

Elucidating post-harvest practices involved in the processing of algarrobo (*Prosopis* spp.) for food at El Shincal Inka site (Northwest Argentina): an experimental approach based on charred remains

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Abstract It is known from previous studies that qualitative and quantitative morphological attributes of food products and residues may permit the identification of different food processing activities in desiccated *algarrobo* (*Prosopis chilensis* and *Prosopis flexuosa*) remains. Experimental approaches are used here in order to (1) evaluate if those diagnostic features persist even after charring and (2) to use these results as a means of interpreting types of processing from archaeobotanical contexts of the Inka site of El Shincal. Experimentation was made on the basis of traditional practices which were registered during previous ethnobotanical work in the area. Diagnostic patterns of *Prosopis* flours and *patay* (bread), as well as of *añapa/alolja* (fresh and alcoholic beverages, respectively) and *arrope* (syrup) residues were stipulated for charred remains. In the specific case of El Shincal, specimens derived from flour manufacture (unrefined and refined) and *añapa/alolja* residues were recognized from different buildings. This must have implied a special organization of the production and the people working on that, in the sense of post-harvest intensification.

Keywords Carbonization experiment · *Prosopis* · Archaeobotany · Palaeoethnobotany · Food processing · South America

Introduction

This paper's main aim is to devise a necessary tool of interpretation of the archaeobotanical record of El Shincal (ESH) archaeological site (Raffino 2004) (Fig. 1). El Shincal is an Inka Administrative Centre located 6 km from the modern village of Londres de Quimivil, Catamarca Province, Northwest of Argentina (27°41'14" S and 67°10'31" W). It is situated in the northwestern extreme of the Pipanaco basin at an elevation of 1,300 m above sea level. In Inka times, El Shincal played an important role in the exchange of goods between settlements in the region (Raffino 2004; Williams and D'Altroy 1998). El Shincal main buildings, shown in Fig. 1, have basically only one occupational component (the Inka), however, archaeological evidence recovered from two samples, belonging to both domestic (building K1) and ceremonial (*ushno*) structures, included the remains of Old World species (cattle, plants such as wheat and barley grains, and peach endocarps) and other archaeological findings, which suggest that ESH continued in this role during the subsequent Hispanic-Indigenous period (Raffino 2004; Capparelli et al. 2005).

Based on the types of the Inka features present, ESH was regarded as a "New Cusco" by Farrington (1999). The site is made up of numerous types of structures (Fig. 1) including the *aukaipata* or *plaza*, a center of political, ceremonial and socio-economic activities and a space of communication between the different buildings of the site—*kallankas* (i.e. K1, K3)—large structures that were used for a number of different purposes—*sinchiwasi* (K7)—a large structure with several rooms that may have served as lodgings for labourers—and *walled household compounds* (RPC; i.e. 5cIII)—rectangular domestic units with patios and roofed areas. The *ushno* is in the middle of the *aukaipata*.

Dedicated with affection to Gordon Hillman who introduced me to the world of food processing in archaeobotany more than 10 years ago

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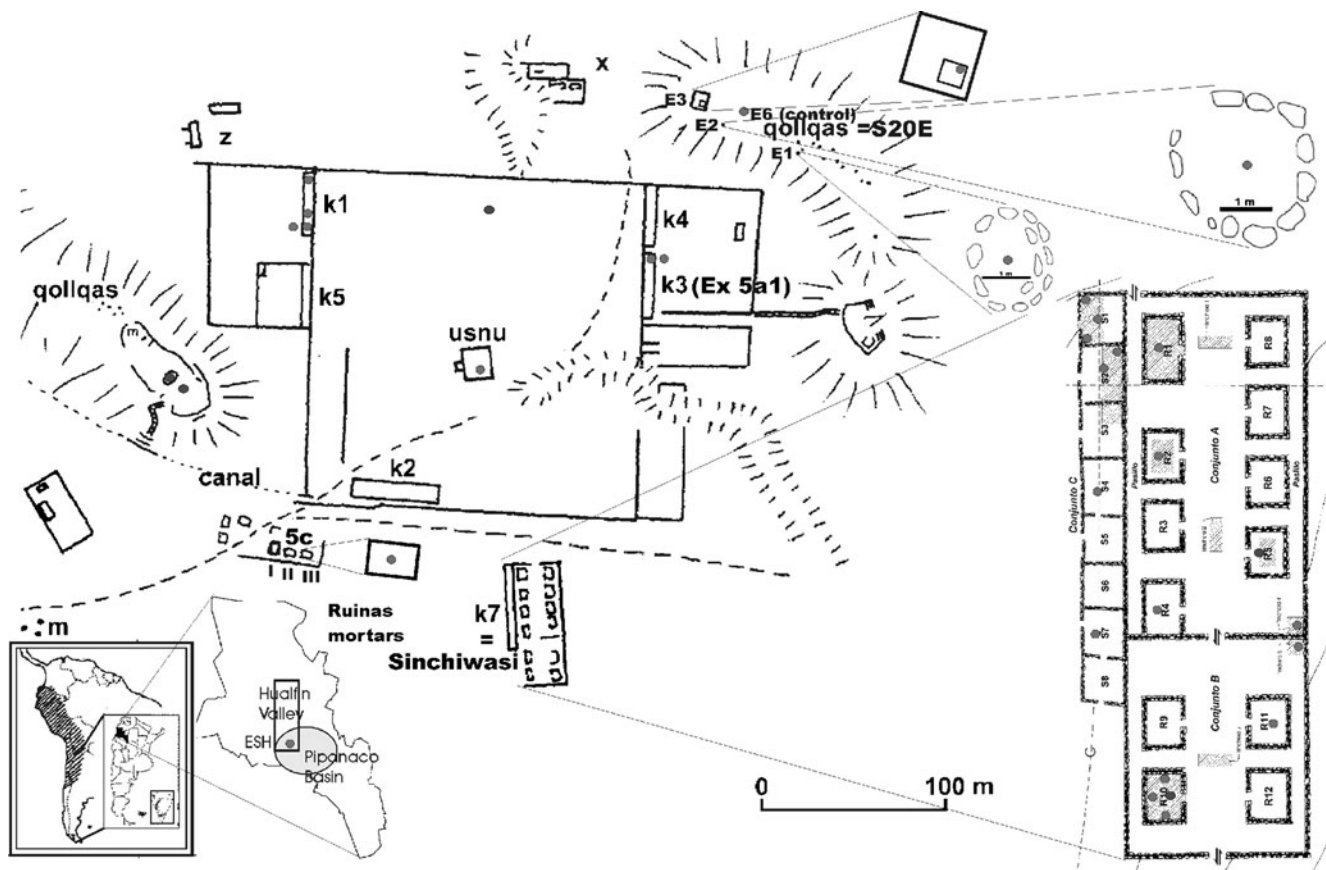


Fig. 1 Location and map of El Shincal Inka site (modified from Capparelli 2009)

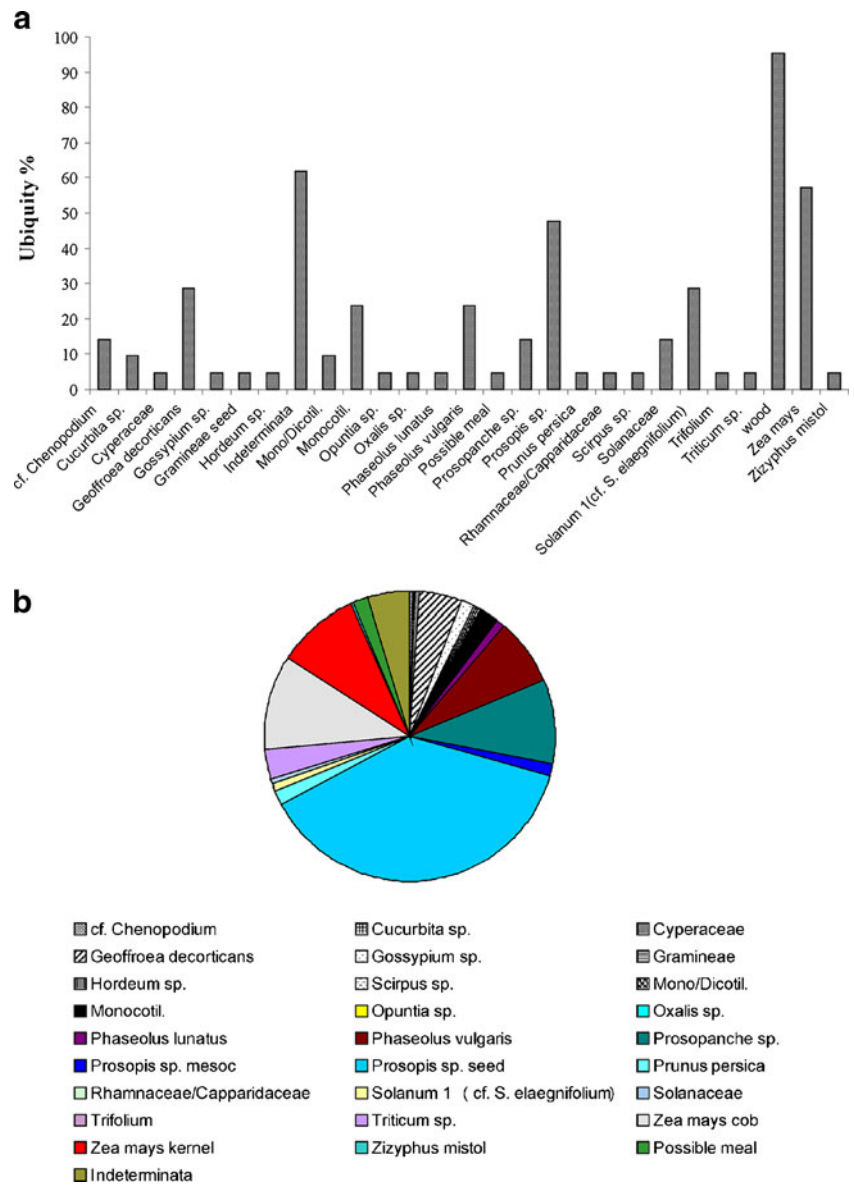
Food processing areas, mainly spaces containing grinding tools (mortars), are distributed around the central square (see for example “Ruinas” mortars in Fig. 1). A large storage area (i.e. S20E2) is located on top of, as well as behind, a hill found in the northeastern sector of the site (Snead 1992; Raffino et al. 2004a, b, c). This area is comprised of *qollqas* structures. *Qollqas* are storehouses which might be similar to those recorded historically by Sánchez Oviedo (see Fig. 6g, h in Capparelli and Lema 2011), but with a one-row round stone basement (see Fig. 1).

