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ORIGINAL PAPER

Recognition of post-harvest processing of algarrobo (*Prosopis* spp.) as food from two sites of Northwestern Argentina: an ethnobotanical and experimental approach for desiccated macroremains

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Abstract Ethnobotanical and experimental approaches were used to: (a) analyse modern *Prosopis* (algarrobo) food production at the Hualfin valley (Catamarca Province, Argentina) in order to establish food production and processing patterns; and (b) characterise the qualitative and quantitative morphological attributes of the food products and residues that may reach the archaeological record as macrobotanical remains. These approaches were applied to the study of archaeobotanical remains from two archaeological sites from the Argentinean Northwest (Huachichocana and Puente del Diablo). It was concluded that the analysis of *Prosopis* macrobotanical remains potentially allows the identification of intermediate and final products, by-products and residues of different food/drink preparations. Patay (bread) is the only final product that can be confirmed, but only if the bread itself is recovered. The other algarrobo preparations are jam and beverages and therefore do not leave records. The proportions of fragmented seeds, seeds with fissured testas and endocarps may indicate the production of unrefined and refined flour. Añapa (beverage) and aloja (alcoholic beverage) residues are characterised mainly by a rolling or folding of the epicarp or testa (also by the loosening of the testa). Aloja can be distinguished from añapa only if certain processes, such as the use of hot water and the chewing of the pods, were used, which produced diagnostic characteristics such as thick black patinas on endocarps or heavily twisted fine threads of epicarp fibres. Arrope (syrup) residues are identified by the presence of closed endocarps with thin black patinas and twisted ribbons of epicarp. Flour- and aloja-making were recognised from Huachichocana III contexts and añapa and flour production at Puente del Diablo.

Keywords Archaeobotany · Northwestern Argentina · Algarrobo · *Prosopis* · Food products

Introduction

The genus *Prosopis* (Family: Fabaceae), together with the genus *Acacia*, dominates a large part of the arid or semi-arid earth's surface (Beresford-Jones 2005: 45). Its 44 taxonomically recognised species (Burkart 1940, 1952, 1976)[1] are distributed along southwest Asia, north and tropical Africa (four species) and in America, where they occur from the southwest USA to Patagonia (40 species). Most *Prosopis* species are crucial within their ecosystems, linking and integrating abiotic and biotic constituents, including human inhabitants (Beresford-Jones 2005: 45). People have exploited *Prosopis* spp. shrub and tree species, wherever they occur naturally, for many purposes including food, medicine, timber, fuel, tannery, fodder and dyes. Frequently, different parts of a same plant are exploited for a variety of economic uses (Simpson et al. 1977; Beresford-Jones 2005; Capparelli 2007).

The fruit of *Prosopis* is an indehiscent drupaceous legume (pod), which has a more or less thick epicarp, a pulpy, sweet mesocarp and a more or less hard endocarp

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[1] *Prosopis* taxonomy is currently being revised (see discussion in Beresford 2005). However, as this revision does yet not include Argentinian species, the Burkart (1940, 1952, 1976) taxonomy will be still used in this paper.

commonly segmented into one-seeded joints. The mesocarp is typically enjoyed as food. Pods of *Prosopis cineraria* are eaten in India (Arya, in Harris et al. 1998) and those of *Prosopis africana* in Africa (Sanni et al. 1993), but the more abundant information about contemporary food uses comes from the New World, where several species are exploited, for example: *Prosopis glandulosa*, *Prosopis velutina*, *Prosopis laevigata* and *Prosopis juliflora* are used in México and SW of USA (Burkart, 1976; Felger, 1977, among others); *Prosopis chilensis* and *Prosopis pallida* in Chile, Peru, Bolivia and Paraguay (Latcham 1936; Felker 1979; Beresford-Jones 2005; Horkheimer 2004, among others); *Prosopis alba*, *Prosopis nigra*, *Prosopis flexuosa*, *P. chilensis*, *Prosopis ruscifolia*, *Prosopis vinalillo*, *Prosopis elata*, *Prosopis torquata*, *Prosopis hassleri* and *Prosopis ferox* in Argentina (see compilation in Capparelli 2008).

The use of *Prosopis* as a food resource is ancient, although evidence of the use of the pods of *Prosopis* is scarce in the Old World. Seeds dated at 11,500 years BP were recovered from the Epipalaeolithic Near Eastern site pf Tell Abu Hureyra (Moore et al. 2000) and the recently residues of *Prosopis* sugars were identified on a basalt pestle recovered from Natufian contexts at Hayonim Cave in the southern Levant (McLaren and Capparelli 2004). In contrast, in the New World, evidence for ancient uses of *Prosopis* pods includes both the historical and archaeobotanical records. Historic documents attest to the importance of *Prosopis*' forests for native people living in North, Central and South America during the sixteenth to the eighteenth centuries and also for Spanish explorers who were saved from starvation by eating *Prosopis* pods (see examples in D'Antoni and Solbrig 1977: 190; Bell and Castetter in Felger, 1977; Beresford-Jones 2005: 195; Giovannetti et al. 2008, among others). Archaeobotanical findings include two types of evidence. First, there is evidence for the effective ingestion of the pods in the form of pod tissues recovered from the gut contents of five Chilean mummies dated from 1400 to 2500 years BP (Holden and Núñez 1993), and from human coprolites found in the Middle Horizon Period (1250–1050 BP) sites of the Ica Valley of Perú (Beresford-Jones 2005: 405, Beresford-Jones et al. 2009). Second, a vast number of macrobotanical remains, representing different parts of the pod, have been recovered from excavations in the southwestern USA, Mexico, Peru, Chile and Argentina (see compilations in D'Antoni and Solbrig 1977; Holden and Núñez 1993; Beresford-Jones 2005; Giovannetti et al. 2008, among others).[2] In Argentina, ancient use of *Prosopis* is indicated by the frequent presence of numerous desiccated or charred macroremains, mainly in the form of entire or fragmented pods, endocarps and seeds, which represent a time span of approx. 10,000 years. These have been recovered from domestic contexts such as hearths, residential structures and/or rubbish heaps, as well as in ceremonial contexts such as tombs and ritual hearths.

The aim of this paper was to explore the likely cultural significance of *Prosopis* in the Argentinian Northwest, by examining the prehistory and history of its human uses, from the earliest hunter-gatherer occupants of the area to the more recent agricultural societies such as the Inka. To achieve this aim, it is necessary to first establish archaeobotanical criteria for the indentificaton of the different uses of this important genus, which are explained below. *Prosopis* macroremains (pods and seeds) are particularly difficult to interpret beyond simple recognition because their processing is complex and frequently involves the preparation of the fruit into several different products and by-products, e.g. flour, breads, drinks and jellies. 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), which, in the tradition of middle range theory, aims to interpret "dynamic" activities from "static" archaeological finds (e.g. Binford 1981; Schiffer 1972, 1976). In the present paper, ethnobotanical and experimental approaches are applied to identify diagnostic macromorphological attributes of the different *Prosopis* products, by-products and residues. The results of these studies are subsequently employed to identify post-harvest practices (in the sense of Capparelli et al., 2010) from *Prosopis* desiccated macroremains recovered in two archaeological sites of the NW of Argentina: Puente del Diablo (Fig. 1a, b) and Huachichocana III[3] (Fig. 1a, c–d).

Despite the fact that *Prosopis* remains are usually recovered from archaeological sites in the Argentinean northwest, they are relatively scarce in early Holocene sites from this region. This is surprising because these early sites are typically situated in dry areas with good preservation of plant remains. Puente del Diablo and Huachichocana III are both early occupation cave sites with exceptional preservation of desiccated *Prosopis* remains. Both sites, which were recovered during excavations in the 1970s, are situated in ravines of the Prepuna Phytogeografical Province (Fig. 1a) that connects the Puna/Altoandina regions. Mean annual precipitation is less than 100 mm here due to influences of the more xeric and warmer ecological areas of Monte/Yungas Provinces (Fig. 1a).

The study of these sites is important because they have special relevance for the understanding of the origins of

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[2] A few starch grains have also been recovered from Argentinian mortars (see Giovannetti el al 2008)

[3] (Capparelli, this volume, pages...) discusses *Prosopis* post-harvest practices from charred remains of El Shincal Inka site (Hualfín valley, Argentina) are analysed.

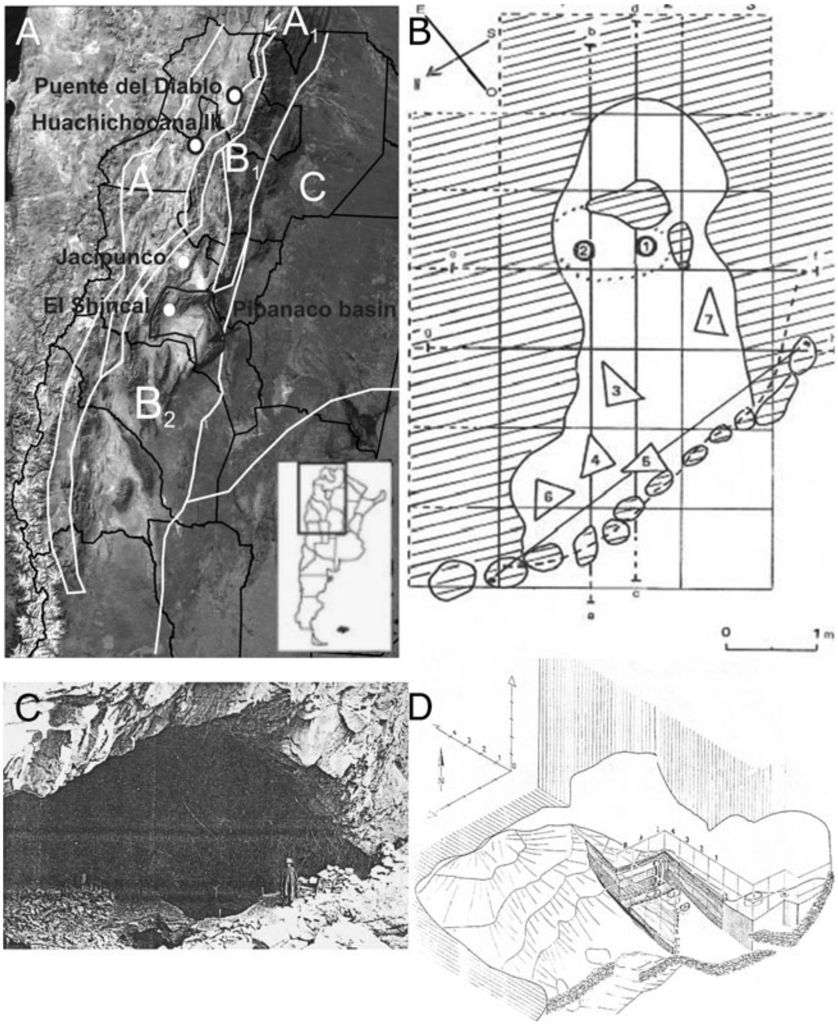


Fig. 1 Ethno- and archaeobotanical research sites. **a** Satellite view of the NW Argentina and the location of the Hualfín valley, Huachichocana III and Puente del Diablo archaeological sites. Phytogeographical provinces: *A* Puna: A_1 Prepuna, B_1 Yungas, B_2 Monte, *C* Chaco. (modified from Capparelli et al. 2005) **b** Puente del Diablo cave, superficial view (taken from MD Arena fieldbook in Lema 2009). **c**–**d** Huachichocana III cave (taken from Fernández Distel 1986). **c** External view. **d** Superficial view

agriculture in NW Argentina and have the potential to provide evidence for local processes of plant domestication (Lema 2009). Huachichocana III was occupied from 10,550–10,150 BP (uncal.) up to the European conquest (Fernandez Distel 1986); Puente del Diablo is a smaller cave with human occupation spanning 10.000 BP (uncal.) to the early Formative (2450–1450 BP approx). Although there is not a clear stratigraphical sequence of occupation, chronological differences at the latter site appear to be spatially distinct, i.e., occurring within different areas within the cave (Lema 2009). Both sites have funerary and domestic occupations. Puente del Diablo is characterised by the presence of different activity areas including lithic workshops, hearths and areas of processing, butchering and the consumption of animals, mainly rodents and camelids (Lema 2009). No excavations were made outside the caves. These rock shelters appear to have been used by highly mobile groups as they moved between different ecological areas, being occupied at different times of the year for residential, occasional refuge and funerary purposes. An initial analysis of both sites indicates an unusual high diversity of desiccated *Prosopis* plant parts (seeds, endocarps and epicarp). The heterogeneity of the plant assemblages in combination with the diversity of archaeological contexts, suggests that a range of plant processing techniques and patterns of consumption are represented. Because *Prosopis* pods can be consumed raw, without heat or other treatment, we regarded this evidence for *Prosopis* processing as significant because it may be indicative of post-harvest intensification, i.e., technological and ecological advances and parallel shifts in the subsistence and social system (Wollstonecroft 2007). In addition, the presence of archaeological contexts of different chronological periods offered a unique opportunity to investigate temporal trends in post-harvest routines. We recognised that, in order to accurately interpret archaeobotanical remains of Huachichocana and Puente del Diablo, we needed to carry out actualist studies of *Prosopis* processing,

Thus, we embarked on an ethnobotanical and experimental study on the nearby Hualfín valley, Catamarca province (Fig 1a), because there is no evidence for modern *Prosopis* food use in the Puna and Prepuna. Two *Prosopis* species were studied—*P. chilensis* and *P. flexuosa*—which are locally known as white (WA) and black (BA) "algarrobo", respectively. In Spanish-speaking countries, algarrobo is the most widely used common name for trees of the Algarobia group (Burkart 1976: 500), being the "algarroba" its respective fruit (Fig. 2). Similar to the "mesquite" denomination for *P. juliflora*, *P. laevigata*, *P. glandulosa*, among others, algarrobo is a collective term for *P. chilensis*, *P. alba*, *P. nigra*, *P. denudans*, *P. pallida* and *P. flexuosa* (FAO, 2007, Website).

