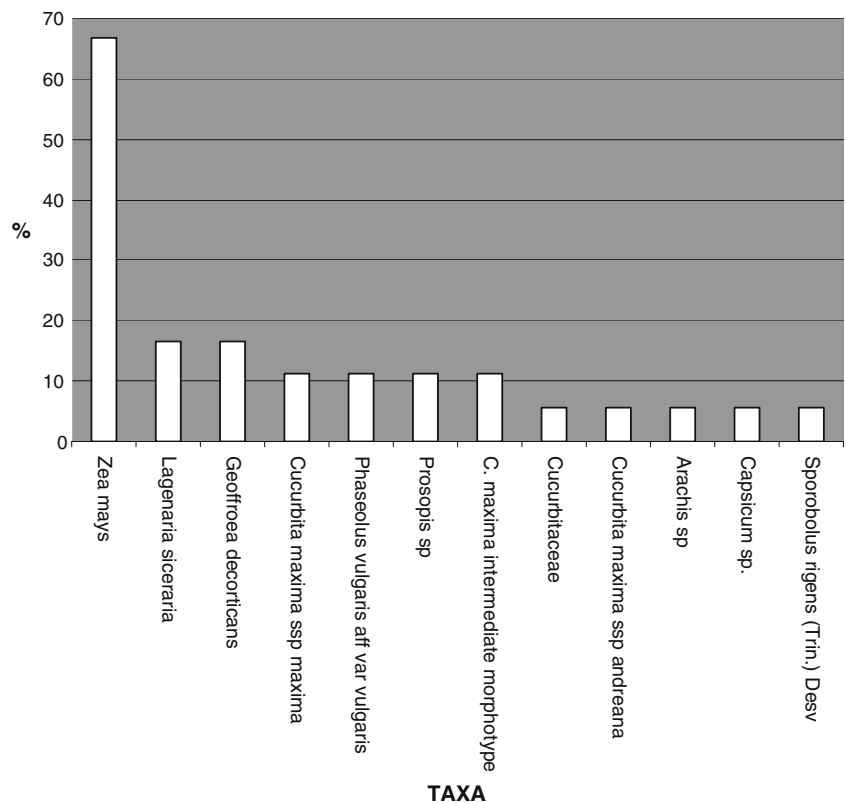


Considering that *Cucurbita* seeds do not have signs of consumption either, *Lagenaria* seeds probably were not stored for future sowing. Therefore despite both genera had similar uses as containers, they were processed in different ways.

Since there are no crop fields or orchards recognized at this archaeological locality, we do not know the size, disposition and conformation of the agricultural settlements. But considering differences in husbandry practices

we can hypothesize that there were cultivated stands where interbreeding was allowed and even perhaps encouraged as a source of diversity, as well as areas where reproductive isolation was kept in order to maintain different *C. maxima* ssp. *maxima* landraces, and maybe other areas where *L. siceraria* was raised. Although populations of this last specie could be cultivated in either of the mentioned areas, we do not have remains of *Lagenaria* seeds stored to be

Fig. 10 Ubiquity of plant remains in funerary contexts at Pampa Grande



sown. If seed disposal was made in the same area of harvesting, dropped seeds would have constituted the seedbed for the next season. Among modern aboriginals of the Chaco, *Lagenaria* is not sowed in the orchard since fruits must be left until they fully ripen and under such circumstances the plants get very big and “drown” the other plants of the orchard; that is why they collect *Lagenaria* from the “orchard of the wood” where the plant can climb trees and develop better fruits (Arenas 2003).

Conclusions

At Pampa Grande, postharvest activities for the processing of *Cucurbita* and *Lagenaria* were probably of “low impact”, having relatively little consequence on the overall production system. Ancient inhabitants of Pampa Grande appear to have cultivated landraces of *C. maxima* ssp. *maxima* with heavy rinds to use them as implements or household tools after eating their flesh cooked among hot ashes. It is possible that cucurbit remains identified as hard rind *Cucurbita* morphotypes were ripened fruits of a landrace that were eaten in the immature stage, with maturation aimed only for the procurement of seeds for the next sowing season. In this hypothetical scenario, the thick rinds of the mature fruits were eventually recognised as useful as containers for various purposes, including the heating of different substances. The pitfall in this hypothesis is the absence of immature *Cucurbita* remains (seeds, rinds or peduncles) at Pampa Grande, despite the excellent preservation conditions at these rock shelters. Another possibility is that these remains actually represent a different landrace developed to have thicker, lignified rinds in order to enhance shell life of the fruits and protect them from diseases to pathogens. This last option will represent a strategy of postharvest intensification, but not through a special or specific kind of processing, but through the development of new landraces as a consequence of changing husbandry criteria and selective pressures over cultivated stands. Spontaneous and intermediate morphotypes were not used as containers, and occur in the same contexts as *C. maxima* ssp. *maxima* and *L. siceraria* ones in Los Aparejos cave. If they were consumed, they probably had to be detoxified, but not if they were used for medical purposes. We do not have evidences of detoxification at Pampa Grande, rinds with thermal alteration or evidence of charring correspond only to domesticated samples and leaching is not evident in the analysed macroremains.

Pampa Grande shows the absence of a clear tendency to the sole development of fruits with thin, palatable rinds, but the coexistence of diverse morphotypes resulting from interbreeding to the generation of different landraces in response to different postharvest and consumption needs.

Therefore, landraces and wild and weedy relatives co-existed and co-evolved thanks to a non-exclusive cultivation strategy which increased the gene flow between crops and their relatives, a husbandry system reported among modern farmers and indigenous communities, mainly in America. Hence, Pampa Grande Cucurbitaceae remains show an ancient reflection of modern traditional systems of knowledge and the ongoing and progressive domestication of gourds, not along a single and straightforward path, but on a diverse, complex and mixed up one.

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