Bearing in mind the evident importance of ESH during Inka times, questions arose about the types of economic activities that formerly supported this community. Excavation and recovery techniques at El Shincal were previously described in several papers (see for example Raffino 2004). Archaeobotanical sampling was implemented with systematic flotation. A total of 33 column samples (see grey points in Fig. 1) were taken from 23 architecturally and functionally different structures (see below for more details in recovery techniques, also see Capparelli 1997; Capparelli et al. 2004, 2005). From this analysis, 2,482 non-woody botanical remains were recovered from the Inka floor, and 24 taxa identified (Fig. 2a, b) (see Capparelli 2009). It can be said that El

Shincal shows a distinctive pattern of plant use with respect to that of other Inka sites. Wild plants appear to have been as important in the food economy as domesticated species: cultivated foods resources (*Zea mays*, *Phaseolus* and *Cucurbita*) represent 22.4%¹ of the total plant remains recovered, while wild foods resources (*Prosopis*, *Geoffroea*, *Zizyphus mistol* and *Rhamnaceae/Capparidaceae*) represent 34.8% (Fig. 2b). *Prosopis*, together with cultivated maize, were the most ubiquitous taxa of El Shincal food remains (Fig. 2a). Both, *Prosopis* and maize, were associated to ritual and domestic units and registered the highest percentages of relative counts and densities (Capparelli 2009). But, how can we meaningfully interpret the cultural relevance of one of them with respect to the other from archaeobotanical assemblages? Ethnobotanical and experimental analysis of *Prosopis* post-harvest practices (can lead to the deposition of different plant parts in different proportions and with different morphological aspects depending on the final product elaborated (Capparelli et al. 2010). Some of these

¹ Values based on density counts (for more details, see Capparelli 2009)

Fig. 2 El Sincal plant taxa. **a** Ubiquity% (number of samples in which each taxon was present). **b** Density% (number of charred fragments per 10 l of sediment) (taken from Capparelli 2009)



practices can be recognised from *Prosopis* pod parts deposited in a site, in particular flour remains as well as *añapa*, *aloja* and *añapa-aloja* residues (see. Capparelli and Lema 2011). On the basis of the ethnobotanical and experimental analysis previously mentioned, the objective of the present paper is to evaluate whether diagnostic features previously recognised to be potentially useful for distinguishing ancient *Prosopis* post-harvest practices from desiccated remains (Capparelli and Lema 2011) persist and are diagnostic even after charring. Finally, these results are used as a means of interpreting types of processing of the *Prosopis* charred remains recovered from several contexts of the Inka site of El Shincal, as well as to calculate a quantitative index of *Prosopis* use versus that of maize. Data presented here are also part of a major project to evaluate different post-harvest *Prosopis* trends over

time through the analysis of archaeological contexts of different chronological periods of the Argentinian Northwest, before and after agriculture started to be practised (see also Capparelli and Lema 2011).

From ethnohistorical documents, as well as our own ethnobotanical work (see Capparelli 2007, 2008; Capparelli and Lema 2011), we know that *Prosopis* (species analysed here are *Prosopis chilensis* and *Prosopis flexuosa*, known in Spanish as white and black *algarrobo*, respectively) was an important resource within the Argentinian Northwest, even after the Spanish conquest and up to the present day. The part used is the fleshy and sweet mesocarp of the pod. Pods are dried in the sun and may be consumed raw or parched or may be pounded in stone or wooden mortars into a flour. This may be used to make *ulpo*, which is a kind of lye, resulting from the dissolution (in water) of *algarrobo* and

toasted maize flour, and *patay*, which is a bread made from fine, sieved, compacted and dried flour. Flour may be also used to make *añapa*, a non-alcoholic beverage, for which the flour is soaked in cold water and then manually squeezed to extract the juice, and *aloja*, which is an alcoholic beverage that is processed in a similar way to *añapa*, except that the soaked flour is subsequently fermented into a drink similar to beer. A few written sources on *Prosopis* processing mention also that hot water-soaked pods might be added to the *aloja* preparation and that chewed pods might be also incorporated to accelerate fermentation (Dasso 2000). A syrup called *arrope* can be made by boiling the pods, mashing and sieving them through a burlap fabric to obtain juice, which is then boiled until it thickens (for more detail of each type of processing see Capparelli and Lema 2011). These different types of processing may deposit different kinds and quantities of *Prosopis* parts on the ground where the different activities were carried out. Today, the resultant residues are usually thrown away on the patio floor. Sometimes, they serve to feed domestic animals such as hens.

Archaeobotanists in the Old World have successfully developed interpretative models of crop processing based on ethnographic and experimental observation (e.g. Hillman 1984; Jones 1984). In this paper, experimental analysis carried out on the basis of the modern traditional practices described above, served to characterize the qualitative and quantitative morphological attributes of various charred *Prosopis* food products and residues, while previous works made it possible to recognize them from desiccated archaeobotanical remains (see Capparelli 2008; Capparelli and Lema 2011). Experimental work on black (*P. flexuosa*) and white (*P. chilensis*) desiccated *algarrobo* showed that unrefined flour remains from white *algarrobo* were mainly seeds with intact testa, entire endocarps—some with mesocarp traces—and halves of endocarps, while black *algarrobo* showed mostly closed and fissured endocarps—some with mesocarp traces—but almost no seeds. On the other hand, refined flour remains can be recognized in *P. chilensis* and *P. flexuosa* by the proportion of seeds with fissured testa, fragmented seeds, fissured endocarps or halves of endocarps, and absence of traces of mesocarp in endocarps. In the case of cold water-soaked *añapa* and *aloja* residues, they can be recognized because the testa of the seeds becomes folded/rolled and loosening in some areas. Cotyledons are clearly visible in several seeds. These alterations are most common within those seeds in which grinding produce fissures in the testa. On the other hand, when grinding did not damage all the testa tissues but only seed epidermis, then, just the epidermis may fold when dried. As regards to the *añapa-aloja* endocarp residues, in those with epi-mesocarp patches, parts of the

epicarp become directly attach to the endocarp surface. Epicarp may also curl in the edges. Clean endocarps present the same features that refined flour, but some of them have a slight black mesocarp patina. If fine and coarse flour fractions are used to prepare the *añapa* or *aloja*, the small epicarp residues of the fine fraction stuck to the endocarp surfaces when dried. By contrast, hot water *aloja* residues showed a thick dark patina on endocarps. Chewed pods showed several fiber bundles (from the external mesocarp of the pod) twisted together. *Arrope* residues are identified by the presence of closed endocarps with a thin dark patina and large pieces of epicarp sometimes twisted. These are the characters which will be evaluated in this paper to know if they are diagnostic for charred remains.

Modern *Prosopis* post-harvest food practices registered at the Hualfin valley showed very few instances of possible contact, of these *algarrobo* products and residues, with fire. As these residues are not commonly used for fuel—instead, they are usually thrown away to the patio floor or serve to feed domestic animals—we can suppose that the charred *Prosopis* remains from domestic-floor and hearth-contexts of El Shincal are derived from the fraction of pod parts that came into contact with fire accidentally. On the contrary, other kind of archaeological contexts, such as the ritual ones, may reflect purposely charred material (this aspect will be discussed below). Different *Prosopis* assemblages from domestic and ritual contexts will be analysed later in this paper on the basis of the experimental work developed below.

Due to the widespread distribution of *Prosopis* species as part of many arid ecosystems and also as plants closely related to humans (Beresford-Jones 2005) the subjects treated here may be of interest to researchers in different regions. For example, ecosystems of the Pípanaco basin (the study area of the present paper) were recognized by Simpson and Solbrig (1977) and Orians and Solbrig (1977) as analogous of those of the Silver Bell, Arizona, USA. Beresford-Jones (2005:177), in his Ph.D. thesis establishes a limited analogy between the ethnobotany of the Sonoran desert and the south coast of Peru, which is justified because of biological and ecological similarities of both areas. Therefore, it is clear from these studies that the south west of North America, the south coast of Peru and the southern extreme of the Hualfin valley are areas more or less related in the way *Prosopis*–people relationships were practised (Capparelli and Lema 2011).

Methodology

We recognize three main factors that may affect charred representation of archaeobotanical *Prosopis* macroremains

differentially with respect to other plant resources: (1) post-harvest processing of *Prosopis* pods; (2) differential resistance of each different pod part to charring; (3) differential fragility of the remains after charring and their relation to potential fragmentation derived from post-depositional processes. The response of *Prosopis* plant parts to these three factors will be analysed in this paper through different experimental designs.

Post-harvest processing of *Prosopis* pods

Sets of *Prosopis chilensis* and *P. flexuosa* unrefined and refined flour, *añapa*, *aloja* and *arrobe* were made following traditional techniques previously recorded by the author along the Hualfin Valley, Catamarca Province, Argentina. The protocol was the same of that described in Capparelli and Lema (2011). Sixteen sets of pod parts were charred in different events. Each of the charring sample consisted of the different pod parts of *P. chilensis* and *P. flexuosa* (i.e. flours—from which the coarse fraction can be either intermediate product of *añapa–aloja* preparation or a residue of *patay–ulpo* production—portions or final products, in the case of *patay*; and residues, in the case of *patay–ulpo*, *aloja–añapa*, *aloja* and *arrobe*) derived from each food preparation as follows: 1, 2—*P. chilensis* and *P. flexuosa* unrefined flour residues, respectively; 3, 4—*P. chilensis* and *P. flexuosa* refined flour residues, respectively; 5, 6—*P. chilensis* and *P. flexuosa* *añapa–aloja* residues (refined flour and cold water), respectively, charred wet; 7, 8—*P. chilensis* and *P. flexuosa* *añapa–aloja* residues (refined flour and cold water), respectively, charred dried; 9, 10—*P. chilensis* and *P. flexuosa* *añapa–aloja* residues (unrefined flour and cold water), respectively; 11, 12—*P. chilensis* and *P. flexuosa* *añapa–aloja* residues (fragmented pods and hot water); 13, 14—*P. chilensis* and *P. flexuosa* *aloja* chewed pod residues; 15—*patay* portion; 16—*P. chilensis* and *P. flexuosa* *arrobe* residues, respectively. Each of these set of pod parts was charred in an ash-filled metal bowl that was indirectly heated. Results of experimental carbonization are comparable between them because all the different charring events were charred under a uniform temperature regime. In this sense, temperatures of each charring event ranged from 170°C at the beginning of the process and to 350°C at the end. To prevent specimens' loss higher temperatures were avoided during this experiment. Temperatures of each event were measured throughout the whole carbonization period with a thermocoupler and thermometer. Duration of the charring process for each individual pod part varied from 5 to 260 min (= 4 h 20 min) depending on the size, hardness and percent of humidity (*añapa*, *aloja* and *arrobe* residues were charred both wet and dried) of the vegetal tissue. In another example, in the case of flour residues, seeds of *P. chilensis* and *P. flexuosa*

charred at approx. 8 min, endocarps at 25 min and entire joints at 65 min. Similar times were observed for *añapa–aloja* residues charred dried. However, while *añapa–aloja* residues charred wet took from 70 to 175 min for seeds, endocarps and entire joints of *P. chilensis*, they took from 185 to 260 min in the case of *P. flexuosa*, probably due to a higher absorption of water during soaking in the latter. All specimens were analysed and photographed under Stereoscopic microscope, and were photographed with both a digital camera and scanning electron microscope; measurements were taken with callipers, and weighted on a digital balance before and after charring. Entire pods of *P. flexuosa* and *P. chilensis* were charred as control samples of non-processed *algarrobo*, as well as to analyse qualitative features of pod parts after post-depositional fragmentation in order to differentiate them from those derived from flour production.