Archaeological case studies and archaeobotanical remains

Materials and methods

The Huachichocana III and Puente del Diablo caves were excavated 30 years ago, and therefore, the archaeobotanical remains were recovered by hand-picking rather than the systematic sampling and flotation techniques that are now more commonly used. Therefore, the materials studied in this paper are from archaeological collections held in the *Instituto Interdisciplinario Tilcara* (Jujuy Province) and at the *Museo Arqueológico de Cachi* (Salta Province), for Huachichocana III and Puente del Diablo, respectively. They were previously identified as *P. nigra* (BA) and *P. alba* (WA) by botanists (see Fernández Distel 1986; Tarragó 1980). These identifications were revised for the present paper, and the algarrobo remains were counted and discriminated by type of organs present, as well as by their qualitative features.

With respect to preservation and taphonomic controls, arid regions of Northwestern Argentina, such as those of Puna/Prepuna, have provided most of the desiccated archaeological remains recovered up to now. Working with dry remains always needs a very careful evaluation of archaeological context and taphonomical issues. In the case of *Prosopis*, nearly one third of all the Argentinean *Prosopis* finds (see review in Giovannetti et al. 2008) are desiccated (e.g. those from León Huasi I, Huachichocana III, Inca Cueva, Puente del Diablo and Pampa Grande, among other sites). In such cases, which are common in archaeological sites in the Argentinean Northwest, the presence of *Prosopis* is usually regarded as the result of natural, rather than cultural, processes, e.g. animals such as rodents. Therefore, the qualitative features of algarrobo remains are examined during excavation to observe any features that indicate non-human uses, e.g. gnawing marks on *Prosopis* endocarps.

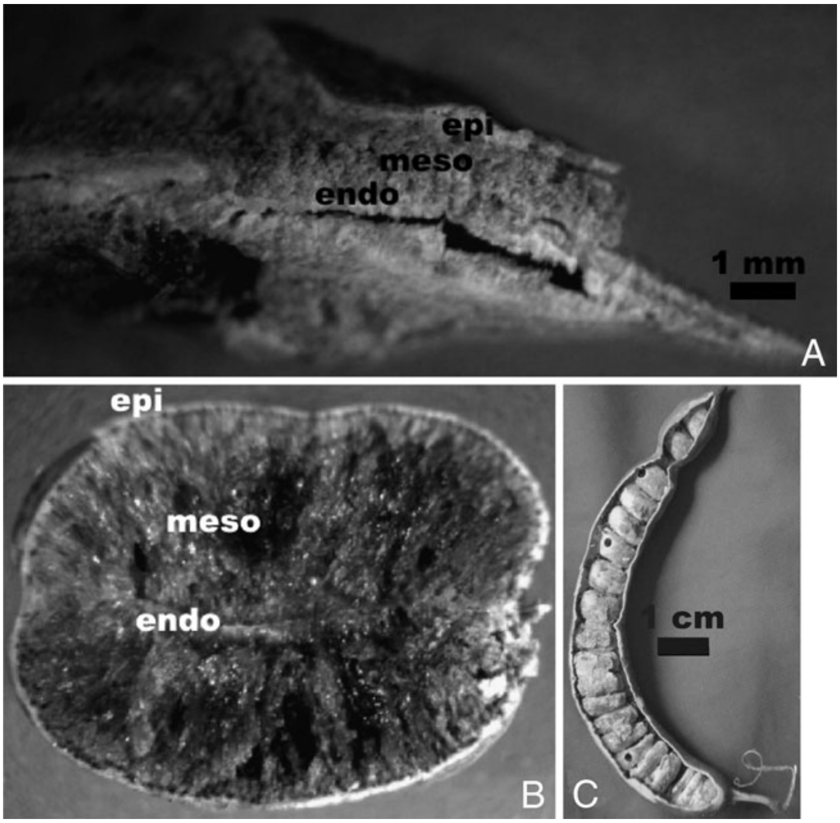


Fig. 2 Main parts of *P. chilensis* and *P. flexuosa* fruit. **a** *P. chilensis* transverse section. **b** *P. flexuosa* transverse section. **c** *P. flexuosa*, view of the endocarps in the pod (modified from Capparelli 2008)

Results

Prosopis remains from the sites are detailed in tables (Tables 1 and 2). Previous taxonomic identification was, in some cases, confirmed and in others, modified, and some specimens were recognised as hybrids (Tables 1 and 2, column 2). Although most of these sites were excavated during the 1970s, the relative abundance and frequency of *Prosopis* within archaeological contexts are difficult to estimate because samples were not systematically collected.

Table 1 *Prosopis* archaeological finds at Huachichocana

Filiations and chronology	Level and context	Taxa	Absolute number	Endocarps with gnawed marks	Qualitative features	Inferred processing and algarrobo derivate
Archaic 3800-2450 BP 3400+/-130 BP uncal.[a]	E2 layer Domestic–funerary hearth	WA	3 Halves endocarps	–	Small epicarp fragments stuck to endocarps in a disorganised way. Slight black patina	Cold? Hot? Water soaking of mixed fine and coarse flour fractions. *Añapa* or/and *aloja*
	E2 layer funerary context	WA	1 Entire endocarp	1	Fissure	–
		Possible hybrid form	1 Entire endocarp			
Formative 2500-1450 BP 1420+/-190 uncal.[a]	E1 layer Sine data	WA	2 Entire and one half seeds 1 Entire endocarp	–	Small epicarp fragments stuck to endocarps randomly. Slight black patina	Cold? Hot? Water soaking of mixed fine and coarse flour fractions. *Añapa* or/and *aloja*
Late period 950-550 BP	D layer domestic context	Possible hybrid form	1 Half endocarp	–	Small epicarp fragments stuck o endocarps randomly. Black patina	Only *aloja* (made from fine and coarse flour fractions and chewed pods) or *aloja*/*añapa*
Inka period 475-414 BP	C layer funerary context (domestic Argentinian lesser grison burial)	*Prosopis* sp.	Epicarp	4	Fine epicarp threads densely interlaced	Chewed pods residues. *Aloja*
		WA	20 Entire endocarps		Endocarps: dark patina, small epicarp fragments stuck to endocarps randomly. Open endocarps without seeds. Epicarp: fine epicarp threads densely interlaced. Epicarp threads with one endocarp attached	Only *aloja* (made from fine and coarse flour fractions and chewed pods) or *aloja*/*añapa* (Fig. 4a)
		WA/BA	7 Entire endocarps Epicarp		-	-
	C layer domestic context	WA	4 Endocarps joined by mesocarp and epicarp remains. 2 pod fragments.	10	Epicarp folded and rolled	Hot water processing: *aloja*? (Fig. 4b)
		BA	74 Entire endocarps 6 entire endocarps		Fissures/fractures. Broken endocarps. Several endocarps together in pairs. Very little patches of mesocarp. Small epicarp fragments stuck to endocarps randomly. Dark patina and thick dark patina	Grinding. Processing with cold/hot water; only *aloja* or *aloja* and *añapa* (Fig. 4c)
	C2 layer domestic context	WA	1 Entire endocarp	1		–
		BA	1 Entire endocarp		Fissure	
Hispanic-Aboriginal period post-1536 AD	B layer Sine data	WA	7 Entire endocarps (2 attached by remaining mesocarp)	–	Abundant traces of mesocarp, small epicarp fragments stuck to endocarps randomly	Hot water processing. Only *aloja* (made from fine and coarse flour fractions) or *aloja*/*añapa*
Sine data	Sine data	WA	2 Entire endocarps	–	Both endocarps with a thick dark patina. 1 open endocarp without seed.	Hot water processing. *Aloja* made from fine and coarse flour fractions. (Fig. 4d)

Absolute number, morphological characteristics and diagnostic features to infer different food processing and algarrobo derivates

[a] Radiocarbon date

Table 2 *Prosopis* archaeological findings of Puente del Diablo site, absolute number, morphological characteristics and qualitative features to infer different food processing and algarrobo derivates

Filiations and chronology	Level and context	Taxa	Absolute number	Endocarps with gnawed marks	Qualitative features	Inferred processing and algarrobo derivate
Probably early formative (2450-1450 BP)	Square E1 level 2 (10-20 cm) associated to human remains	Possible hybrid forms	25 Entire endocarps	6	Fracture, fracture+fissures	Grinding. Soaking in cold water. Flour and *añapa*
		BA	8 Entire endocarps		Epicarp traces attached directly to the endocarp surface and rolled	
Probably early formative (2450-1450 BP)	Square E1 level 3 (20–30 cm); no data	BA	7 Entire endocarps	2	Fractures	–
Early formative (2450–1450 BP)	Square E2 level 1 (0-10 cm) occupational context	BA	19 Entire endocarps	3	Fractures, fissures, epicarp traces attached directly to the endocarp surface	Grinding flour
		WA?	2 Entire endocarps			
Early formative (2450–1450 BP)	Square E2 level 2 (10-20 cm) associated with human remains	Possible hybrid forms	8 Entire endocarps	1	Fractures	Grinding flour (Fig 4e)
		BA	20 Entire endocarps		Fissures, fractures, fissures+fractures, epicarp traces attached directly to t he endocarp surface	
Early formative (2450–1450 BP)	Square E2 level 3 (20-30 cm) occupational context	BA	1 Entire endocarp	–	Fracture	–
Early formative (2450–1450 BP)	Square E2 level 4 (30-40 cm) occupational context	Indet.	2 Entire	–	Open endocarps without seeds	Grinding flour
Probably early formative (2450–1450 BP.)	Square E3 level 1 (0–10 cm) no data	BA	1 Entire endocarp	–	–	–
Sine data	No data	WA	1 Half endocarp	1	Epicarp traces attached directly to the endocarp surface	Grinding flour
		BA	3 Entire and 2 halves endocarps		Fractures, epicarp traces attached directly to the endocarp surface	
Probably early formative (2450-1450 BP)	Square C3 level 1 (0-10 cm); no data	Indet.	10 Entire endocarps	–	Fracture, entire epicarp or traces attached directly to the endocarp surface	Grinding flour
Sine data	Square C3 level 3 (20-30 cm) occupational context	Indet.	2 Entire and 1 halves endocarps	–	Fracture	–
10.000 BP (uncal.)[a]	Square C3 level 7 (60-70 cm) associated with human remains	Indet.	2 Entire	–	Open endocarps without seeds.	Grinding flour
Probably early formative (2450-1450 BP)	Sector B2/B3/C3 level 2 (10-20 cm) no data	Indet.	1 Entire endocarp	–	–	–
Probably early	Square B3 level 1 (0-10 cm)	Possible hybrid	7 Entire and 2 halves	3	Fractures	Grinding. Soaking in cold water. Flour and *añapa*

Table 2 (continued)

Filiations and chronology	Level and context	Taxa	Absolute number	Endocarps with gnawed marks	Qualitative features	Inferred processing and algarrobo derivate
formative (2450-1450 BP.)	possible occupational context	forms	endocarps			
		BA	8 Entire endocarps		Fractures, in a terminal endocarp epicarp traces attached directly to the endocarp surface, fissures and epicarp patches still attached to surface	
Probably early formative (2450-1450 BP)	Square B3 level 2 (10-20 cm) occupational context	BA	7 Entire endocarps	3	Fractures, epicarp traces attached directly to the endocarp surface	Grinding flour
Sine data	Square B3 level 3 (20-30 cm) occupational context	Possible hybrid forms	7 Entire endocarps	2	Fractures	–
		BA	4 Entire endocarps, 2 attached between one another			
Archaic 3800-2450 BP	Squares B1 – B2 associated with a mummified body	Possible hybrid forms	7 Entire and 2 halves endocarps	1	Fractures	Grinding. Soaking in cold water. Flour and *añapa*
		BA	6 Entire endocarps		Terminal endocarp with epicarp attached, epicarp traces attached directly to the endocarp surface and rolled, mesocarp and epicarp remains.	
Probably early formative (2450–1450 BP)	Square A2 level 1 (0-10 cm) possible occupational context	BA	35 Entire endocarps	10	Dark patina, epicarp attached to endocarp fissures, fissures and dark patina; epicarp patches attached directly to the endocarp surface sometimes rolled and with dark patina, fractures.	Grinding (Fig. 4f) Cold? Hot? Water soaking of a mixture of fine and coarse flour fractions. Flour. *Añapa* or/and *aloja* (Fig. 4h)
		Possible hybrid forms	9 Entire and 3 halves endocarps		Fracture, epicarp traces attached directly to the endocarp surface, sometimes rolled	
		WA?	1 Half endocarp		–	
Probably early formative (2450–1450 BP)	Square A2 level 2 (10-20 cm) occupational context	BA	10 Entire endocarps	2	Epicarp traces attached to surface and rolled	Grinding flour and *añapa* (Fig. 4g)
		Possible hybrid forms	10 Entire and one halve endocarps		Fractures, epicarp traces attached directly to the endocarp surface and rolled	
Probably early formative (2450–1450 BP)	Square A3 level 1 (0–10 cm) no data	Possible hybrid forms	5 Entire endocarps	2	Fractures	Grinding Cold? Hot? Water soaking of a mixture of fine and coarse flour fractions. Flour. *Añapa* or/and *aloja* (Fig. 4i)
		WA	3 Entire endocarps		Fractured with dark patina	
		BA	9 Entire endocarps		Fissures, fissures and dark patina, epicarp traces attached directly to the endocarp surface, one of them with dark patina, terminal endocarp with epicarp attached	
Sine data	Square A3 level 3 (20-30 cm) occupational context	BA	2 Entire endocarps	1	–	–
Sine data	Square A3 level 4 (30–40 cm) no data	BA	1 Entire endocarp	1	–	–

[a] Radiocarbon date

Nevertheless, the quantity of *Prosopis* remains is notably high in the analysed sites (Table 1 and 2, column 4) given the antiquity of these cave contexts as well as the typically low frequencies of plant macroremains that are typically recovered from sites in the north western Argentina, even when techniques such as flotation and fine-sieving are applied. Taphonomic controls included examination of the *Prosopis* endocarps to observe potential non-human animal uses (e.g. gnaw marks; Fig. 3, Tables 1 and 2, column 5) and the presence of endocarps without mesocarp or epicarp (exocarp) remains. Identified organs were mostly endocarps, but seeds and epicarp remains are also present. Qualitative features of these structures were described and analysed including their taxonomic classification and archaeological provenance (Fig. 4; Tables 1 and 2, column 6). In the section below, we explain our ethnobotanical and experimental methods, in detail, how post-harvest practices were inferred from the *Prosopis* remains.

Ethnobotanical approach

Study area

Although *Prosopis* consumption has declined, such that it is rare among urban people today, in rural communities of Argentina, its consumption as food and drinks persists. This is the case in the Hualfín valley (Monte Phytogeographical Province, Catamarca), presented in this paper, which served as the base for the experimental approach. The ethnobotanical samples were collected along a 50-km tract from the locality of Jacipunco (27º 14’ 0”S, 67º 0’ 8” W) in the north to El Shincal (27º 41’ 14”S, 67º10’ 31”W) in the south (Fig. 2a). The locality of El Shincal, where the Inka site of the same name is located, extends over the NW sector of the Pipanaco basin. It has been ecologically and floristically studied by Capparelli (1997). Ecosystem of this area is similar to that of the NE sector of the basin where the same *Prosopis* species discussed in this paper are found. The latter were described by Simpson and Solbrig (1977) and Orion and Solbrig (1977). These authors established a clear analogy between this ecosystem and that of the Silver Bell, Arizona, USA where *P. velutina* dominates. They recognised parallel adaptations, which indicate convergent evolution of both ecosystems involving organisms associated with *Prosopis*. Similarly, Beresford-Jones (2005: 177), in his PhD thesis, established a limited analogy between the ethnobotany of the Sonoran desert and the south coast of Peru, justified by biological and ecological similarities of both areas. From these studies, it is clear that, in the south west of north America, the south coast of Peru and the southern extreme of the Hualfin valley, similar *Prosopis*–people relationships developed, a fact that may be of interest of researchers in one or other of these regions.

Materials and methods

Analysis of modern *Prosopis* food production was based on ethnobotanical studies carried out since 1992 by one of the authors (AC) in the Hualfín Valley between the localities of Jacipunco and El Shincal, Catamarca Province, Argentina (Fig. 1a; see also Capparelli 2007, 2008). At present, the economic base of the Hualfin Valley is commercial farming, growing European as well as South American crops and livestock. Nevertheless, farmers retain many of their aboriginal traditions, including the collection of a wide range of native wild plants for food, medicinal resources, dyes, textiles, fuel and woodworking activities. A general view of the main activity areas of a domestic unit (DU) can be seen in Fig. 5. Eight villages located along the Hualfín valley were sampled: Cerro Negro, El Shincal, Puesto Zapata, Londres de Quimivil, Quillay (La Ciénaga), Hualfín, Jacipunco and Corral Quemado. Open and semi-structured interviews were conducted with randomly ($n=43$) selected Hualfin valley inhabitants; each interviewee represented one DU. Interviews were complemented by direct and participant observation.

Two native *Prosopis* species are of importance as food in this area: *P. flexuosa* and *P. chilensis*. Type specimens of both species were deposited in the Herbarium of the

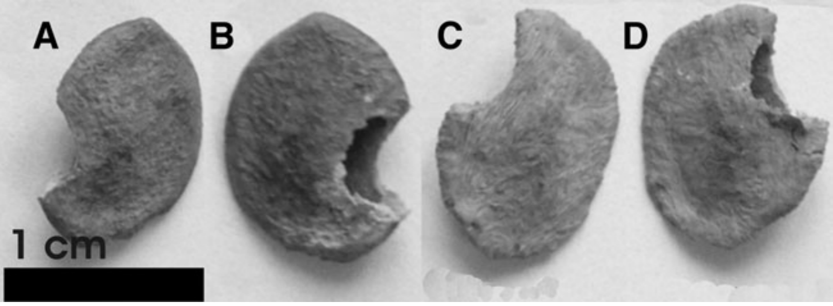


Fig. 3 Marks ascribable to rodent activity on black algarroba archaeological endocarps from Puente del Diablo. **a**, **b** Context S2 2-207. **a** Face. **b** Reverse. **c**, **d** Context S3 2-221. **c** Face. **d** Reverse

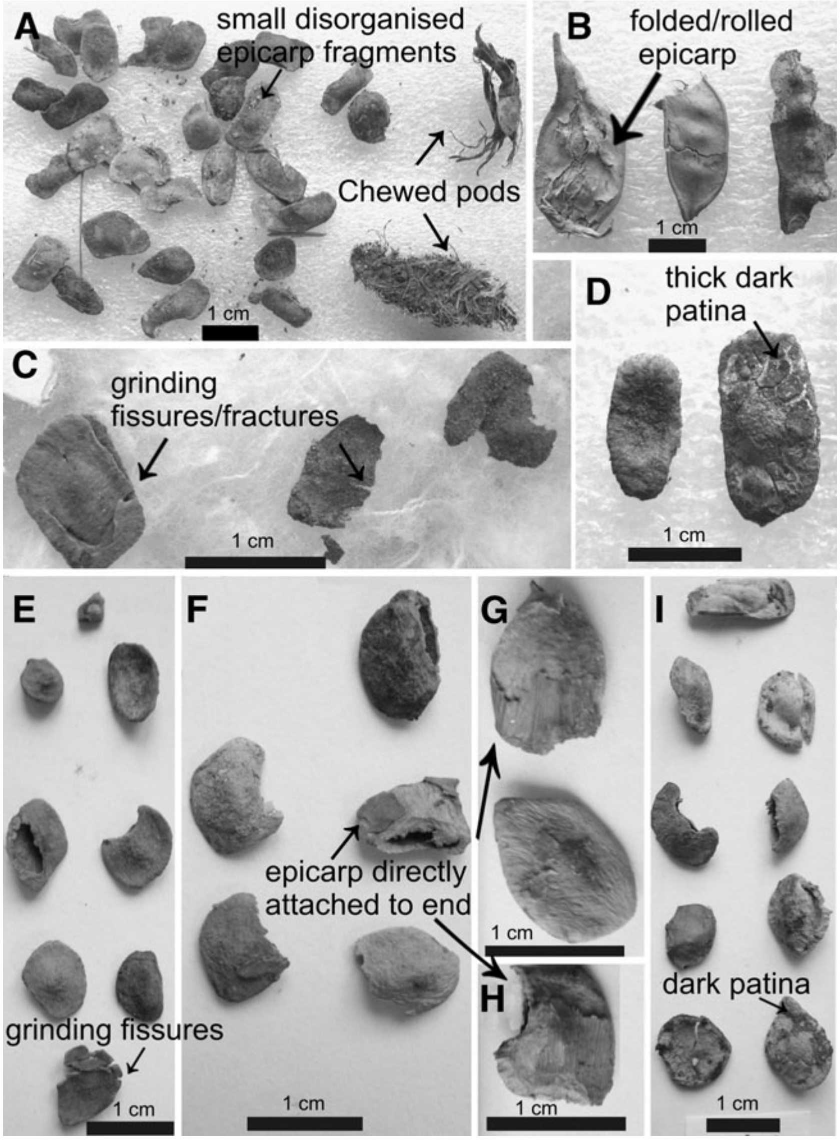


Fig. 4 *Prosopis* archaeological finds. **a–d** From Huachichocana III. **e–i**. From Puente del Diablo (see description of contexts in Table 2 and 3). Abbreviations: *end* endocarp

Department of Vascular Plants of the La Plata Museum [LP], as Capparelli 7 [LP] and Capparelli 6 [LP], respectively.

Results

The algarroba selection The Hualfin population distinguishes distinct flavours among the different algarroba trees, saying they generally prefer pods from trees with the sweetest fruits. In the lower altitudes of the Hualfin Valley b, where both *P. flexuosa* and *P. chilensis* are found, the white algarroba (Fig. 6a) is preferred over the black because it is sweeter. People say that the black pods (Fig. 6b) taste stronger (“fuerte”) or rougher (“áspera”), differences that can be attributed to their higher tannin content (Capparelli 2007). Where only black algarroba is available, as for example in the upper valley, pods are gathered and separated into classes based on the degree of darkness (Fig. 6c), the clearer being the most acceptable for food processing. People distinguish the species by their distinct characteristics, the most important being the colour of the pod. Other distinguishing features include the colour of the *Prosopis* wood (*P. flexuosa* is darker), the length of the folíoles (*P. chilensis* is larger) and the size of the trees (*P. chilensis* is larger). For both species, thick pods are always preferred to thin pods. Once gathered, *Prosopis* fruit pulp can be eaten directly by chewing the fresh pods, but more often, pods are stored whole or as partly processed commodities (Fig. 6c–e), after being sun-dried (Fig. 6f; see below).