Differential resistance of each *Prosopis* pod part to charring

A second charring experiment was carried out for the purpose of observing which of the different *Prosopis* pod parts were the most resistant to calcination. Joints, epicarp fragments, endocarps, and seeds were charred all together in an ash-filled metal bowl that was directly heated. Temperatures here reached 400–450°C and charring lasted 15 min. Maize grains were also charred and used as a comparative sample.

Differential fragility of the remains after charring and their relation to potential fragmentation derived from post-depositional processes

After charring, two of each different *Prosopis* pod part (joints, pieces of epicarp, entire endocarps, halves of *P. chilensis* endocarps, and seeds) were softly smashed all together with a pestle in a mortar to evaluate relative fragility.

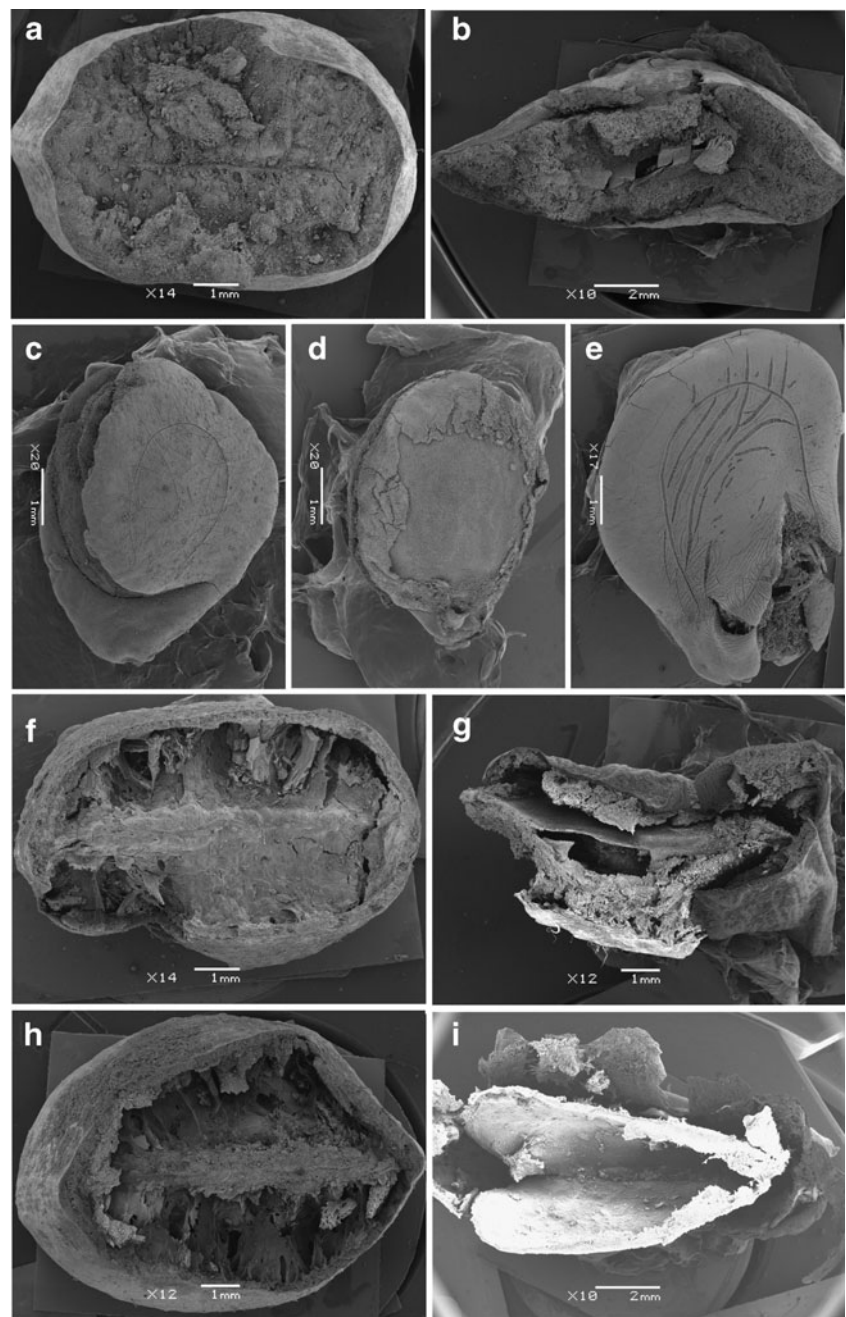
Results

Post-harvest processing of *Prosopis* pods

The effect of carbonisation on pod fragments and seeds was similar for both species analyzed and is shown in Figs. 3 and 4.

Flour derivatives Epicarp fragments preserve better when they have mesocarp traces, otherwise, they became very fragile after charring. Mesocarp traces showed a compacted texture (Fig. 3a, b). *P. chilensis* closed endocarps preserved their aspect, but some of them opened freeing their seeds

Fig. 3 Experimental post-charring effects on *Prosopis* pod parts. **a–c** Flour residues. **d–g** *Añapaloja* residues (cold water soaking). **h–i** *Añapaloja* residues (hot water soaking). **a, c, d, e** and **g** *Prosopis flexuosa*; **b, e, g** and **i** *Prosopis chilensis*



after charring. *P. chilensis* halves of endocarps have little potentiality to survive because single shells, like the epicarp, became very fragile after charring.

Some seeds of *P. chilensis* and *P. flexuosa* can resist carbonization without changing significantly except for shrinkage in length and width. However, it is more common that splits appear in seeds after charring mainly along the fissure line or along the chalazae area (Fig. 3c). Albumen and cotyledons commonly protruded through these new splits. In seeds that already had fissured testa before charring, albumen and cotyledons commonly protruded along those fissures after charring. In all cases, the portions

of testa remaining (whether in an intact seed or between the splits of a protruded seed) still had a good preservation state after charring, even the epidermis, which preserved almost complete. Contrary to what occurs for *añapaloja* residues (see below), testa fragments are not curled or folded.

Changes in dimensions of flour specimens after charring are given in Table 1. *P. flexuosa* and *P. chilensis* endocarps presented almost no change in size, except for an increase of thickness in *P. flexuosa*, probably due to an increase in seed thickness. *P. chilensis* halves of endocarps presented no or little variations in length and width but reduced their thickness and weight drastically, becoming very fragile.

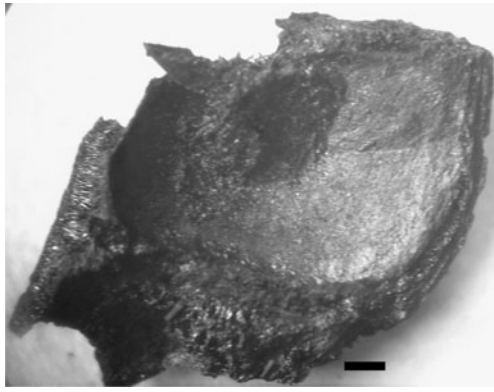


Fig. 4 Breakage by the suture of their endocarps in experimental charred and smashed *Prosopis chilensis* entire pods. Scale=1 mm

Both *P. flexuosa* and *P. chilensis* seeds shrinkage more in length (10% to 15%) than in width (0% to 2%), becoming rounder, and increased to 55% their original thickness.

Entire non-processed pods The qualitative aspects of the pods remained almost the same as those before charring. Epicarps persisted around the pod and had a smooth and lustrous surface. Quantitative features changed. Pods shrinkage in length and width (from 7% to 18%), increased in thickness (from 19% to 25%) and lost weight strongly (from 46% to 54%) after charring (Table 2). After smashing the pods in a mortar it was observed that pod joints commonly broke by the suture of their endocarps (Fig. 4), and that fragmented pod piece retains all its endocarp, mesocarp and epicarp sections. It is therefore very difficult to obtain endocarps without mesocarp traces or clean entire endocarps from this kind of fracture. Also, in *P. flexuosa*, most of the seeds get stuck to their respective endocarp, breaking in small pieces when smashing. On the contrary, in *P. chilensis*, some seeds are released from the endocarps. These seeds have the testa better preserved, and the testa appears more brilliant and smooth than that of those charred separately from the endocarps.

Añapa/alaja residues *P. chilensis* and *P. flexuosa* epicarp, mesocarp and seeds were more deteriorated after charring than those processed for flour (Fig. 3d, i). The mesocarp in cold water *añapa/alaja* usually presents holes after charring, and a softer aspect than that of the flour (Fig. 3f, g), which is due to its dissolution in water. This can be seen from values of thickness reduction on *añapa/alaja* endocarps with mesocarp still attached, which ranged from 19% to 36%, with respect to that of flour, which is null (Table 1). Also, reduction in weight in joint residues of *añapa/alaja* is almost twice (from 61% to 82%) than in flour ones (from 43% to 45%) (Table 1).