The algarroba drying and storage The Hualfin people dry the entire *Prosopis* pod by taking advantage of Zonda, a

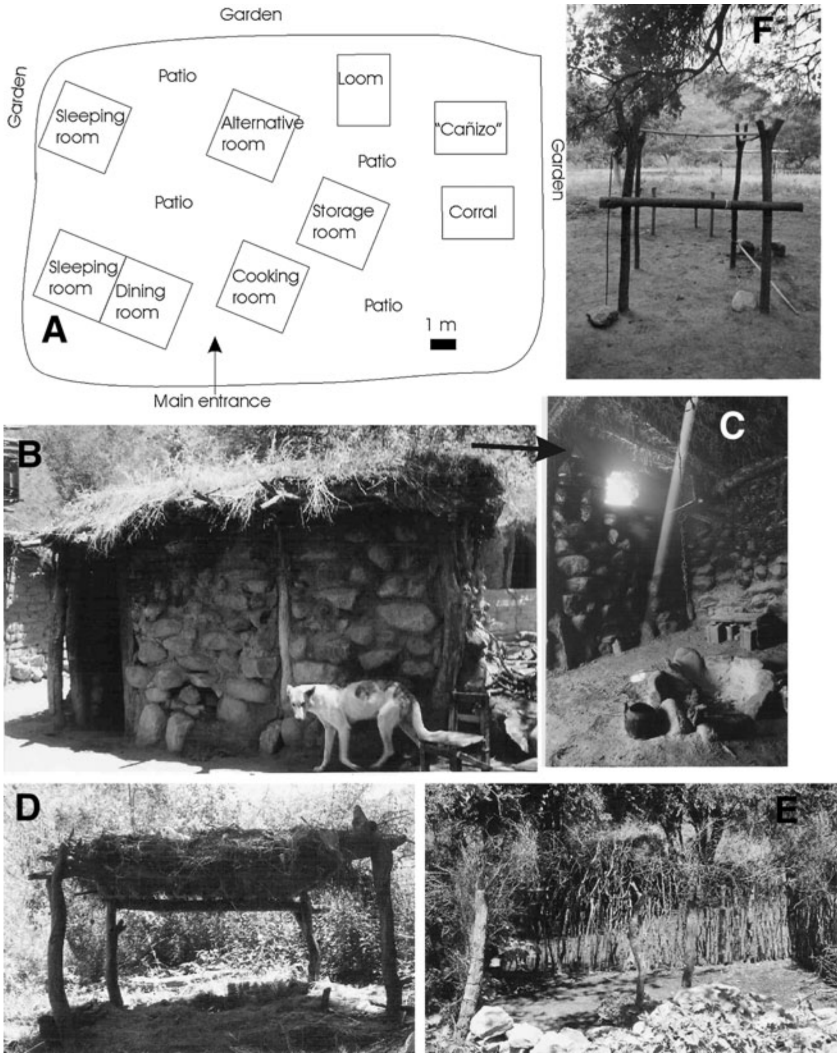


Fig. 5 A typical domestic unit from the Hualfín Valley. **a** Spatial distribution of the main features present. **b** Cooking room or kitchen. **c** The interior of the cooking room with a central hearth surrounded by vertical stones. **d** "Cañizo". **e** Corral for the goats. **f** Horizontal loom

dry, warm wind that blows from the Chilean desert through the Andes Mountains. *Prosopis* pods are dried slowly, for 1 or 2 months, over a cañizo, a wooden structure made from four posts and roofed with cane, mud and grass (see Fig.6f). Once dried, the algarroba intended for human consumption are commonly stored inside houses. Only mature fruit is stored, either as entire pods (Fig. 6c) or as partly processed commodities (Fig 6d). The pods are stored for up to a year in buckets, baskets, wicker-work, bags made from synthetic fabrics or sackcloth (Fig. 6c), but cotton bags were probably used in the past. The bags are often hung from house rafters, where smoke from the cooking hearths protects and fumigates the fruit and thus deterring insects and microbes (Fig. 6e).

Traditional storage methods used in the Hualfín Valley were documented in detail by Sánchez Oviedo (1936), an agronomist who travelled throughout Argentina during the first half of the last century. He recorded huaspanes (Fig.6g) and pirhuas (Fig.6h), cylindrical huts with conical roofs that were traditionally used to store food plants until the middle of the last century. Both were constructed from four or more *Larrea* sp. stakes, interlaced with *Senna* sp. twigs. The stakes were joined together at the apex and then covered with mud to keep rain out. The stored foods separated by an approximately 5-cm layer of ashes per 10 cm of food. Huaspanes and pirhuas were primarily used to store maize cobs, but, algarroba pods, mistol (*Zyzyphus mistol*) and chañar (*Geoffroea decorticans*) were also stored in them. Ethnohistoric records from other regions of Argentina report that these three plants were blended together into a flour mixture to make bread ("patay", see below for more details; Burkart 1952; Filipov 1996).

Algarroba as human food The pods can be used to make *arrope* (Fig. 7a), a syrup which requires the fruit to be chopped into small pieces. However, the dried pods are more commonly prepared into flour by grinding and sieving. Grinding separates the seed–endocarp complex

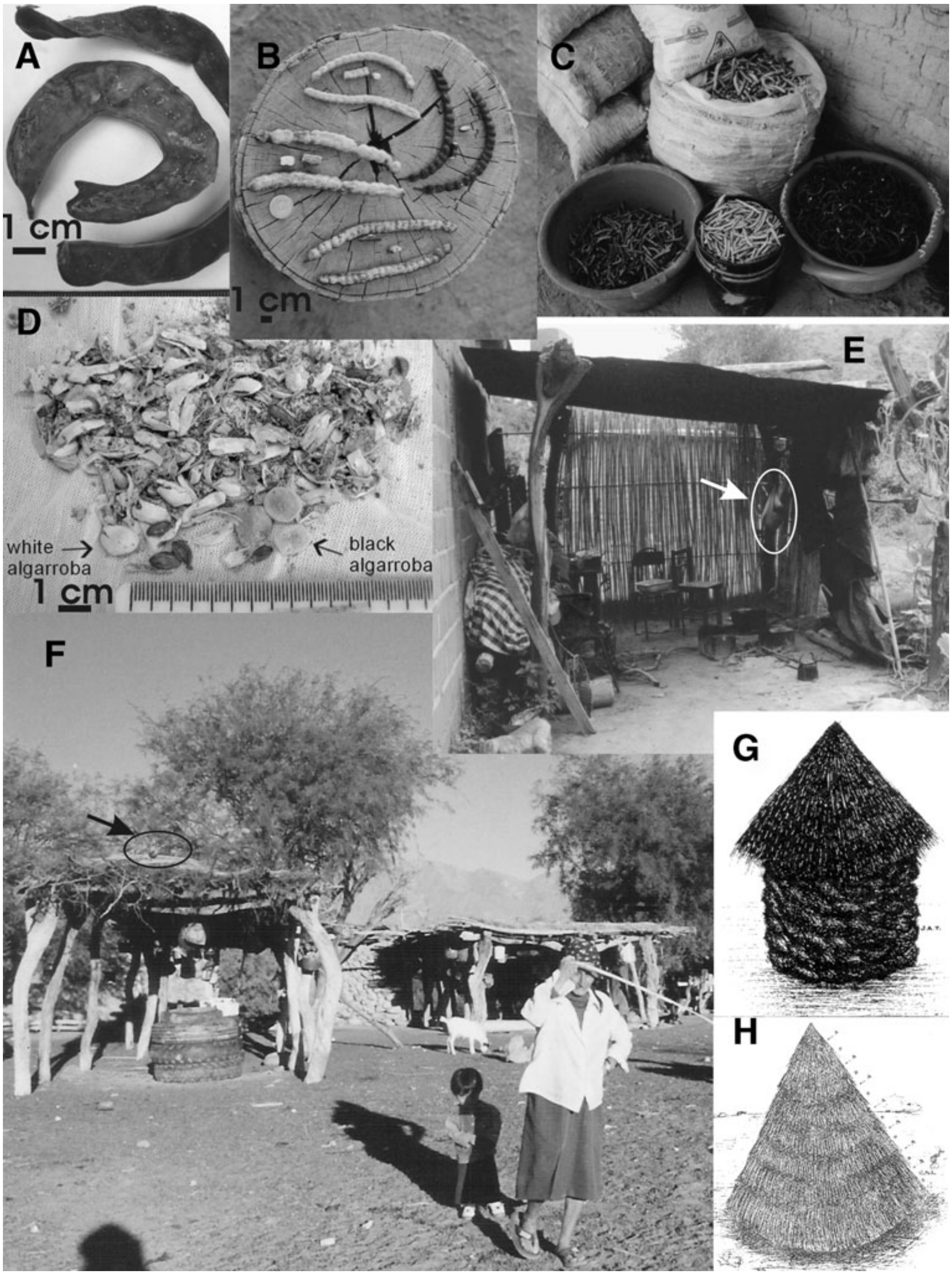
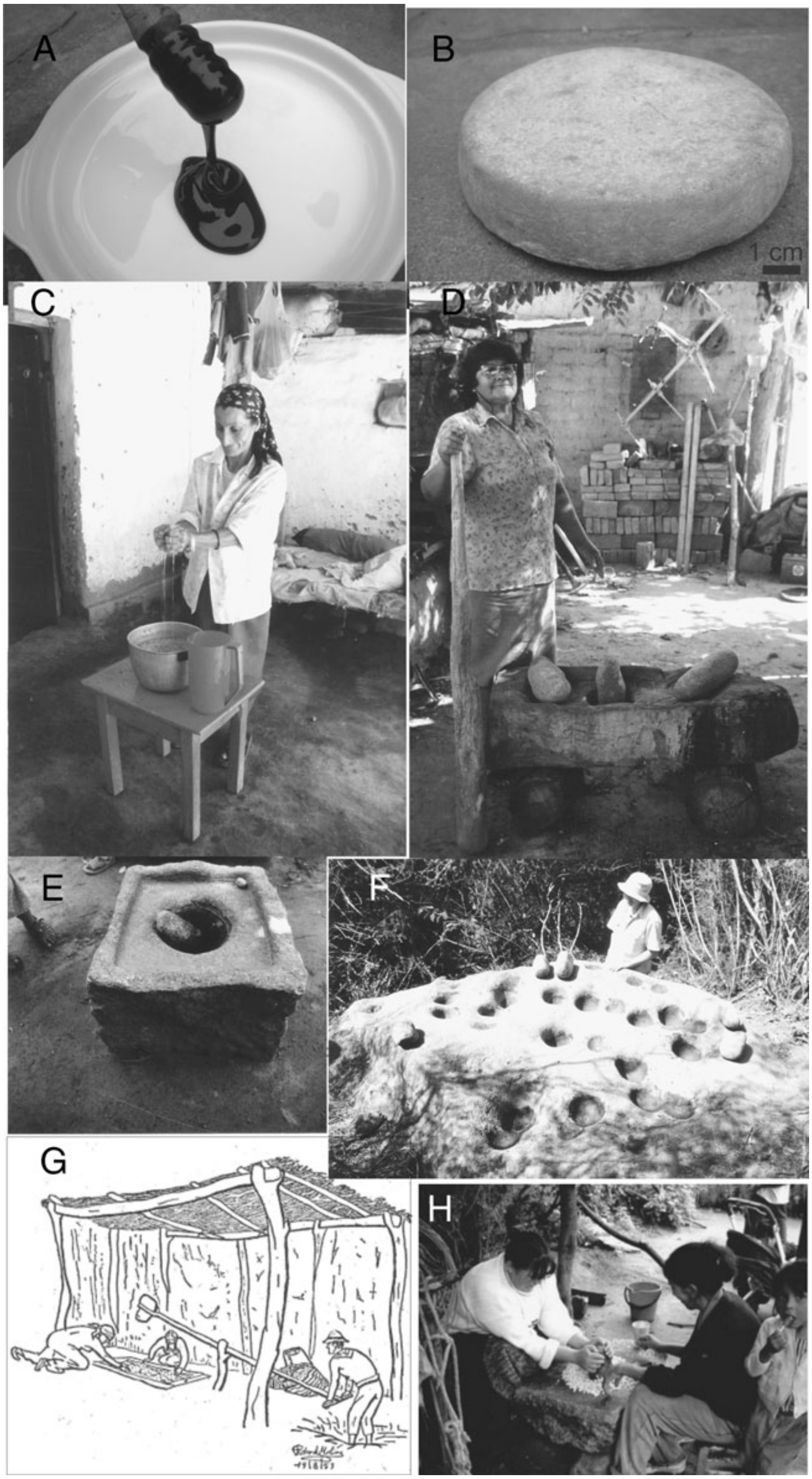


Fig. 6 *Algarroba* selection and storage. **a** *P. chilensis*. **b** *P. flexuosa*. **c** *P. flexuosa* selected by colour of the pods. **d** Storage unrefined flour recorded at Quillay. **e** Bag with algarroba pods hung over the hearth. **f** Cañizo with algarroba sun-drying. **g** *Huaspan* storage structure. **h** *Pirhua* storage structure (**c** from Capparelli 2007; **g**, **h** from Sánchez Oviedo 1936)

(commonly referred by people as "seeds") from the edible pulp (mesocarp); both fractions are separated afterwards by sieving. The flour is used to make different foods, such as a sweet bread/cake called *patay* (Fig. 7b), a non-alcoholic beverage called *añapa* (Fig. 7c), an alcoholic beverage called *aloja* and *ulpo*, which is another kind of fresh non-alcoholic lye consumed by shepherds.