Due to the fact that dissolution of mesocarp in hot water-soaked residues is more intense than that of cold water,

some features are more evident in the former. For example, the surface may present waves along the pod, epicarp curls in the edges of individual joints, and mesocarp present larger holes (Fig. 3h, i). Also, in hot water-soaked pods epicarp or mesocarp may separate from the complex endocarp seed (Fig. 3i). These charred epicarp or mesocarp fragments are fragile and can easily be fragmented.

Clean endocarp residues of *añapa/alaja* presented similar features to those of refined flour after charring, except that some *P. flexuosa* and *P. chilensis* closed endocarps opened freeing their seeds, and some *P. chilensis* endocarps separated into two shells. Black patina of the endocarps, which showed to be useful for distinguishing hot water soaking from desiccated remains (see Capparelli and Lema 2011), it is obviously not useful for charring remains.

Endocarp residues of *añapa/alaja* showed variations in size after charring. *P. flexuosa* endocarps became rounder both charred wet and charred dry, because length shrinkage is more than that of width. *P. chilensis* endocarps became rounder after wet charring but enlarged after dry charring. Thickness reduced after soaking in all the cases except for *P. flexuosa* dry charring, which presented no variations. *P. chilensis* halves of endocarps reduced their thickness and weight drastically, becoming very fragile, as it happens for flour specimens (Table 1).

P. chilensis and *P. flexuosa* *añapa/alaja* seeds were more deteriorated than the flour ones after charring (i.e. more seeds became deformed by splits, protrusion of albumen and cotyledons, and changes in the testa aspect). In some of the seeds the testa has wrinkled, folded, rolled, and/or strongly split, or disappeared by patches or completely (Fig. 3d). In others, only the epidermis changed. It may present several parallel longitudinal or transversal splits (Fig. 3e), or may fold or disappear by patches. *P. flexuosa* seed epidermis was more deteriorated than that of *P. chilensis*.

Seed residues of *añapa/alaja* usually increase in size when soaked. This increment depends on the water absorbed. If seed epidermis (formed by malpighian macrosclereids) is not injured by the grinding, then, the seed does not absorb any water. But, with a minimal injury of that layer after grinding (what generally happens), the seed absorbed water and increase its size. In seeds with minimally injured testa, which were wet and charred, these increases in size still persist after charring from 3% to 6% in length and width, and from 48% to 82% in thickness (Table 1). But, if the seeds are charred once dried, they shrink from 3% to 12% in length and width, increasing their thickness from 33% to 35% (Table 1).

Similar to what was noted for desiccated remains, charred chewed pod residues are easily distinguished by the presence of very fine threads of mesocarp fiber bundles heavily twisted and occasionally attached to terminal

Table 1 Percent of change in length, width, thickness and weight of *Prosopis chilensis* (WA) and *Prosopis flexuosa* (BA) pod parts processed for flour and *añapa-aloja* after charring

Product/residue	Closed endocarps with epi-mesocarp still attached				Closed endocarps				Shells of endocarps (only WA)				Entire seeds				
	Length	Width	Thickness	Weight	Length	Width	Thickness	Weight	Length	Width	Thickness	Weight	Length	Width	Thickness	Weight	
Flour																	
BA	Ini	7.37	10.00	6.14	0.23	8.10	7.86	2.20	0.10	-	-	-	-	5.46	3.87	1.95	0.01
	SD	0.21	0.07	0.68	0.03	0.13	1.13	0.62	0.04	-	-	-	-	0.06	0.20	0.27	0
	Final	7.37	9.51	6.14	0.13	8.10	7.86	3.37	0.06	-	-	-	-	4.87	3.87	3.02	0.00
	SD	0.19	0.07	0.72	0.02	0.40	0.40	1.22	0.01	-	-	-	-	0.23	0.24	0.51	0
	% cha	0	-4.87	0	-44.93	0	0	53.53	-29.41	-	-	-	-	-10.82	0	54.87	-30
WA	Ini	10.62	11.94	5.13	0.23	10.11	7.41	4.19	0.07	8.92	6.35	0.22	0.01	6.58	4.55	2.47	0.05
	SD	4.47	1.06	0.15	0.11	1.41	1.04	0.52	0.02	0.36	0.04	0.02	0	0.35	0.22	0.08	0.01
	Final	8.94	11.56	5.13	0.13	10.11	7.17	4.19	0.04	8.92	6.35	0.1	0.00	5.61	4.47	3.82	0.02
	SD	5.08	1.01	0.14	0.07	1.22	1.50	0.77	0.03	1.12	0.11	0	0	0.31	0.28	0.38	0
	% cha	-15.76	-3.21	0	-42.86	0	-3.28	0	-38.1	0	0	-53.49	-50	-14.73	-1.69	54.73	-67.86
Añapa-aloja residues (soaked in cold water)																	
BA charred wet	Ini	8.59	10.59	6.10	0.28	9.47	7.05	3.22	0.10	-	-	-	-	5.71	4.73	2.01	0.03
	SD	1.39	0.75	0.75	0.05	0.52	0.52	0.64	0.03	-	-	-	-	1.01	0.84	0.14	0.00
	Final	8.26	7.66	4.05	0.05	6.56	5.73	2.38	0.02	-	-	-	-	5.89	4.73	3.65	0.02
	SD	-	-	-	-	1.01	0.37	0.03	0.00	-	-	-	-	0.59	0.50	0.17	0.00
	% cha	-3.84	-27.69	-33.61	-82.35	-30.69	-18.76	-26.27	-76.21	-	-	-	-	3.03	0	81.73	-25.93
BA charred dry	Ini	7.98	8.87	7.14	0.24	9.08	7.41	2.93	0.11	-	-	-	-	5.31	3.91	2.06	0.02
	SD	1.84	1.94	0.36	0.03	0.56	0.89	0.35	0.02	-	-	-	-	0.12	0.08	0.08	0.00
	Final	6.58	8.87	5.75	0.06	8.14	7.63	2.93	0.05	-	-	-	-	5.14	3.56	2.73	0.01
	SD	0.83	0.27	0.13	0.02	0.46	0.53	0.44	0.02	-	-	-	-	0.33	0.20	0.54	0.00
	% cha	-17.55	0	-19.46	-7.06	-10.36	3.00	0	-51.16	-	-	-	-	-3.32	-9.04	32.58	-50.00
WA charred wet	Ini	12.3	12.09	5.99	0.31	10.23	6.77	4.31	0.07	10.34	6.99	0.2	0.01	6.48	4.35	2.12	0.04
	SD	2.57	0.25	0.20	0.02	2.01	0.59	0.18	0.02	0.91	1.69	3E-17	1E-18	0.19	0.28	0.37	0.01
	Final	10.29	10.31	4.33	0.09	10.23	7.3	3.3	0.04	9.46	7.28	0.1	0.00	6.69	4.63	3.14	0.03
	SD	1.97	0.65	0.70	0.01	0.07	0.99	0.71	0.01	1.19	1.44	2E-17	5E-19	0.46	0.78	0.76	0.01
	% cha	-16.1	-14.63	-27.57	-71.68	0	7.78	-23.49	-52.27	-8.57	4.15	-50	-50	3.19	6.36	47.96	-36.00
WA charred dry	Ini	12.88	12.60	5.41	0.18	10.07	8.38	4.75	0.08	10.39	7.91	0.7	0.06	6.25	4.57	2.00	0.03
	SD	1.64	1.40	0.45	0.02	0.28	1.24	0.69	0.01	2.04	1.40	0.71	0	0.28	0.1	0.23	0.01
	Final	11.54	10.74	3.48	0.07	9.18	6.65	3.99	0.02	9.51	7.28	0.1	0.01	5.5	4.57	2.7	0.01
	SD	-	-	-	-	0.93	0.82	0.31	0.01	1.41	1.07	1E-17	5E-19	-	-	-	-
	% cha	-10.4	-14.76	-35.67	-61.11	-8.84	-20.68	-16.13	-73.91	-8.50	-7.96	-85.71	-75.00	-11.95	0	34.8	-73.33

Ini media of the initial state, *SD* standard deviation of the media, *final* media of the post-charring values, % cha percentage of change

Table 2 Percent of change in length, width, thickness and weight of *Prosopis chilensis* (WA) and *Prosopis flexuosa* (BA) entire non-processed pods after charring

Entire pods	Averages	Length	Width	Thickness	Weight
BA (N=5)	Ini	128.30	11.78	5.83	3.63
	SD	7.64	0.93	0.55	0.38
	Final	112.00	10.97	6.93	1.67
	SD	12.12	0.64	0.53	0.01
	% cha	-12.73	-6.90	18.87	-53.86
WA (N=2)	Ini	149.00	14.31	4.26	3.14
	SD	15.56	1.73	0.11	0.90
	Final	122.5	12.54	5.33	1.70
	SD	10.61	0.66	0.40	0.45
	% cha	-17.79	-12.37	25.00	-45.95

Ini media of the initial state, *SD* standard deviation of the media, *final* media of the post-charring values, *% cha* percentage of change

endocarps, however these fine threads of fibers became very fragile and easily fragmented after charring.

Conglomerates, coming from the desiccation of fine flour *añapa/aloja* residues (see Capparelli and Lema 2011), separated into individual pieces after charring. It is not possible to distinguish what the grade of refinement of the flour used from charred remains was. On the contrary, however, those conglomerates coming from *arrope* residues that were charred when wet can be recognized (see below).

Patay The *patay* bread become more compacted and hard when charred.

Arrope residues Endocarps having a slight black patina are characteristic of desiccated *arrope* residues, but this is not preserved after charring. Pieces of twisted epicarp were even more curled after charring and became very fragile. Wet and charred residues (endocarps and pieces of epicarp) became stuck together, but not those dried and charred. Dimensions could not be measured because of the fragmentation and destruction of pod joints.

Other considerations With respect to comparing specimens that were wet and charred with those dried and charred, the former had greater amounts of ash adhering to their surface, and sometimes showed patches of a brownish colour instead a deep black one. If wet *añapa/aloja* residues are taken to the calcination point, then spheres of grey and brownish ashes replace each pod joint.