Interviewees were not clear about the duration and intensity of the grinding process to prepare these different products. One, for example, reported that, for *patay* and *aloja*, the process finishes when "seeds" lose the mesocarp, but others referred to a lower grade of refining. Grinding is usually carried out in patio areas and can be done with a wooden (upper valley; Fig. 7d) or a stone (lower valley) mortar and a stone pestle. Today, only one villager in the valley makes and sells stone mortars (Fig. 7e). People frequently make a tool by breaking a piece from the huge pitted stones, similar to common artefacts found on local archaeological sites (Fig. 7f). Utilising such material in this manner is not a recent practice; for example, one woman recalled that, in her infancy, mortars were not made but found ("el mortero no se hacía, se encontraba"). Another

Fig. 7 Algarrobo processing. **a** *Arrope*. **b** *Patay*. **c** Griselda Cedrone making *añapa*. **d** Doña Morales and her wood mortar. **e** Commercial stone mortar. **f** Archaeological stone mortars at El Shincal. **g** "Cimbra" grinding structure. **f** Doña Betty Yapura and her friend grinding maize in her patio, at El Shincal village. (**c**, **d** from Capparelli 2007; **g** from Cáceres Freyre 1962)



traditional algarrobo grinding method called "cimbra" was documented in detail by Cáceres Freyre (1962: 12) for the Pipanaco basin during the first half of the twentieth century. It involved balancing a big stone ("maray") on top of a long wooden stick ("cimbrón"; Fig. 7g) and breaking and grinding the pods over a large (algarrobo wood) plate, about 1×1.5 m. This plate may have had a border made from wood or mud to prevent spillage. This type of grinding appears to have gone out of favour as it was not mentioned during the ethnographic study.

Producing algarroba flour is not an easy task. One person continually pounds the pods in the mortar with a pestle, while others catch pods that spill out and return them to the mortar (see similar tecnique employed for maize in Fig. 7h). Sieving is carried out nowadays using a large piece of burlap cloth, which is equivalent to a c. 1–1.5-mm diameter mesh. In the Hualfín valley, the use of mortars is not confined to processing *Prosopis*. Two interviewees reported that the mortar was used to grind several plant foods, including maize (Fig. 7h), algarroba and red peppers (*Capsicum*).

Arrope production Entire pods are first put into a bag and trodden by people until they are coarsely broken, after which they are quickly washed in a ceramic pot. A measure of pods is then boiled with two measures of water until a softened mush is formed. The mixture is then kneaded and pressed through a fine cloth, and the collected liquid is boiled slowly (approx. 6 h) until a honey-like syrup is formed. No sugar is added. The *arrope* is eaten with bread, biscuits or cheese. It can also be used as a cake ingredient or as a sweetening agent for other foods. Cáceres Freyre (1962) reported that arrope was sometimes prepared from the residues of the patay flour, but that was not recorded today in the Hualfín valley.

Patay production Patay is a kind of bread or cake made from the finest fraction of the algarroba flour. It is obtained by pounding whole stored pods or else by a second grinding of stored coarse flour. The fine fraction is obtained by sieving the flour through a large piece of burlap cloth; it is put into ceramic pans and compacted by leaving the pan out in night-time dew, then drying in the sun or by cooking it in hot ashes. No sugar is added to the flour. The bread becomes crisp due to sugars present in the pods ("con la dulzura que se derrite el patay queda duro"). The resulting cake is called *patay*, and, in this form, the flour can be eaten or stored for a long time.

Añapa production Today, this beverage is the most popular use of algarroba flour. Unrefined flour is generally used, without sieving (Fig. 6c), and, if *patay* processing has been carried out previously, its residues are generally used to make *añapa* ("molían la algarroba, la pasaban por el cedazo y con lo gruesito hacían añapa"). To achieve it, flour is soaked (1 h to 3 days, depending on the informant) and subjected to one of three methods of drink production: (1) the decanted fraction is pressed between both hands ("se chusma") and the juice is stored in a jar for drinking ("se hace un ovillito y el juguito se pone en una jarra"; Fig 7c; (2) the liquid solution is simply decanted by means of a jar and drunk; and (3) the liquid is filtered into a jar via a colander or a piece of cloth. Some informants reported that they keep the *añapa* in a ceramic pot, wrapped with a damp cloth, to keep it fresh.

Aloja production The preparation of the alcoholic beverage *aloja* is similar to the *añapa*, except that the ground pods are kept in a soft form in water within a ceramic pot for at least 10–15 days.[4]

Ulpo production Some of the interviewees mentioned that shepherds often took a mixture of algarroba and toasted maize flours with them while they were away with their flocks. They could mix the flour in cold water. *Ulpo* might have been the name of both, the fine algarroba flour by itself and of this drink, as it was recorded by Cáceres Freyre (1962) in the first half of the last century. Shepherds would normally drink it also for breakfast mixing the flour with either hot or cold water.

After processing, different types of discarded residues are produced (Fig. 8). Table 3 show the main diagnostic characteristics of the residues of each algarrobo product mentioned in Fig. 8. Residues types 3 and 6 of Fig. 8 are not represented in this table because the former is like residue type 7 but with a smaller proportion of initial fragmented/fissured endocarps and seeds (because it is made from unrefined coarse fraction of flour), while the latter also is like residue type 7 but in this case small pieces of the fine fraction are stuck to the larger ones (because it is made from fine and coarse fraction of refined flour) (see below).

Residues are thrown onto the patio floor or garden. Alternatively, the waste is used to feed domestic animals such as horses or sheep or to feed hens living in the patio floor. Fifty percent of those interviewed said that they also gathered algarroba for animal fodder.

Experimental approach

Materials and methods

Experimental *Prosopis* processing was carried out to characterise the qualitative and quantitative macromorphological attributes of both the products and residues. Those attributes, such as the type of pod fragmentation, flour texture, preservation state and changes in the appearance of constitutive organs, were recorded before and after each processing stage. The same traditional methods described above, with the exception of the type of sieve, were followed to obtain experimental *patay*, *añapa*, *aloja* and *arrope*. We replaced the traditional burlap cloth to make the processing easier.

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[4] Ethnographic reports from Chaco area record that hot water, not cold, can be used for flour maceration (Metraux 1963:349) and that chewed pods are commonly added to the maceration bulk (Metraux 1963, Peleschi [1881] in Dasso 2000, Fernández Distel 1986).

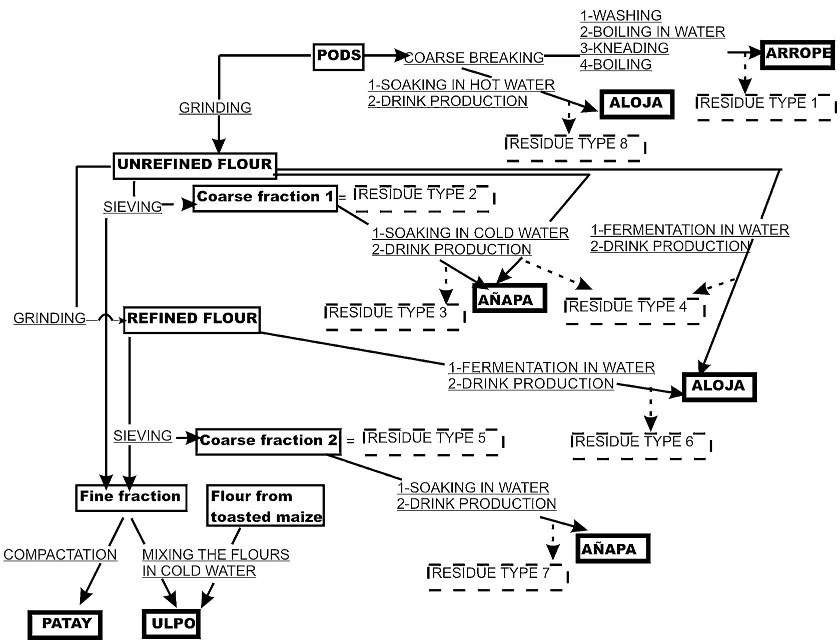

Fig. 8 *Scheme* showing the different intermediate and final products derived from *Prosopis* food production at the Hualfin Valley, their main elaboration stages and the different kind of residues generated

In order to evaluate the direction of morphological changes according to the grinding of the pods and flour refining, different types from less refined flour (here called, unrefined flour) to more refined (here called, refined flour) were obtained after two different grinding periods of 90 and 140 s, respectively, with the same intensity and the same stone pestle (770 g weight). The flour was considered refined when endocarps showed no traces of mesocarp. These types were obtained from samples ranging 5.8–6.8 g of black (*P. flexuosa*) and white (*P. chilensis*) algarroba pods, respectively. Black and white algarroba pods were weighed and ground separately in order to discriminate better the effects of grinding for each species. The <1-mm fraction of the first set of refined flour from both species was mixed together and pressed onto the walls of a ceramic pot to make the patay bread. The pot was left in the dew for one night. As *patay* is the only *Prosopis* product that could be bought in shops in the Hualfin Valley, two loaves were also obtained from a commercial source to compare the morphological attributes of their flour with the flour produced experimentally.

The >1-mm fraction (refined) of the same flour obtained after grinding to make *patay* was soaked in water (1:4 ratio) and left for 20 h to make *añapa*. In order to evaluate differences between *añapa* made from flours lacking or containing the fine fraction, a second *añapa* was made after soaking another set of flour, in this case, containing both fine and coarse fractions.

Aloja was made from another set of unrefined flour, obtained similarly to that of the *añapa*, but in this case it was soaked for 10 days. Effects of hot water and chewing were also registered experimentally according to ethno-

Table 3 Description of the components of the residues mentioned in Fig. 8

Type of residue according to Fig. 8	Product (byproduct)	Original components and main processing	Description in Table 4
1	Arrope	Coarsely broken pods+boiling and kneading	Tenth to 11th columns
2	Patay or ulpo	Coarse fraction of unrefined flour not used for añapa manufacture	First to second columns
3	Patay or ulpo (añapa)	Coarse fraction of unrefined flour+soaking in cold water	–
4	Añapa or aloja	Coarse+fine fractions of unrefined flour+soaking in cold water	Sixth column
5	Patay or ulpo	Coarse fraction of refined flour not used for añapa manufacture	Third to fourth columns
6	Añapa or aloja	Coarse+fine fractions of refined flour+soaking in cold water	–
7	Patay or ulpo (añapa)	Coarse fraction of refined flour+soaking in cold water	Fifth column
8	Aloja	Coarsely broken pods+fermentation in hot water	Seventh column

graphic reports mentioned above. Changes in seed and endocarp dimensions after *añapa* and *aloja* processing were recorded, before and immediately after soaking, and after drying the soaked residues.

To make *arrope*, 9.2 g of *P. flexuosa* and 9.2 g of *P. chilensis* dried pods from Jacipunco were coarsely broken by hand and then boiled separately for 10 min in double their volume of water. They were subsequently rubbed against a 1-mm mesh metal sieve. The resulting juice was boiled until syrup point (15 min approximately).

Results

Those macroscopic qualitative characters of *Prosopis* pod parts derived from the different kinds of processing, which potentially may be visible in the archaeobotanical record, are analysed in detail below (see also, Table 4). Quantitative features are treated tangentially, as they were object of study of a previous publication (Capparelli 2008).

Flours The <1-mm fraction (=fine flour) of the unrefined flour of WA and BA were comprised of mainly mesocarp tissue. The <1-mm fraction of the refined flour of WA and BA contained both epicarp and mesocarp tissue, however, that made from BA also contained small pieces of endocarp. The presence of mesocarp traces in both endocarps and fragments of epicarp and of seeds with intact testa allows distinguishing unrefined flour residues (Figs. 9a, b) from refined ones. These mesocarp traces oxidised and became more obscure after a few hours of exposure to the air. The refined flour of both species can be recognised by the absence of mesocarp traces, the high proportion of fissures in the endocarps and seed testa. Other features of the two flour types relate to the specific *Prosopis* species. Characteristics of both types of flour of the WA, for example, include separation of the endocarps into two single shells and the freeing of the inner seeds (Fig. 9a), while the opposite was recorded for BA (Fig. 9b). Table 5 shows relative percentages of each organ after grinding, calculated on the base of their absolute numbers.