Differential resistance of each *Prosopis* pod parts to charring

As regards the results of the second charring experiment, it is worth mentioning that except for individual joints, that

were 100% recovered as well as maize kernels, the loss of *Prosopis* pod parts ranged from 20% to 85% after charring (Table 3). This loss was numerically different between each category (such as endocarps/seeds/epicarp–mesocarp pieces). The recovery of epicarp fragments and seeds reached 80% of the initial number. However, endocarps were the most susceptible to conversion into ashes, even more than seeds. In the case of *P. flexuosa*, despite the production of abundant entire endocarps with grinding, these fissured or were broken with charring. Also they have a much higher likelihood of being destroyed by charring than *P. chilensis* closed endocarps. Endocarp tissue are composed mostly by fibers and sclereids, but in the case of *P. flexuosa* the fibers are shorter and are positioned in a looser and less compacted way than in *P. chilensis*. The ligneous constitution probably makes them calcinate before seeds do. In the case of *P. chilensis*, tissue of each shell is very thin, fibers are longer and more compacted than in *P. flexuosa*. In the experiment developed here from 20 original charred endocarps, just three and a half endocarps and three seeds remained after charring. It is clear that calcinations of the seed may take place with more intensive charring.

Differential fragility of the remains after charring

The smashing of the different *Prosopis* pod parts affected most to epicarp fragments and halves of *P. chilensis* endocarps. The pounding of these specimens showed that epicarp fragments and single shells of *P. chilensis* endocarps, despite having a high recovery rate after charring, are the most fragile pod parts compared with individual joints, seeds and those entire endocarps that resist charring.

Finally, some features useful either for desiccated or charred remains, share limitations. For example, those

Table 3 Differential resistance of *Prosopis* pod parts to charring

Specimens prior to carbonization	Specimens after carbonization	% of specimens recovered
3 individual joints and endocarps with large patches of meso-epicarp	3 individual joints and endocarps with large patches of meso-epicarp	1
10 pieces epicarp–mesocarp	8 pieces of epicarp–mesocarp	80
20 clean entire endocarps (10 of WA+10 of BA)	3 and a half endocarps+3 seeds	15
5 halves of endocarps WA	4 halves of endocarps WA	80
5 seeds	4 seeds	80
Total <i>Prosopis</i> parts=43	Total <i>Prosopis</i> parts=22	51
10 fragments of maize processed for locro	10 fragments of maize processed for locro	
Total maize parts=10	Total maize parts=10	100

WA *Prosopis chilensis*, BA *Prosopis flexuosa*

characters related to changes in testa seed of *añapa/alaja* residues, which are highly diagnostic for post-harvest practices, affect diagnostic features (fissure line, among others) that are taxonomically important for genus or species recognition. Therefore, taxonomic identification might be possible just for a few of the remains. Other limitations may appear if comparisons are going to be made between this experimental results and remains that might have been charred at more intense regimens. We do not exactly know at which temperatures were El Shincal remains charred, information that will be object of future works. By now, we assume that charring regimes were similar in experimental and archaeological cases. In this sense, even when it is more difficult to recognize post-harvest practices in charred specimens than in desiccated ones, a conjunction of qualitative characteristics of pod parts present in each assemblage (some features related with changes in dimensions after charring might be also useful), their relative quantities, and their contextual associations with other archaeobotanical and archaeological remains can help to recognise charred *Prosopis* specimens derived from different processing practices. A summary of the most important diagnostic features for the recognition of potential post-harvest processing of *Prosopis* pods for food, which considers the results of the three different charring experiments presented here, and are described on the basis of the previous data obtained from desiccated remains are shown in Table 4. Similarly to what was observed in the case of the *quinoa* (*Chenopodium quinoa*) (see López et al. 2011) these different kind of preparations are more probably to be recognizable from contexts where final stages of processing were carried out, also from those where the preparations are disposed for consumption, and finally—in the case of unrefined or refined flour—from storage contexts. As a complement of Table 4, a general dichotomy key was elaborated in order to potentially distinguish each type of processing from *Prosopis* charred archaeobotanical samples, as follows.

Dichotomy key to potentially distinguish each type of processing from *Prosopis* charred archaeobotanical samples:

A—resinous masses of mesocarp flour strongly compacted with little epicarp fragments spread within the mass—**fine mesocarp flour-patay**

AA—Other remains—**B**

B—Closed and clean endocarps as the predominant fraction of the sample, together with large pieces of epicarp sometimes twisted, which became very fragile after charring and have low possibilities to survive—**arrope residues**²

BB—Seeds, endocarps (with or without mesocarp), and sometimes joints, constituted the assemblage—**C**

C—Seed testa normal; neither rolled nor folded, with good preservation state, even the epidermis, which can be almost complete. Splits may appear in seeds after charring. Albumen and cotyledons commonly protruded through these splits. Epicarp fragments, when present, not rolled neither folded on the edges. Mesocarp, when present, with compacted texture—**D**

CC—Seed testa mainly rolled, folded, or with parallel splits. Testa may disappear by patches or completely, leaving cotyledons visible in some cases. Also, folded pieces of testa separated from the seed may appear. Some seeds charred wet may increase their size. Epicarp fragments, when present, may appear also rolled and folded on the edges, and directly attached to the endocarp surface because of the dissolution of the mesocarp. Mesocarp, when present, usually with holes, and a softer aspect than that of the flour. Low archaeological visibility in general, because tissues remnant after soaking are highly deteriorate—**E**

² Ancient *arrope* have to be interpreted with caution because some ethnobotanists, based on ethnohistorical written documents, support that its manufacture for Argentina is post-hispanic (see discussion in Capparelli 2007)

Table 4 Summary of the most important diagnostic features for charred remains of final and intermediate products, as well as residues of algarrobo post-harvest practices for food

Unrefined flour (>1 mm), intermediate product or residue type 2	Refined flour (>1 mm), intermediate product or residue type 5	<i>Aitapa-aloja</i> in cold water (unrefined flour < and >1 mm), residue type 4	<i>Aloja</i> in hot water, (fragmented pods), residue type 8	<i>Aloja</i> chewed pod residues	<i>Patay/Ulpo</i> (<1 mm), final product	<i>Arrope</i> , residue type 1
WA	BA	WA	WA	WA	WA=BA	WA
<p>Epicarp: scarce due to fragility of structure. Just those pieces with mesocarp patches are more resistant to charring</p> <p>Endocarps: scarce due to fragility of charring. Same morphological features of desiccated flour</p>	<p>Endocarps: scarce due to fragility of charring. Same morphological features of desiccated flour except for an increase in thickness</p> <p>Endocarps: scarce or rarer due to fragility of individual shells. Same morphological features of desiccated flour</p>	<p>Remains are scarce due to fragility of structures</p> <p>Endocarps: in those with epi-mesocarp patches, some parts of the epicarp directly attached to the epicarp surface. Epicarp may also curl in the edges. Mesocarp presents holes and a softer aspect than that of flour. Clean endocarps present the same morphological features that in refined flour</p>	<p>Remains are scarce due to fragility of structures</p> <p>Joints: dissolution of the mesocarp is more intense than in cold water soaking. Pod epicarp may present waves on its surface. In the edges it may become strongly folded</p>	<p>Epicarp: scarce due to fragility of structure. Twisted fine threads became more compacted because of dissolution of the resinous fraction of the flour</p> <p>Endocarps: all closed, containing their respective seeds, sometimes the terminal ones remained attached to the twisted threads of the epicarp</p>	<p>Dry <i>patay</i> became compacted and brilliant when charred, probably because of the dissolution of the resinous fraction of the flour</p>	<p>The same as those of the previous column</p> <p>Twisted ribbons</p>
<p>Seeds: regular. They may appear in more number than in desiccated specimens because charring may affect the endocarp but not its seed. Similar morphological characteristics of WA</p> <p>generally preserved in a good condition. Reduction in length and width and increment of thickness</p>	<p>Seeds: abundant. The same features as in unrefined flour except that the number of fissured-fissured-fragmented seeds increases</p>	<p>Seeds: testa becomes folded/rolled and/or strongly split. In several seeds, it disappears partially or completely. In others, just the epidermis changes: it presents several longitudinal or transversal splits, or disappears by patches. Seeds charred wet increases their size in wide, large and thickness, while those charred once they had dried increases only their thickness and shrinkage in the other dimensions</p>	<p>Endocarps: same features as in previous columns</p> <p>Seeds: the same as those features of <i>aitapa</i> previous columns</p>	<p>Endocarps: scarce residues remained stuck one to the others</p>	<p>Conglomerates of residues</p>	<p>Conglomerates of residues</p>

The table takes in account considerations about calcinations resistance and post-charring fragility. For residue type numbers, please refer to Capparelli and Lema (2011). Abundant, regular and scarce are relative estimative quantities of specimens compared with those of the same column

WA Prosopis chilensis, *BA Prosopis flexuosa*

D—Presence of mesocarp tissue in some pod parts, whether as part of individual joints or in patches over the endocarp surface. Individual joints may be fragmented by the endocarp suture line as a consequence of post-charring fragmentation—**residues of unrefined flour**

DD—Mesocarp tissue, if present, is very few. Endocarps, when present, mostly with clean surface. But in fact, whole endocarps presented a lower resistance to charring with respect to seeds, and halves of endocarps of *P. chilensis* have little potentiality to survive because single shells, like epicarp, became very fragile after charring. Seeds (mostly in the case of *P. chilensis*) are predominant—**residues of refined flour**

E—All features described in CC present—**residues of añapa-aloja**

EE—All features described in CC plus very fine threads of mesocarp fiber bundles heavily twisted and occasionally attached to terminal endocarps (these fine threads of fibers became very fragile and have little potentiality to survive because they are easily fragmented after charring—**residues of aloja**

Application of the experimental results to the case of El Shincal Inka site

Previous researches on the site and the archaeobotanical analysis

This site was widely studied during nearly 20 years. Raffino (2004) resumes archaeological, archaeobotanical and ethnohistorical investigation on the area. Archaeobotanical studies started by the author during the 1990s decade and continue up to now (for more detail on recovery methods, identification procedures and interpretation of plant remains see Capparelli 1997, 2009; Capparelli and Raffino 1997; Capparelli et al. 2004, 2005). The most important aspects of these studies that are relevant for this paper are briefly described as follows.

Recovery techniques (for more details, see Capparelli 1997; Capparelli and Raffino 1997; Capparelli et al. 2004, 2005)

A total of 861 l of sediment from 33 column samples (see grey points in Fig. 1) were processed by machine-assisted flotation. The machine utilized had a linen bag to collect light fraction, while a mesh size of approximately 1.5 mm was used to retain heavy fraction (see Capparelli and Raffino 1997).

Each of these column samples, from 20×20 cm, covered depths from 0 to 90 cm. They were taken from 23 of the main architecturally and functionally different structures of the site (one to four from each architectural structure

depending on the case) (see Fig. 1, grey points). Near a hundred of flotation samples ranged between 6 and 8 l of sediment were processed. In the laboratory, light and heavy floated fractions were sieved with a 2 and 0.4 mm meshes. Fractions >2 mm were sorted by eye, while those between 0.4 and 2 mm were fully sorted under a stereoscopic microscope. Material from screening and manual recovery during archaeological excavations was also examined.

Depending on the post-depositional accumulated sediment, the Inka floor at El Shincal extends at an average of 60–70 cm deep from the modern ground surface. However, we observed high densities of remains in a wider range, between 40 and 90 cm deep, which might be the effect of vertical migration of remains due to root intrusions of the dense modern vegetation cover. Therefore, layers of column samples in between 40 and 90 cm were considered for this paper, similarly to the methodology applied in a previous publication on El Shincal Inka economy (see Capparelli 2009). The Hispanic-aboriginal cultural event mentioned above was represented at El Shincal only in the *ushno* and the K1 northern sample, while in the rest of the samples just the Inka event was present. In the case of the *ushno*, both Hispanic-aboriginal and Inka event formed a palimpsest difficult to distinguish one from the other (see below). In the case of K1 northern sample, wood charcoal was the unique plant remains recovered, for what it was not considered in this paper. Less productive deposits were used as controls for evaluating the remains in features and richer deposits.

*General archaeobotanical results and the recognition of post-harvest practices from El Shincal specific *Prosopis* findings*

Including the wood charcoal, the absolute fragment count of archaeobotanical remains recovered at El Shincal was $n=13,116$. Excluding the wood charcoal, the absolute fragment count was $n=2,482$. The number of identified taxa was 24 (including seeds, fruit, parenchyma tissue, rhizomes, stems, taproots, but not wood charcoal). In general, the plant remains from ESH are well preserved, possibly due to their being protected by a post-depositional layer of sediment measuring 40–70 cm in depth.

One thousand eleven charred *Prosopis* macroremains were recovered from the Inka floor occupation (see Table 5), which were analysed in this paper in terms of the recognition of *Prosopis* post-harvest practices. These remains come from domestic floors and small charred lenses (S20E2, K1, *Aukaipata*), domestic hearths (Sinchiwasi, 5cIII, K3), as well as from ritual hearths (*ushno*). They consisted predominantly of seeds, but a small fraction of individual joints fragments and an even lower quantity of endocarps were also recovered (Table 5).

Table 5 *Prosopis* archaeobotanical macroremains recovered from each different structure at El Shincal (the few differences between these counts and those of previous publications, i.e. Capparelli et al. 2005 and Raffino et al. 2002, are due to an improvement in taxonomic identification)

Structure, type of context and level	<i>Prosopis</i> specimens recovered and food product inferred
K7 (Sinchiwasi, 5f), R10, central domestic hearth	Refined flour for <i>añapa</i> , <i>aloja</i> , <i>patay</i> and/or <i>ulpo</i>
Ue7	312 (fragmented and entire seeds) of which 169 entire seeds (97% WA, 3% BA)
K7, (Sinchiwasi, 5f) R2, central domestic hearth N5	1 seed fragment (albumen and cotyledon)
Total K7	313
5cIII, central domestic hearth	All the remains with the testa seed deteriorated
N5	7 seed fragments
N6	5 seed fragments
N7	2 seeds
N8	2 WA seeds, 1 BA seed and 5 seed fragments
Total 5cIII	22
Ushno, ritual hearth	<i>Añapa?</i> <i>Aloja??</i>
Ue4	1 entire seed <i>Prosopis chilensis</i> 1 entire seed <i>Prosopis</i> sp.
8	116 entire seed <i>P. chilensis</i> 55 entire seeds <i>Prosopis flexuosa</i> 46 entire seed <i>Prosopis</i> sp.
9/10	51 entire seed <i>P. chilensis</i> 12 entire seeds <i>P. flexuosa</i> 138 entire seed <i>Prosopis</i> sp.
11	2 entire seed <i>P. chilensis</i> 1 entire seed <i>Prosopis</i> sp.
12	9 entire seed <i>P. chilensis</i>
13	9 entire seed <i>Prosopis</i> sp.
17	13 entire seed <i>Prosopis</i> sp.
20	17 entire seed <i>Prosopis</i> sp.
22	6 entire seeds <i>P. flexuosa</i> 6 entire seed <i>Prosopis</i> sp.
C. v.	1 entire seeds <i>P. flexuosa</i>
s/ref	9 entire seed <i>P. chilensis</i> 8 entire seeds <i>P. flexuosa</i> 14 entire seed <i>Prosopis</i> sp. 6 endocarps <i>Prosopis</i> sp.
Total Ushno	521
K1, Floor and lens of charred remains	<i>Añapa/aloja</i>
N 4	8 seed fragments
N 5	18 seed fragments <i>Prosopis</i> sp. 2 seed fragments <i>P. chilensis</i>
N 6	11 seed fragments with rolled testa 1 seed <i>P. flexuosa</i> semejant ushno 1 endocarpo
N 7	3 <i>P. chilensis</i> seed fragments 1 <i>P. flexuosa</i> seed fragment 7 seed fragments <i>Prosopis</i> sp.

Table 5 (continued)

Structure, type of context and level	<i>Prosopis</i> specimens recovered and food product inferred
K1 patio, floor	
N6	6 seed fragment
Total K1	58
K3 (viv lado E), domestic hearth	Unrefined flour
N5	1 endocarp with traces of compact mesocarp (external fibrous and internal flourlike) and its corresponding seed
	1 fragment of endocarp tissues with their correspondent mesocarp and epicarp <i>P. flexuosa</i>
	3 fragments of endocarp of <i>P. flexuosa</i> 2 seed fragm <i>P. chilensis</i>
N6	2 little fragment of seed
K3 viv lado E Patio floor	1 little fragment of seed
N6	
Total K3	10
Aukaipata E floor & lens of charred remains	Unrefined flour
Ue3–Ue8	6 <i>P. chilensis</i> fragments of endocarp tissue with their correspondent mesocarp and epicarp covering the entire endocarp surface 3 similar fragments belong to <i>P. flexuosa</i> 1 seed of <i>P. chilensis</i>
Total Aukaipata	10
S20 EII, floor	Unrefined flour
N5	5 seed fragments
N6	1 fragment of <i>Prosopis</i> testa seed 4 seed fragments 1 fragment endocarp with mesocarp traces
N7	2 fragment of <i>Prosopis</i> seed
N8	4 fragment of <i>Prosopis</i> seed 1 individual joint of <i>P. flexuosa</i>
N9	1 fragment of <i>Prosopis</i> seed
Total S20 EII	19
ESH total	1,011 specimens

Ue stratigraphic Unit, N level, c/v corte de vaca unit, s/d sine data

Discussion: ESH remains interpreted on the basis of the experimental results

A distinctive pattern of *Prosopis* pod parts distribution was recognized at ESH through the analysis of the most diagnostic remains, which is interpreted to be associated with different post-harvest practices at different buildings, as follows.

Aukaipata, K3 and S20E2 are treated together because of similarities in *Prosopis* remains.

Aukaipata is a center of political, ceremonial and socio-economic Inka activities (Raffino 2004:261; D'Altroy

2003:241) and a space of communication between the different buildings of the site. The most diagnostic remains coming from the *aukaipata* floor context consisted predominantly of *P. chilensis* and *P. flexuosa* fragments of endocarp tissues with their correspondent mesocarp and epicarp, both covering the entire endocarp surface (Fig. 5a, b). Experimental analysis showed that these kinds of specimens are produced as a consequence of a post-charring fragmentation, in this case of individual joints.

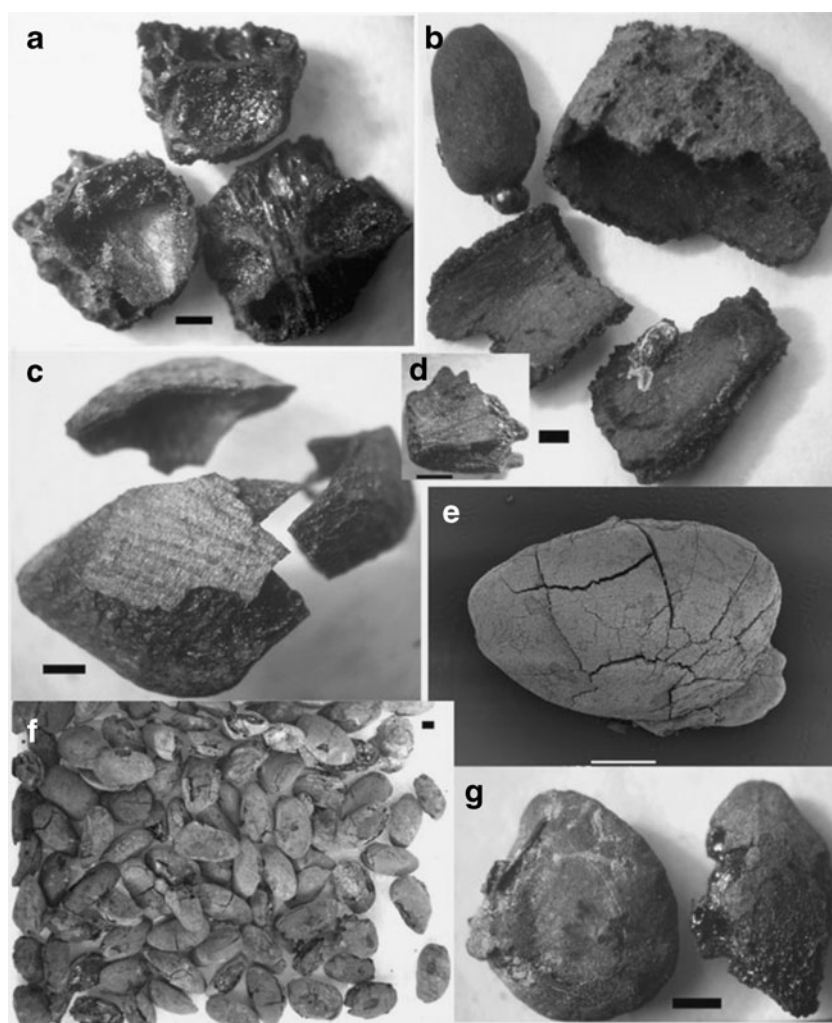
Kallanka K3. Kallankas were used for a number of different purposes by the Inkas: (1) for public feasts, (2) as multiple purpose areas and (3) as occasional lodgings for soldiers (Raffino et al. 2004a; D'Altroy 2003:241). From the domestic hearth in K3, remains consist mostly of endocarp tissues with their correspondent mesocarp and epicarp, like those recovered from the *aukaipata*, as well as endocarps with traces of mesocarp (Fig. 5c). This mesocarp does not present aspects of having been soaked before charring because the texture is compact. Other plant

remains found there include an endocarp of *Geoffroea decorticans* (chañar) and one maize kernel (see Capparelli et al. 2005).