Patay Some differences were observed between the experimental *patay* cake (Fig. 9c) and the commercial *patay* (Fig. 9d, e). The outer surface of the experimental patay had a coarse texture, while the commercially produced *patay* had a finer homogeneous texture, although, in transverse section, a coarser texture was observed. This could be the result of what Cáceres Freyre (1962) considered as “to give *lustre* to the patay”, which is to spread a very fine fraction of the flour first in the ceramic pot and then the remainder for the whole patay to give the appearance of having been made with the finest materials.

Añapa The pod part associations and the appearance of *añapa* residues depend on the type of flour (unrefined–refined) or flour fraction (fine–coarse) used in its preparation. Similar trends were observed in each analysed species in hydrated (Fig. 10a, b) and dehydrated (Fig. 10c, d) pod parts. In hydrated samples from refined and unrefined flour, neither entire nor halved endocarps changed their original morphology and dimensions. Seeds increased in length and width by nearly 30% and in thickness from 21% to 90% during soaking. Seeds with fissured testa split along fissures, which is primarily the result of hydration of the albumen layer. In these cases, the testa was easily removed, and the albumen layer became gelatinous. Also, the cotyledons were visible in some seeds, while in others, each layer of seed tissues separated from the other. After añapa processing, the number of whole seeds was reduced to 33% of the original sample (see Capparelli 2008). In dehydrated samples, seeds retained most of their original dimensions. No quantitative differences were registered in endocarp dimensions before and after hydration. In those endocarps that had originally epicarp–mesocarp traces, the mesocarp dissolved, leaving the epicarp directly attached to the endocarp surface (this last feature can be seen also in unprocessed thin pods or in terminal joints). In other specimens, the dissolution of the mesocarp produced a slight black patina on the surfaces of the endocarp. In the case of the *añapa* made from both (> and <1 mm) fractions of flour, small fragments of flour that were suspended in water in the hydrated sample became stuck to larger elements of the residue on drying (Fig. 10d). This is due to the sugary mesocarp acting as a cementing agent. No differences were observed among species.

Aloja The macromorphology of the wet and dehydrated residues of cold water-fermented samples (Fig. 10e, f) were similar to that of *añapa* in both species. However, seeds deteriorated more and again the number of whole seeds was reduced to 33% of the original sample after processing (see Capparelli 2008). In hot water, the mesocarp of macerated joints dissolved easier than in cold water, which results in the epicarp becoming attached directly to the endocarp at some joints. Some samples were observed to have retained a large portion of the entire mesocarp, the endocarp surface developing a thick dark patina when dried, a characteristic that can help distinguish the use of hot-water *aloja* (Fig. 10g) from cold water soaking. Epicarp threads in terminal areas become more rolled than in *añapa* samples. These last features are more evident in hot water-soaked aloja residues than in cold water-soaked residues due to the fact that coarsely broken pods are usually used for hot water soaking while ground pods are usually used in cold water soaking, and also, the fact that dissolution of mesocarp is more intense when hot water is used. Chewed pod residues are easily distin-

Table 4 Summary of the most important diagnostic features for desiccated remains of algarrobo final and intermediate products, as well as residues mentioned in Fig. 8

Unrefined flour (>1 mm), intermediate product or residue type 2		Refined flour (>1 mm), intermediate product or residue type 5		Añapa-aloja in cold water (refined flour >1 mm), residue type 7	Añapa-aloja in cold water (unrefined flour <&> 1 mm), residue type 4	Aloja in hot water, (fragmented pods), residue type 8	Aloja chewed pods residues	Patay/ulpo (<1 mm), final product	Arrope, residue type 1	
White algarroba	Black algarroba	White algarroba	Black algarroba	White=black algarroba	White=black algarroba	White=black algarroba	White=black algarroba		White algarroba	Black algarroba
Epicarp: Scarce. With mesocarp patches. Endocarps: Abundant. Mostly separated into single shells opening along the pod suture line and freeing their seeds. Some freed their seeds but had still both shells lightly attached. Very few groups of joined endocarps. Some with patches of epi- and/or mesocarp. Seeds: Abundant (almost the initial processed number). Half of them remained entire, from which some have an intact testa, and some have the testa fissured.	Epicarp: Scarce. With mesocarp patches. Endocarps: Abundant. Mostly entire. Some fissured, still retaining their seeds. Others, partly broken. Fissures and fractures occur at any part of the endocarp. Some with patches of epi- and/or mesocarp. Seeds: rare. When present, usually entire with intact testa.	Endocarps: Abundant. Clean. Almost all separated into single shells. Some shells V-fissured. Seeds: Abundant. Mostly fragmented. Those that remained entire had highly fissured testa.	Endocarps: Abundant. Clean. Nearly half entire or lightly fissured, and nearly half broken into small fragments. Seeds: Few. Nearly half of them entire (all with fissured testa) and the other half broken.	Endocarps: in those with epi- and mesocarp patches parts of the epicarp directly attached to the endocarp surface. Epicarp may also curl in the edges. Clean endocarps present the same features that refined flour. Some with a slight black mesocarp patina. Seeds: Testa becomes folded/rolled and loosened in some areas. Cotyledons clearly visible in several seeds. These alterations are most common within seeds with fissured testa.	Apart from the features described in the previous column, it was observed that small fragments of the flour become stuck to the large elements of the residue (mostly endocarps) in a disorganised way.	Joints: Some parts of the epicarp directly attached to the endocarp surface. Part of it in lightly twisted strings. In the edges it may become strongly folded. Endocarps: those closed do not open after soaking. Some of them still attached one to the other. Black mesocarp patina usually very thick. Seeds: the same as those features of añapa previous columns	Epicarp: Abundant. Separates longitudinally in fine threads, which twist heavily when spout out Endocarps: All closed, containing their respective seeds, sometimes the terminal ones remained attached to the twisted threads of the epicarp.	Coarse texture flour due mainly to the presence of small epicarp (WA and BA) and endocarp (BA only) fragments distributed within the finer mesocarp matrix.	Epicarp: Abundant. Wide pieces, with a thin mesocarp patina attached to small areas. Endocarps: Abundant. All closed, containing their respective seeds and with a thin black patina derived from mesocarp attached to small areas. When dehydrated closest remains become stuck together	The same as those of the previous column except that epicarp instead remaining in wide pieces it separates longitudinally in ribbons, which twist when dehydrated

Abundant, scarce and rare are relative estimative quantities of specimens compared with those of the same column

Abbreviations: *WA* white algarroba, *BA* black algarroba

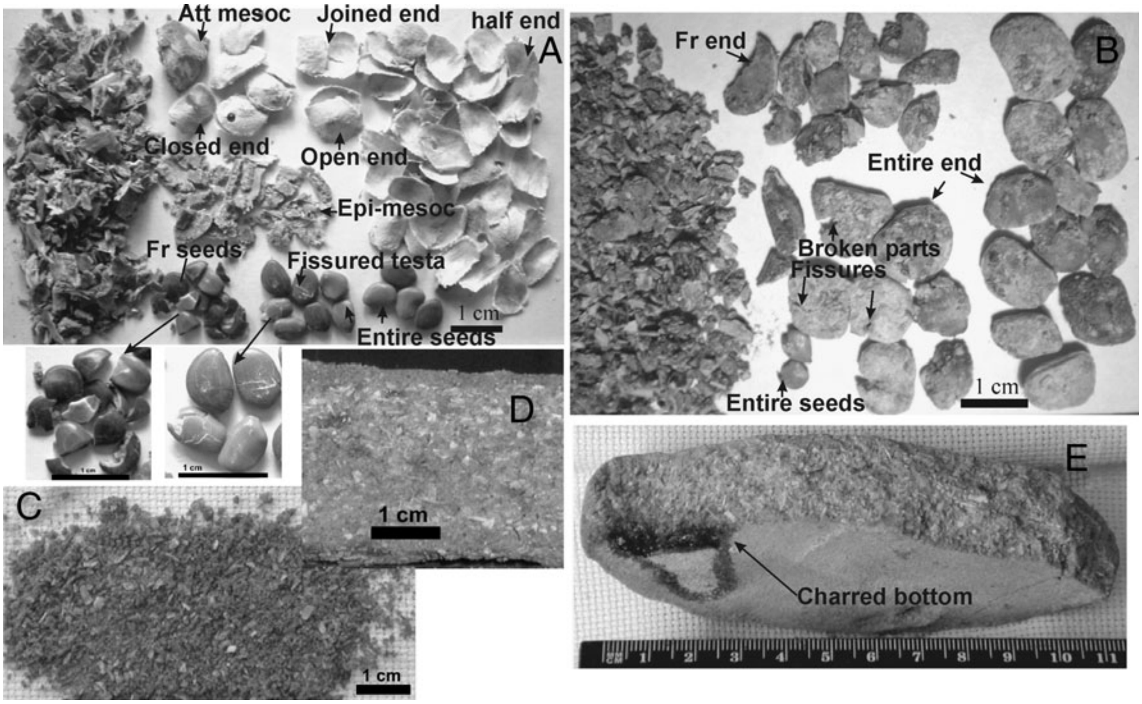

Fig. 9 Algarroba flours and patay. **a** Fraction >1 mm of unrefined flour from white algarroba. **b** Fraction >1 mm of unrefined flour from black algarroba. **c** Fraction <1 mm of refined flour. **d** Commercial patay showing exterior fine texture. **e** Commercial patay showing charred bottom. Abbreviations: *Att mesoc* attached mesocarp, *end* endocarp, *epi-mesoc* epicarp–mesocarp, *fr* fragmented

guished by the presence of very fine threads of mesocarp fibre bundles heavily twisted and occasionally attached to terminal endocarps (Fig. 10h, i). No differences were observed among species.

Arrope In arrope residues, endocarps show a dark mesocarp patina on their surfaces. But, as the pods here were boiled and kneaded, this patina is not as thick as that of hot-water *aloja* residues. The WA epicarp is harder than the BA and separates into broader ribbons when rubbed against the sieve (Fig. 11a) whereas BA separates into finer ribbons (Fig. 11b). When dehydrating, epicarp threads of BA became twisted, although not as tightly as in chewed *aloja* residues.

Table 5 Percentage of each pod part remaining after being processed for unrefined and refined flours calculated on the base of absolute number (taken from Capparelli 2008)

P. chilensis (WA)								
	Endocarps			Seeds				Epicarp–mesocarp
Flour type	Closed	Open	Halves	Inside endocarps	Entire non-fissured testa	Entire fissured testa	Fragmented	
Initial, %	100	0	0	100	100	0	0	100
Unrefined	28	4	68	28	16	28	28	40
Refined	0	16	84	0	0	20	80	0
P. flexuosa (BA)								
	Endocarps			Seeds				Pod fragments
Flour type	Closed entire	Close fissured	Fragmented	Inside endocarps	Entire non-fissured testa	Entire fissured testa	Fragmented	
Initial, %	100	0	0	100	100	0	0	0
Unrefined	48	28	24	92	8	0	0	8
Refined	44	16	40	76	0	12	12	0

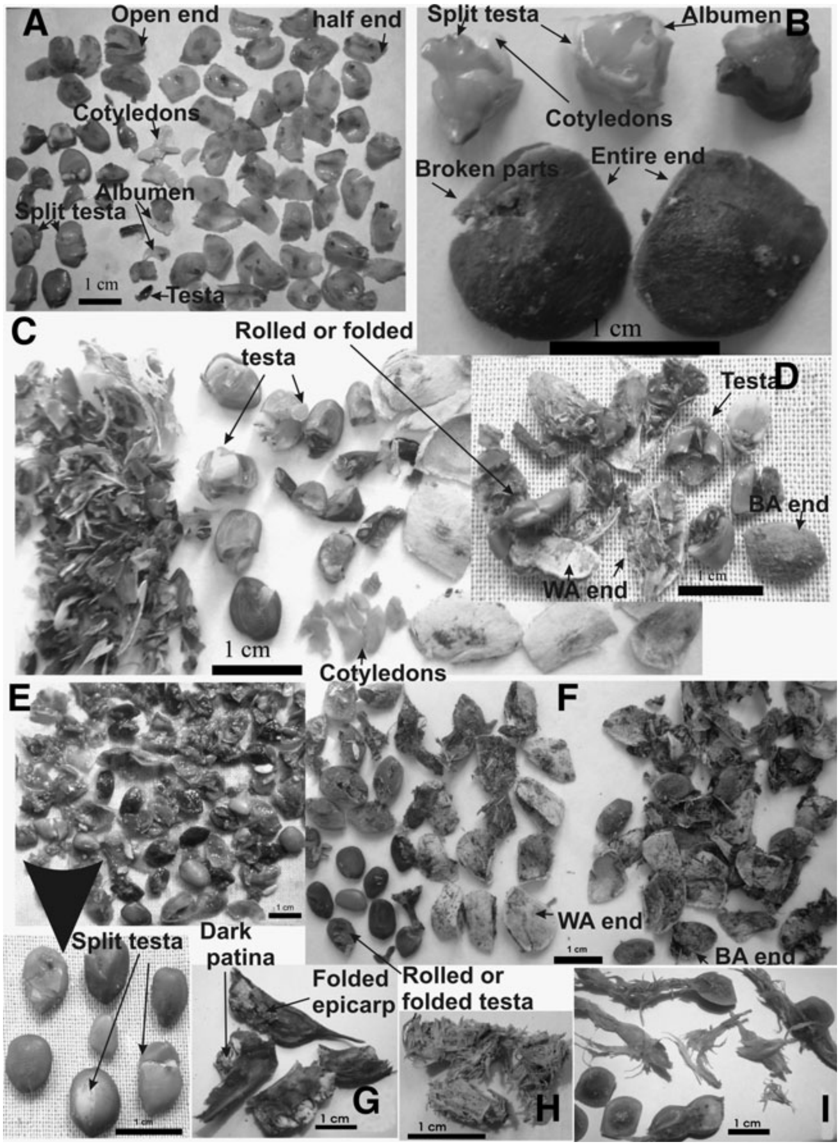

Fig. 10 Añapa and aloja residues. **a**, **b** Wet añapa residues from refined flour. **a** White algarroba. **b** Black algarroba. **c** Dehydrated añapa residues from white algarroba refined flour. **d** Dehydrated añapa residues from white and black algarroba unrefined flour. **e**, **f** Aloja residues from cold water maceration of white and black algarroba refined flour. **e** Wet. **f** Dehydrated. **g** Aloja residues from hot water maceration of white algarroba. **h** Chewed pods of black algarroba. **i** Aloja residues from cold water-macerated chewed pods of black algarroba. Abbreviations: *end* endocarp

Discussion

As it can be seen from these results, raw algarrobo pods might be consumed, but post-harvest practices transform algarrobo into forms that are better represented at archaeological sites. These post-harvest practices can be as simple as transporting the fruits for storage, resulting in the deposition of the pod in or near storage areas; or else the subsequent ingestion of the pod, which can produce clean endocarps hazardously spread as residues of direct consumption. But, the more complex the post-harvest practices are, the greater the likelihood of leaving remains that will be preserved archaeologically. The more complex the post-harvest practices are, the wider the algarrobo spatial distribution of different activity areas (storage room, cooking area, patio, see Fig. 5), especially in those areas near mortars. Different types of artefacts (mortars, pestles, ceramic pots, bowls and bags) might also preserve traces of algarrobo products. As there are only a few situations in which algarrobo post-harvest practices involved the use of heat, then it can be expected that, in the Hualfín valley, most of algarrobo charred remains are derived from accidental charring and may only represent a very small proportion of the volume of that used (this is more widely discussed in Capparelli, this volume). Conversely, dessiccated remains may provide a better record of algarrobo use in particular situations, but unfortunately, dessiccation is restricted to arid areas, which are limited.

From desiccated algarrobo macroremains, it is possible to recognise different kinds of routine practices. Patay is the only algarrobo product that can be deposited as a macroremain (e. g. Lagiglia 1957), because the other products are beverages or jellies. Intermediate products, such as unrefined or refined flours, can also be recovered. In such cases,

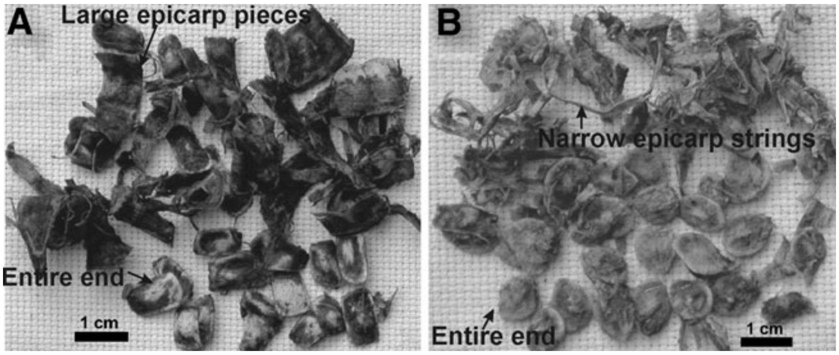

Fig. 11 Dehydrated arrope residues. **a** White algarroba. **b** Black algarroba. Abbreviations: *end* endocarp

it is not possible to distinguish whether they had been used to prepare añapa, aloja, ulpo or patay. These intermediate products are primarily recovered from areas around mortars due to pod parts spilling out during pulverising or else in storage contexts and/or storage containers, such as those used to transport flour from one part of a settlement to another. If a coarse fraction of unrefined or refined flour was found in other contexts and without evidence of soaking, it may be a residue (Fig. 8, residue types 2 and 5) produced during the stages of sieving or compacting of patay/ulpo production. But, the coarse fraction of unrefined or refined flour can be used as an intermediate product in the preparation of añapa. This practice can be recognised by the presence of parts of the coarse fraction of unrefined or refined flour with evidence of soaking (Fig. 8, residue types 3 and 7). In this case, it cannot be discerned if the fine fraction of these flours had been used to make patay/ulpo preparation. On the other hand, the recovery of residues type 4 or 6 (Fig. 8), which can be distinguished from those of 2 and 5 (Fig. 8) by the presence of small pieces of epicarp attached to the endocarps, suggesting that both fine and coarse flour fractions had been used to prepare either añapa or aloja, without previous patay/ulpo preparation. Añapa and aloja made from cold water soaking cannot be distinguished. However, other practices involved in aloja manufacture, such as the use of coarsely broken pods, the addition of pods fermented in hot water or of chewed pods, allow us to confirm the manufacture of aloja, not añapa. These practices left different residues, such as type 8 (Fig. 8) or twisted fine threads of chewed epicarp, which are diagnostic.

Another important implication of the results is that WA and BA have different mechanical responses to grinding; therefore, species identification is important when interpreting the types of post-harvest activities from *Prosopis* remains. For example, most of the endocarps of WA opened during the first grinding, freeing their seeds. In contrast, for BA, most of the endocarps remained closed during processing, while experiencing more or less fragmentation fissures depending on grinding intensity, they never opened up. These differences rely on the fact that WA endocarps are thinner, more fibrous and flexible than BA endocarps, which are thicker, more woody and brittle. Grinding produced fissures in WA seeds, which may assist in the identification of this processing activity. Seeds are also released in BA but in lower frequencies than in WA. Therefore, the recovery of a few BA seeds does not necessarily imply processing difficulties or lower quantities used, but instead, suggests the manufacture of unrefined flour, during which most of these seeds remain inside their own endocarps. It was noted in other experiments with other species that *Prosopis caldenia*, *P. denudans* and *P. alba* responded in a similar way to *P. chilensis*, while *P. nigra* and *Prosopis alpataco* had a similar response to *P. flexuosa*.

The results of the present study indicate that the remains from those products prepared from flours (*añapa*, *aloja*, *patay* and *ulpo*) may have been highly fragmented prior to deposition. A quantitative experimental approach carried out from the same data set presented here showed, for example, that 80% of the initial number of WA seeds would be fragmented during refined flour production and just the 20% would remain entire (Capparelli 2008). It was also noted that only 33 % of whole seeds of WA or BA processed for aloja would remain entire after fermentation. These figures suggest that for flour and drink production an identifiable number of whole WA seeds recovered from an archaeological site will only be a very small fraction of those initially incorporated to the flour-making process.

The diagnostic features of algarrobo food/drink products and residues presented in this paper have been used to infer the manufacture of different algarrobo derivates. As regards the ethnobotanical data, in most of the algarrobo products (with the exception of arrope), the morphological characteristics of pod parts are the result of similar types of processing (grinding from entire pods to unrefined flour, grinding again from unrefined to refined four, soaking in cold water from flour to aloja and añapa making, and soaking in hot water from coarsely broken pods to aloja-making).

As a result of these analyses, in Table 1 (two last columns), the presence of different types of algarrobo derivates from Huachichocana III and Puente del Diablo archaeological sites are inferred. When insufficient morphological evidence exists, question marks reveal the possible interpretations. It is considered that those archaeobotanical remains that are similar to the intermediate/final products and residues described experimentally were the result of the manufacture processes for the products recorded ethnographically. It is interesting to remark that, at Huachichocana III, WA occurs in greater frequencies than BA, and that almost all the contexts with *Prosopis* findings—from the earliest to the latest—appear to have been used primarily for processing methods that included grinding, together with cold and/or hot water (see Table 1 and Fig. 4a–d). Either *añapa* or *aloja* appear to have been made from a mixture of fine and coarse flour fractions (i.e. Fig. 4a, c). Processing involving the use of hot water was also identified (Fig. 4a, b, d), and chewed pods were added occasionally to the maceration bulk (Fig. 4a).

In contrast, at Puente del Diablo, BA is predominant (see Table 2 and Fig. 4e–i), and findings show substantial evidence of grinding (i.e. Fig. 4e, f), sometimes, together with cold water soaking (i.e. Fig. 4g, h), while the dark patina indicative of hot water soaking is scarce (i.e. Fig. 4i). This last characteristic could be the result of a very fine grinding which left the endocarps with few mesocarp residues, which generates little patina once it is immersed in hot water. Despite *añapa* and cold water *aloja* residues not being distinguishable from one another, it is suggested that *añapa* was more likely produced than *aloja* at Puente del Diablo. This interpretation is forwarded here because soaking appears to have been carried out on a flour that lacked a fine fraction (no small epicarp fragments stuck to endocarps in a disorganised way were observed), an ethnographically common occurrence when *añapa* is made from *patay* residues.

The presence of endocarps from animal droppings (such as foxes coprolites) can be inferred when they are extremely “clean”, without either mesocarp or epicarp remains (the digestible part) on their surfaces. At this point, the experimental work, developed in this paper, shows that grinding can release also the same type of “clean” endocarps, but in this case, they can be distinguished by the presence of fissures and fractures. Trampling across an archaeological site may also account for the presence of these features. For this reason, information about the archaeological context of origin is essential in the interpretation of archaeobotanical remains, especially in the case of *Prosopis*. When endocarps have characteristics which make its cultural affiliation doubtful, the presence in the same archaeological context of other *Prosopis* remains (such as epicarp threads or endocarps with mesocarp or epicarp patches, see Tables 1 and 2) suggest food processing activities. Several endocarps of Puente del Diablo site are quiet “clean” with few mesocarp or epicarp remains, which may indicate an intensive use of *Prosopis*, where people possibly subjected their pods to sequential stages of processing order to obtain as many preparations as possible. In the case of endocarps from level 3 of squares E1, E2, C3 and B3, the presence of clean ones with fractures without any other type of *Prosopis* remains does not allow for the differentiation between grinding or heavy trampling as the cause of these kinds of characters. Other endocarps remains at Puente del Diablo, such as those from the upper layers of E3 square, level 2 from B2/B3/C3 sector and of the deeper layers of A3 square, had no features related to any kind of processing. Again, since these were not associated to other *Prosopis* remains, they could be the result of natural, not cultural, factors. In some endocarps, remains with mesocarp and epicarp traces, indicating processing, gnaw marks were also present. In several of these contexts, animal bones had cut marks and/or thermal alteration as well as gnaw marks. This association, together with the presence of rodent coprolites in these, suggests that rodent activities occurred at a time close to the abandonment of these sites, rather than in association with the burrowing habit of these animals.