S20E2 This place is part of a large storage area of the site. Endocarps with mesocarp traces (Fig. 5d) and individual joints of *P. flexuosa* were the most diagnostic *Prosopis* remains recovered here together with desiccated rhizomatous fragments of *Prosopanche americana*, which can be either ancient or recently intrusive.

These three structures are spatially close and share similar kinds of remains which permit us to infer the use of unrefined *Prosopis* flour. The kind of *Prosopis* assemblages at these places is similar to those assemblages coming from recent excavations carried out by Giovannetti (2009) on the sediment around two bedrock boulders which contains numerous mortar holes at El Shincal, the “Ruinas” and “EGP” complexes. The first one is placed near 5cIII buildings, while the second one is located on the cultivation

Fig. 5 *Prosopis* archaeobotanical remains from ESH: flour remains. **a** *Aukaipata*; **b** S20E2; **c–d** K3; **e–f** Sinchiwasi; **g** 5cIII. Scale=1 mm



field around the site. From these excavations several *Prosopis* pod fragments and endocarps with traces of mesocarp were recovered, in a proportion nearly to 1:1 with seed remains (Giovannetti 2009). Other associated plant remains were maize, beans and chañar, among others. Grinding produces a lot of pod parts which spills off the grinding surface during processing. For example, it was reported by Cáceres Freyre (1962) that in the use of the “cimbra” (a particular wood structure with a heavy stone used to grind *Prosopis* pods in the Pipanaco basin during the first half of the twentieth century, see Capparelli and Lema (2011) for more detail) it was necessary to have two people helping with putting the spilled parts of the pods back on the grinding surface. This habit can be also observed in modern maize grinding (see Fig. 7h in Capparelli and Lema 2011). The spilling out of the *Prosopis* unprocessed, or partly processed pod parts, during grinding is consistent with the high quantity of individual joints, still with edible mesocarp attached, near the grinding areas found by Giovannetti (2009). The used of El Shincal mortars for *Prosopis* grinding was confirmed also through the recovery of *Prosopis* starch grains from the grinding surface of one of the EGP individual mortar holes (Giovannetti et al. 2008). In sum, remains from the *aukaipata*, S20E2 and K3 are interpreted as specimens of unrefined flour that may had been accidentally charred while being transported from the storage to the further processing/consumption areas.

Sinchiwasi Rooms of the Sinchiwasi, such as room R10, include two terraces (“beds”) on opposite sides that are each separated from a central hearth area by a partition wall. They may have served as lodgings for labourers (Raffino et al. 2004b). On the opposite of what occurs at the previous structures analyzed, the Ue7 of the R10 central hearth presented a *Prosopis* assemblage constituted only by seeds. From this context 312 *Prosopis* seeds were recovered (Fig. 5e, f), together with 56 pieces of highly fragmented *G. decorticans* (chañar) endocarps and five small pieces of maize (grain and cob) (Capparelli 2009). From the 312 *Prosopis* specimens, 169 were entire seeds. 97% of them were preliminary identified as *Prosopis chilensis*, while only 3% were ascribable to *P. flexuosa*.³ The dominance of white *algarrobo* seeds in this assemblage may be due to the fact that this species releases almost all seeds during fine grinding, which does not occur with *P. flexuosa*. The testa of these seeds was normal; neither rolled nor folded (Fig. 5f). In most cases, the endosperm had burst out of the seed along the fissure line and/or the edges (Fig. 5e).

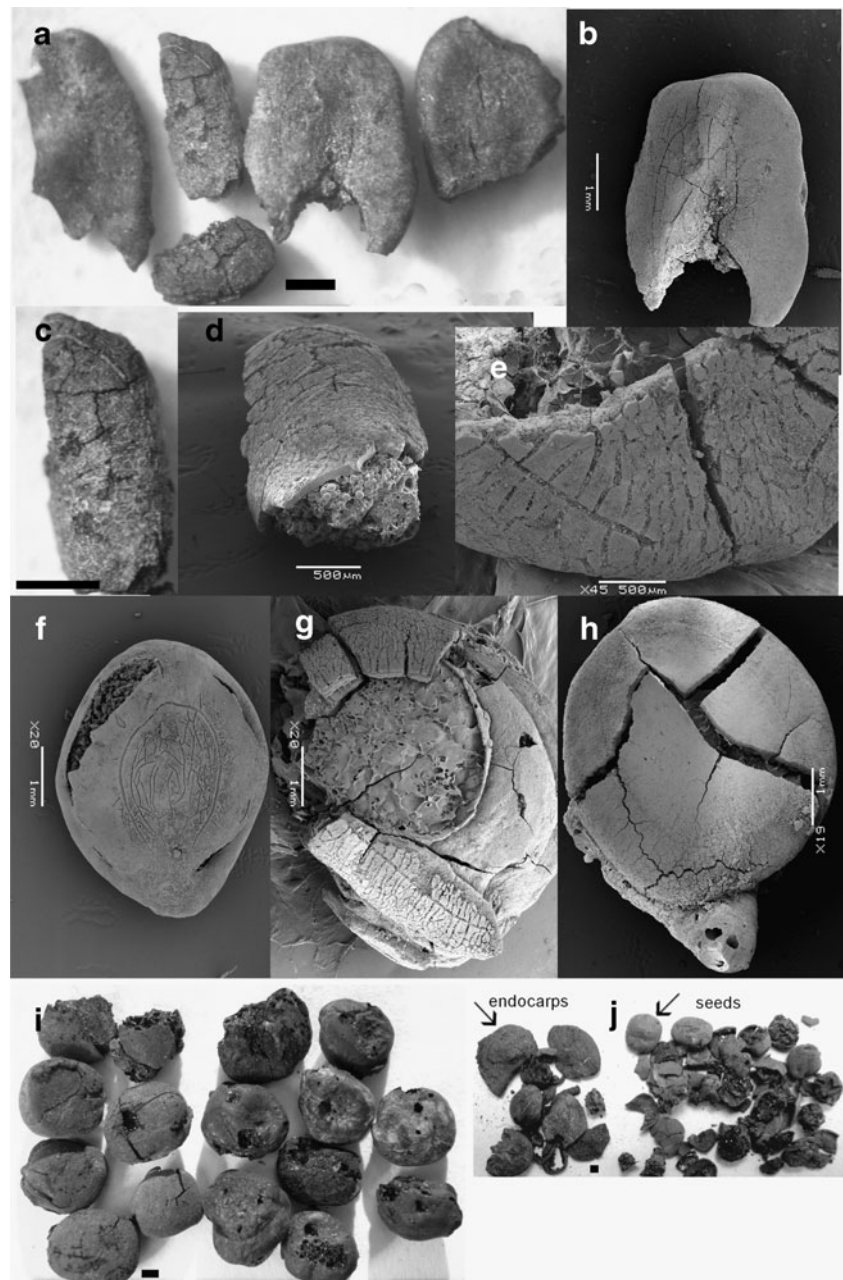
³ Identification is based on qualitative and quantitative features of seeds and endocarps of diagnostic value that authors are preparing for publication (Capparelli et al. In Prep.).

The large proportion of *P. chilensis* seeds with neither rolled nor folded testa, but with protrusions of endosperm along the fissure line, together with the absence of joints and endocarps with mesocarp–epicarp traces, permit us to interpret these remains as the result of preparing refined flour. This refined flour could have been used to prepare *aloja*, *patay* or *ulpo* (see Capparelli and Lema 2011). It is interesting to note that this architectural structure is interpreted as lodging guests/foreign labourers from the Chaco region (suggested by the ceramics present, Lema et al. 2009). Since Chaco is an area where *algarrobo* is even more abundant than in El Shincal, it is possible that these people had brought to the site knowledge on how to prepare various *Prosopis* foods.

5cIII From this room, only five *Prosopis* seeds of *P. chilensis* and *P. flexuosa* were recovered, together with some seed fragments. A diverse archaeobotanical sample was recovered from this feature. 5cIII appeared to have been a kitchen building, where mostly useful parts of cultivated species were found, together with ordinary ceramics, in a central hearth fired with shrub woods (Capparelli 2009). Surprisingly, *Prosopis* remains were very scarce here, with respect to cultivated plants such as maize (kernels), squash (seeds) and beans (cotyledons). Although it is clear that the emphasis was not put on *Prosopis* processing in this building, some activities involved this species. Because seeds are the only part present, we infer that refined *Prosopis* flour was used here. Seed testa in the 5cIII remains is much deteriorated, with other plant tissues sometimes stuck to the folded testa (Fig. 5g). Unfortunately, up to now we cannot recognize from these seeds diagnostic characters that identify the processes that were applied on them.

K1 The identification of this structure as a kallanka, a space for multiple activities, was confirmed in K1 by the variety of artifacts found here: mortars, clay, bone instruments, flints, instruments for spinning wool, *pucos* and globular bowls. Relatively high plant diversity was encountered here: *Prosopis* maize kernels and cobs, and cotyledons of beans, and *Solanum* seeds were recovered, among others (Capparelli et al. 2005). However, densities of botanical remains were very low. Several explanations were proposed for this low density of plant remains. Perhaps the floors of the rooms were frequently swept out, or there was only a low level of activities involving fire (see Capparelli 2009 for more detail). This is consistent with the fact that just small lens of charred remains were found here. *Prosopis* seed findings from K1 are the only ones that present characteristic of *añapa/aloja* residues (Fig. 6a). They are represented by folded pieces of testa separated from the seed (Fig. 6b), some of them rolled (Fig. 6c, d). The

Fig. 6 *Prosopis* archaeobotanical remains from ESH: *añapalaloja* residues. **a–d** K1; **e–j**, *ushno*. Scale in (**a**, **c**, **i** and **j**)=1 mm



manufacture of *añapalaloja* by cold water soaking (not involving fire) is thought to have been carried out here with refined flour already prepared in other places of the site. These results are consistent with early ethnohistorical written documents of the area, such as those about the moving of the city of San Juan de Vera del Valle de Londres (presumably Londres de Pomán, situated on the East of the Pipanaco basin) to the Catamarca valley, and dated between 1679 and 1681 AD (Charcas 23 R7 N71, Archivo General de Indias, Sevilla). This document describes the arboreal species of *Prosopis* in the Pipanaco basin and its intense utilization by aboriginal people. In one paragraph, the Spanish people say that the aborigines are

used to get drunk with strong drinks which they made from the *algarrobo* fruit, which is abundant in that region (“... otros vicios de embriaguez que lo ejercitan con brebajes fuertes que hacen de la algarroba que tienen en abundancia en aquella Jurisdicción...” (Capparelli 1997).