Post-harvest processing is present from the earliest contexts at both sites. *Prosopis* grinding was detected at Puente del Diablo in a burial dated in 10.000 BP uncal.; añapa were products also made during Archaic and Formative periods at both sites and was used in domestic and funerary contexts. A diversification of processing techniques is associated with an increase in the number of *Prosopis* remains recovered from later contexts at both caves. In the case of Archaic and Formative contexts of Puente del Diablo, this can be linked to a general diversification of plant consumption with the addition of crops, such as *Cucurbita* sp. and *Phaseolus vulgaris* (Lema 2009). In the case of Huachichocana III, the presence of chewed pods associated to hot water *aloja* processing is exclusive of the Inka period and is linked to the burial of a domestic Argentinian lesser grison (*Galictis cuja*). It is interesting to note that, at this site, during the Inka occupation, when the state’s economy is considered to be agricultural, quantities of *Prosopis* remains are very high and are associated with post-harvest practices not recorded in earlier contexts (see also Capparelli in this same volume).

These results are consistent with the use of *Prosopis* by other native North, Central and South American people. Beresford-Jones (2005) noted that *Prosopis* was very important to “incipient cultivators” in the Tehuacán Valley, Mexico, the southwestern 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 2005: 323).

Since there are similarities between the ethnographic observations on fruit processing presented in this paper with those recorded in SW USA (see the work of Felger (1977) on the Seri Indians of North America), in Peru (see, for example, Horkheimer 2004: 123), in Chile (Holden and Núñez 1993) and in other areas of the NW Argentina [Di Lullo (1943; 1944); Rusconi (1958); Cáceres Freyre (1962) and Figueroa and Dantas (2006)], and the NE Argentina (Arenas 2003, Filipov 1996, among others) and Patagonia (see Capparelli and Prates, 2010), and as a result of the similar human uses of *Prosopis* in similar ecosystems, the experimental analyses presented in this paper might be useful to interpret ancient *Prosopis* processing in other parts of the Americas.

Conclusions

Fruits of arboreal species of the genus *Prosopis* have been very important components in the diet of past and present societies in several areas in the world but mainly in America. Yet, until now, their archaeobotanical remains have scarcely been identified beyond simply noting their use or non-use. This paper shows that differences in the processing of *Prosopis* pods can be recognised in archaeobotanical remains. Species-level identification is also important for the interpretation of these differences. Using ethnobotanical analogies, a great diversity of products derived from BA or WA can be recognised, the qualitative features of their processed products in various pod parts and their possible archaeological recognition has been evaluated. The applicability of these studies to archaeological cases has been confirmed, allowing better analytical understanding of activities in the past. As a result, taxonomic differences in use, different processing activities, type of food preparation, as well as taphonomic controls and archaeological contextual relationships were analysed. Finally, it is suggested that different complexes of algarrobo production can be identified through macromorphological analysis of archaeological remains of *Prosopis*, revealing a methodological pathway that can be applied in archaeological studies in other parts of the world.

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References

Arenas, P (2003) Etnografía y alimentación entre los Toba-Nachilamole#ek y Wichí-Lhuku'tas del Chaco Central Argentina). P. Arenas (ed). Latín Gráfica S.R.L., Buenos Aires

Beresford-Jones DG (2005) Pre-hispanic *Prosopis* human relationships on the South Coast of Peru: riparian forest in the context of environmental and cultural trajectories of the Lower Ica Valley. Magdalene Colledge, University of Cambridge, Cambridge. PhD Thesis

Beresford-Jones DG, Arce S, Oliver T, Whaley Q, Chepstow-Lusty A (2009) The role of Prosopis in ecological and landcape change in the Samaca basin, lower Ica Valley, South coast Peru from the Earlier Horizon to the Late intermediate period. Latin Am Antiq 20(2):303–332

Binford L (1981) Bones: ancient men and modern myths. Academic Press, New York, pp 21–30

Burkart A (1940) Materiales para una monografía del género *Prosopis* (Leguminosae). Darwiniana 4(1):57–128

Burkart A (1952) Las Leguminosas argentinas silvestres y cultivadas. Buenos Aires, Acme

Burkart A (1976) A monograph of the genus *Prosopis* (Leguminosae subfam. Mimosoideae). J Arnold Arbor 57:217–525

Cáceres Freyre J (1962) Fabricación del patay en los algarrobales del Campo de Palcipas (La Rioja y Catamarca). University of La Plata La Plata, Argentina, Serie Contribuciones 76:1–22

Capparelli, A (1997) *Reconstrucción ambiental de la instalación arqueológica Inka El Shincal*. PhD Thesis. Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata

Capparelli A (2007) El algarrobo blanco y negro—*Prosopis chilensis* (Mol.) Stuntz y *P. flexuosa* DS, Fabaceae- en la vida cotidiana de los habitantes del NOA: subproductos alimenticios. Kurtziana 33:103–119

Capparelli A (2008) Caracterización cuantitativa de productos intermedios y residuos derivados de alimentos del algarrobo (*Prosopis flexuosa* DC y *P. chilensis* (Mol.) Stuntz, Fabaceae): aproximación experimental aplicada a restos arqueobotánicos desecados. Darwiniana 46(2):175–20

Capparelli A, Prates L (2010) Identificación específica de frutos de algarrobo (*Prosopis* spp., Fabaceae) y mistol (*Ziziphus mistol* Grises., Rhamnaceae) en un sitio arqueológico de Patagonia. In: Pochettino ML, Ladio A (eds) Traditions and transformations in Ethnobotany. Cyted, S.S. de Jujuy

Capparelli A, Lema V, Giovannetti M, Raffino R (2005) The introduction of old world crops (wheat, barley and peach) in Andean Argentina during the 16th century AD: archaeobotanical and ethnohistorical evidence. Veg Hist Archaeobot 14:472–484

Capparelli A, Valamoti S, Wollstonecroft M (2010) Recent research in post-harvest traditions in human prehistory: Old and New World palaeoethnobotanical approaches to linking the archaeology and ethnobotany of plant processing. In: Pochettino ML, Ladio A (eds) Traditions and transformations in Ethnobotany, Cyted, S.S. de Jujuy

D'Antoni HL, Solbrig OT (1977) Algarrobos in South American cultures, past and present. In: Simpson BB (ed) Mesquite: its biology in two desert scrub ecosystems. Dowden Hutchinson & Ross Inc, Pennsylvania, pp 189–199

Dasso MC (2000) Celebración de la aloja: la preservación del fundamento mítico entre los Mataco-Wichí del Chaco central. Scr Ethnol 22:61–76

Di Lullio, O (1943) El folklore de Santiago del Estero. Material para su estudio y ensayos de interpretación. Universidad Nacional de Tucumán, Departamento de Investigaciones Regionales, Instituto de Historia, Lingüística y Folklore X. Secc. Fol.. Publ. III. Tucumán, 446pp

Di Lullio O (1944) El folklore de Santiago del Estero. Medicina y Alimentación. Provincia de Santiago del Estero. Publicación Oficial, Santiago del Estero, p 431

FAO, (2007) El género *Prosopis* "algarrobo" en América Latina y el Caribe. Distribución, bioecoloía, usos y manejo. www.Fao.org/docrep/006/ad314s/AD314S01.htm Consultado 14 de marzo 2007

Felger RS (1977) Mesquite in indian cultures of Southwestern North America. In: Simpson BB (ed) Mesquite: its biology in two desert scrub ecosystems. Dowden Hutchinson & Ross, Inc, Pennsylvania, pp 150–176

Felker P (1979) Mesquite, an all purpose leguminous arid land tree. In: G.A. Ritchie (ed) New Agricultural Crops, pp 89–132. Colorado: Westview Press, Boulder

Fernández Distel A (1986) Las cuevas de Huachichocana, su posición dentro del precerámico con agricultura incipiente del Noroeste argentino. Beitrage zur allgemeinen und vergleichenden Archaologie, band 8, Mainz, pp: 353–430

Figueroa GG, Dantas M (2006) Recolección, procesamiento y consumo de frutos silvestres en el noroeste semiárido argentino. Casos actuales con implicancias arqueológicas. La Zaranda de ideas 2:35–50

Filipov, A (1996) Estudio Etnobotánico de la recolección entre los Pilagá. PhD Thesis, Faculty of Natural Sciences of La Plata, University of La Plata, unpublished ms

Giovannetti MA, Lema V, Bartoli CG, Capparelli A (2008) Starch grains characterization of *Prosopis chilensis* (Mol.) Stuntz and *P. flexuosa* DC, and their implication in the analysis of archaeological remains in Andean South America. J Archaeol Sci 35:2973–2985

Harris PJC, Pasiecznik NM, Bradbury M, Ramirez L (1998) Problems and potential of *Prosopis*. In: Etkin NL, Harris DR, Houghton PJ (eds) HDV Prendergast. Plants for food and medicine, Royal Botanical Gardens, Kew, pp 277–293

Hillman G (1984) Interpretation of archaeological plant remains: the application of ethnographic models from Turkey. In: Van Zeist W, Caspary WA (eds) Plants and Ancient Man. Studies in palaeoethnobotany. Biologisch-Archaeologisch Institute, State University, Groningen. AA Balkema, Rotterdam, pp 1–41

Horkheimer H (2004) Alimentación y obtención de alimentos en el Perú prehispánico, 2nd edition, Perú: instituto Nacional de Cultura

Jones G (1984) Interpretation of archaeological plant remains: ethnographic models from Greece. In: Van Zeist W, Caspary WA (eds) Plants and ancient man. Studies in palaeoethnobotany. Biologisch-archaeologisch institute, State University, Groningen. AA Balkema, Rotterdam, pp 43–59

Lagiglia H (1957) La presencia del patay en una tumba indígena de San Rafael (Mendoza). Notas del Museo 1. San Rafael, Museo de Historia Natural

Latcham R (1936) La agricultura precolombina en Chile y los países vecinos. Santiago de CHile: Universidad de Chile

Lema V (2009) Domesticación vegetal y grados de dependencia ser humano-planta en el desarrollo cultural prehispánico del noroeste argentino. PhD Thesis, Faculty of Natural Sciences of La Plata, University of La Plata, unpublished ms

McLaren F, Capparelli A (2004) The early use of *Prosopis* L. Species as food: Old World and New World evidence. In: Abstracts of The International Society of Ethnobiology- Ninth International Congress, Panel 27: Ethnobotanist of distant pasts: honour of Gordon Hillman, http://www.kent.ac.uk/anthropology/ice2004/panels/panel27.htlm, visited June 2004

Metraux A (1963) Indians of the Gran Chaco: ethnography of the Chaco. In: Steward J (ed) Handbook of South American Indians, vol 1, Cooper Square Publishers. INC, New York, pp 197–380

Moore AMT, Hillman GC, Legge AJ (2000) Village on the Euphrates from Foraging to Farming at Abu Hureyra. OUP, Oxford

Holden and Nuñez (1993) An analysis of the gut contents of five wed-preserved human bodies from Tarapacá, Northern Chile. Journal of Archaeological Science 20: 595–611. Academic Press Limited, Inglaterra

Orians GH, Solbrig OT (1977) In: Orians GH, Solbrig OT (eds) Convergent evolution in warm deserts. An examination of strategies and patterns in deserts of Argentina and the United Status. Dowden Hutchinson & Ross Inc, Stroudsburg

Rusconi C (1958) Acerca del pan de patay. Revista Museo Historia Natural de Mendoza 11:193–208

Sánchez Oviedo, C (1936). La vieja terapéutica vegetal en el noroeste argentino. Almanaque del Ministerio de Agricultura de la Nación. Año XI. pp 289-297

Sanni AI, Lie E, Lindberg AM (1993) Fatty acid composition of *Prosopis africana* and its fermented product okpehe. Chem Mikrobiol Technol Lebensm 15(3–4):89–90

Schiffer MB (1972) Archaeological context and systemic context. Am Antiquity 37:156–185

Schiffer MB (1976) Behavioral Archaeology. Academic Press, New York

Simpson BB, Solbrig OT (1977) Introduction. In: Simpson (ed) Mezquite, its biology in two desert scrub ecosystems. Dwden Hutchinson & Ross Inc, Stroudsburg, pp 1–25

Tarragó, MN, (1980) El proceso de agriculturización en el Noroeste Argentino, zona valliserrana, y sus relaciones con zonas vecinas. In: Actas del V congreso Nacional de Arqueología Argentina

Wollstonecroft, M (2007) Post-Harvest Intensification in Late Pleistocene Southwest Asia: Plant Food Processing as a Critical Variable in Epipalaeolithic Subsistence and Subsistence Change Tesis para optar al grado de Doctor en Arqueología. Instituto de Arqueología, University College London. Inédita