Comparisons between the archaeobotanical assemblage of K1 and those of K3 showed significant differences (Capparelli 2009). For example, samples from the K1 floor and lens contexts were composed of 38.4% of cultivated species and 27.5% of wild food remains (all *Prosopis* seeds). Samples from the K3 hearth context were composed of only 3.1% of cultivated plants and 72.1% of wild food plants. These differences were interpreted as indicative of

different sets of activities carried out in each of the two kallankas. More specifically, a greater emphasis on the processing of cultivated than wild resources, including maize kernel separation from the cobs, was proposed for K1; and an emphasis on the managing of wild resources was proposed for K3 (Capparelli 2009). However, as regards to the type of *Prosopis* post-harvest practices detected here, such as the manufacture of *añapa/aloja*, may lead to an underestimate of *Prosopis* use in this building. This is because of a low archaeological visibility of *añapa/aloja* remains due to non-use of fire, and also because tissues after the soaking stage are highly deteriorated. Also, the disposal of *Prosopis* residues could have involved feeding them to domestic animals.

Ushno The greatest quantities of *Prosopis* remains of ESH were recovered from the *ushno* context, together with, chañar, maize, beans, *Cucurbita*, among other native plants, as well as to European crops, such as wheat, barley, and peaches (see Capparelli et al. 2005; Raffino et al. 2004c). The assemblage was formed by several *Prosopis* seeds and a few closed endocarps (possibly of black *algarrobo*); epicarp or mesocarp pieces were absent. The major portion of the *ushno* seeds consists predominantly in seeds with split testa (Fig. 6e), with folded testa (Fig. 6f), and without testa (Fig. 6g, h). As we see from experimental analysis, the lost of the testa seed is common for *aloja/añapa* residues. In the *ushno*, also, seeds are larger than those of the other parts of the site (see Fig. 6h). It can be argued that these seeds are the result of the use of pods larger in size with respect to those of the Sinchiwasi, for example. But the few endocarps recovered showed standard endocarp sizes, taking into account an expected increase in size after soaking.

The high absolute counts and high densities of archaeobotanical remains that were recovered from the *ushno* may be the result of a persistent use of this ceremonial place during the Hispanic-Indigenous period (Capparelli et al. 2005). The richness of the archaeobotanical assemblage of the *ushno* may also be partly due to the fact that ritual contexts have greater preservation potential than domestic contexts for several reasons (Capparelli 2009), including: a diversity of burning activities; the selection of plant organs with unusual characteristics, (i.e. larger than the regular ones); as well as the high frequencies of plants deposited in the features as a result of repeated use and/or a deposition of high quantities of material during each activity. Another factor that may have promoted preservation is that the types of fires used in the rituals may have been more suitable for the charring and preservation of plant remains than other activities carried out at the site. In the case of *Prosopis* remains, the fact that they were purposely charred at the *ushno* ritual hearth and not accidentally charred (as in the

other domestic contexts) may explain the highest quantity of seeds recovered. *Añapa/aloja* residues commonly decanted from the jar where they were prepared could easily fall into the fire when the liquid fraction of the drink was offered.

The site as a whole

Unrefined flour was recognized from S20E2, Aukaipata, and K3 assemblages, while an advanced grade of *Prosopis* processing was observed in R10 of Sinchiwasi, K1, *ushno* and 5cIII. The characteristics of these *Prosopis* assemblages of macroremains at ESH suggest that edible *algarrobo* pods may have reached the site after a first stage of processing. As regards the archaeobotanical findings recovered around each excavated stone mortar of ESH (see Giovannetti 2009), as well as starch grains analysis of one of this mortars (Giovannetti et al. 2008), the grinding of *Prosopis* pods must have taken place at the grinding stones placed around the main buildings of the site. Pods could also have been ground on “cimbra” type mortars similar to those that were registered in use by Cáceres Freyre at the beginning of the twentieth century on the bottom of the Pipanaco basin (see Cáceres Freyre 1962; Capparelli and Lema 2011). Whether grinding was finished in the large stone mortars area around the site or inside some of the main buildings is still unknown.

Modern ethnobotanical data show that pods are dried on the “cañizos”, built on the fields that surround the residential area, and then are ground and stored in bags in storage rooms (see Capparelli and Lema 2011). In sum, structures similar to the “cañizos” might have been built at ESH on the field that surrounds the main construction of the site for drying up *Prosopis* pods, which might have been coarsely grinding on the mortars around the site previously to take them into the main buildings.

Prosopis vs maize

A gross numerical estimation of *Prosopis* processing is developed here. Although we recognize that this kind of quantitative comparison has biases, we consider that this estimation can give a better sense of the variables affecting *Prosopis* remains in archaeological representation.

The weight of *Prosopis* remains recovered at domestic contexts of El Shincal, which are thought to have been charred accidentally (the *ushno* was not taken in account because it might have implied purposive charring) was 4.57 g. Supposing arbitrarily that just the 1% of the total volume of residues produced are finally charred (this includes also differential resistance to charring of *Prosopis* pod parts), and supposing also that all the 4.57 g are residues (in fact, most of them are, because they are seeds),

the original quantity of residues prior charring would have been 457 g. If this value is multiplied by the loss of weight during carbonization (50% on average), the remains recovered would represent 914 g of *Prosopis* residues. We know by experimental analysis that entire recognizable seeds after refined flour production ranged around 12–20% (a median of 16% is used here) of the total original seeds from the pods (Capparelli 2008; Capparelli and Lema 2011). Therefore, these residues would represent a total of 5,712.5 g of residual seeds. Each seed weights an average of 0.04 g, and thus 142,812.5 seeds are represented by this quantity of residues. Each pod has an average of 17 seeds (Capparelli 2008), and then 8,400 pods would have been processed. Each pod weights in average 3 g, thus, at least 2,800 g of pods would have been processed at ESH. This quantity might represent, for several contexts, the result of just the last set of activities carried out by people on the site, if we take in account that activity floors and hearths may have been currently swept or cleaned, respectively.

From previous estimations of production of cultivated resources at El Shincal, made on the basis of the extrapolation from the subsistence requirements of one person using fallow and permanent agricultural systems, the cultivated surface of ESH (approximately 726 ha) could sustain from 1,613 to 2,792 people (Capparelli 1997:162). This is many more than the minimum of 586 inhabitants calculated by Raffino (2004:29) to have been living there.⁴ However, even when Inka people were able to produce enough cultivated food resources, such as maize, beans and squash (Capparelli 2009), *Prosopis* pods may have played an important role as food/drink products in the daily live of ESH inhabitants

These results are consistent with the use of *Prosopis* by other native North, Central and South American people, mentioned by Beresford-Jones (2005), who noted that *Prosopis* was very important to “incipient cultivators” in the Tehuacán Valley, Mexico, the south-western USA, the coast of Peru and the coast of Chile (see Beresford-Jones 2005 for a review of that evidence). He also maintained that even the agriculturalists of the Sonoran desert, “such as the Akimel O’odham and their predecessors the Hohokam, depended upon wild foods for up to 50% of their food supply. By far the most important of these were *Prosopis* beans...” Beresford-Jones et al. (2009:323).

Final considerations

The recognition of different *Prosopis* post-harvest practices at El Shincal represents an advance in the understanding of

Inka societies and its economy. Up to now, the importance of *algarrobo*’s food products to native South American people and to Spaniards living in these areas during the 16th to the 18th centuries was attested by historical records (see Cobo (1653) and Cieza de León (1553) in Beresford-Jones 2005:229; De las Casas in Yacovleff and Herrera 1934:291; and other records in D’Antoni and Solbrig 1977; Boixados, 2002; Quiroga 1999; Noli 1999). Results from El Shincal analyzed here, and from Huachichocana III (Capparelli and Lema 2011) are the first archaeological sites in which *Prosopis* findings were analyzed in order to recognize different post-harvest practices, and from where the manufacture of *Prosopis* flour and drinks by the Inka state can be confirmed.

In the Kollasuyu territory (the southern section of the Inka state, see Raffino 2004), *Prosopis* remains have been recovered from several sites. Surprisingly, all of them are from Argentina, and six out of seven come from the modern province of Catamarca where El Shincal is located. These Catamarca sites are Potrero-Chaquiago (Williams 1985), Punta de la Peña 3-La Tranca (Rodríguez pers. comm. Intihuatana de Fuerte Quemado (Kriskautzky and Morales 1999); Mishma 7 (Sempé de Gomez Llanes 1986); Batungasta (Ratto et al. 2007); and Los Colorados (Giovannetti 2009). The exception is Huachichocana III, located in the modern Jujuy province (Capparelli and Lema 2011). ESH provided one of the largest finds of *Prosopis* in Kollasuyu, by comparison to the sparse finds at other sites. Food/drink products prepared at ESH were diverse and took place at different buildings. This implies a special organization of *Prosopis* production, in the sense of a post-harvest intensification (sensu Wollstonecroft 2007). In Inka times, El Shincal played an important role in the exchange of goods between settlements in the region (Raffino 2004; Williams and D’Altroy 1998), and *Prosopis* may have been one of those exchanged resources. On the other hand, the sacred associations of the *Prosopis* tree are ancient in the Andes (see discussion in Beresford-Jones 2005:224) and *Prosopis* at ESH may have had also a special significance for the people living there, since the largest number of seeds recovered from the ritual hearth of the *ushno*.

As result of the homologous role of *Prosopis* to humans in various similar ecosystems (the Southwest USA, Peru, Chile, and elsewhere in Argentina), the experimental analyses presented in this paper might be useful for interpreting ancient *Prosopis* processing outside the Hualfín valley.

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⁴ Raffino based his estimation on the relationship of one inhabitant per 3 m² of the area corresponding to the buildings potentially roofed

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