RECENT ARCHAEOBOTANICAL FINDINGS OF THE HALLUCINOGENIC SNUFF COJOBA (*ANADENANTHERA PEREGRINA* (L.) SPEG.) IN PRECOLONIAL PUERTO RICO

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*Archaeological starch grains consistent with those produced and stored in modern cojoba (*Anadenanthera peregrina*) seeds were identified, for the first time in the West Indies, in a coral milling base recovered in a small precolonial habitation site of Eastern Puerto Rico, in a context dated to A.D. 1150–1250. Ethnohistoric, ethnographic, and previous archaeological data on cojoba from the West Indies and South America were surveyed in order to form plausible sociocultural interpretations of the findings. After experimentally assessing some ethnographic protocols that possibly replicate various ancient ways of processing cojoba seeds for producing hallucinogenic powders related to the so-called* ritual de la cojoba, *this report proposes that cojoba seeds were processed and used here mainly as an hallucinogenic complement to the healer for the divination of illness.*

*Granos de almidón arqueológicos que coinciden con aquellos producidos y almacenados en las semillas modernas de cojoba (*Anadenanthera peregrina*) fueron identificados, por primera vez en las Antillas, en una base de molino de coral recuperada en un pequeño sitio habitacional del oriente de Puerto Rico, en un contexto fechado entre 1150 y 1250 d.C. Para figurar interpretaciones socioculturales plausibles de estos hallazgos, exploramos datos etnohistóricos, etnográficos y arqueológicos previos acerca de la cojoba en las Antillas y en Suramérica. Luego de evaluar experimentalmente algunos protocolos etnográficos que posiblemente replican varias formas antiguas del procesamiento de semillas de cojoba para producir polvos alucinógenosvinculados con el llamado ritual de la cojoba, este reporte propone que la cojoba fue procesada y utilizada aquí, principalmente, como un complemento alucinógeno de los curanderos para la adivinación de enfermedades.*

Among the precolonial inhabitants of the West Indies, the use of the hallucinogenic snuff called cojoba (*Anadenanthera peregrina* (L.) Speg.), known as *yopo* or *cebil* in South America) was documented by early chroniclers who described in a general way the plant's importance and variable uses, though they mainly discussed its role in what they called the *ritual de la cojoba* (Román 2007). Archaeologically speaking, paraphernalia presumably associated with this important ritual are fairly common, with the Greater Antilles region having the greatest number and diversity of related artifacts, including inhaling tubes, vomiting sticks, snuff bowls and platters, and canopied idol tables (Kaye 1999). Although there is an abundance of ritual artifacts, the true identity of the hallucinogenic substance used in the West Indian cojoba ritual has not been firmly established, nor have traces of this plant or other hallucinogenic substances been identified in objects traditionally associated with this rite. Furthermore, historiographic analysis on the use of cojoba has been sometimes confusing and two different plants (tobacco [*Nicotiana tabacum*] and cojoba) have been postulated separately as the ones directly involved in the ritual (Boomert 2001; Lovén 1935; Ortíz 1987).

The lack of adequate archaeobotanical data for the presence and use of cojoba in the West Indies is not surprising, considering the perishable nature of the botanical remains (e.g., seeds, chemical substances within the seeds) that can be used

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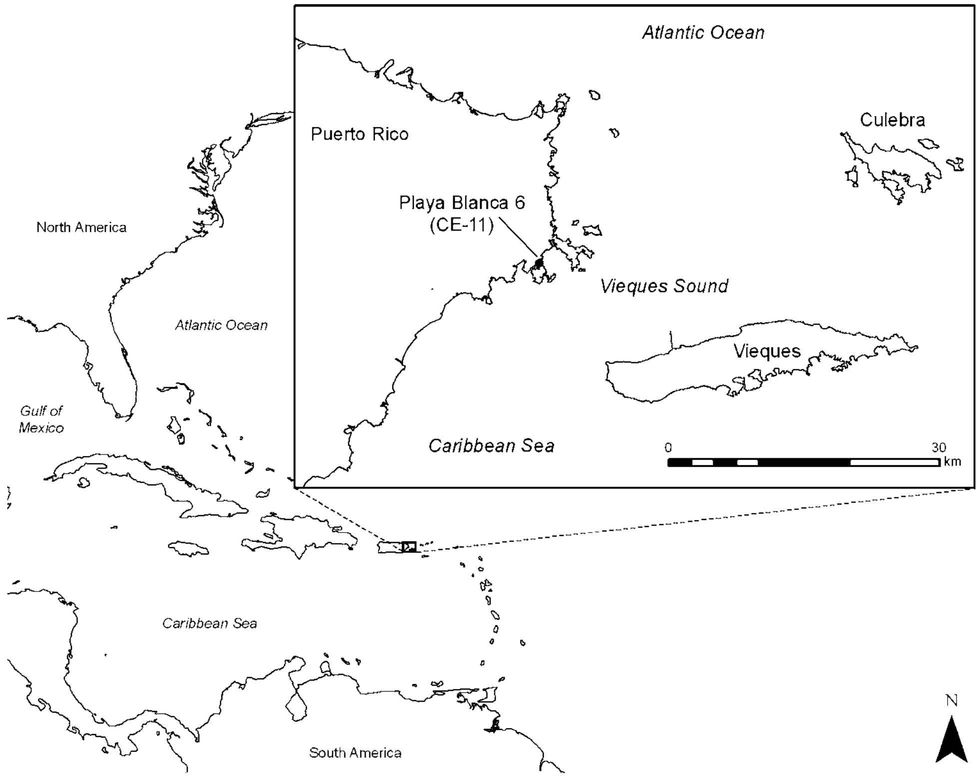

Figure 1. Location of Playa Blanca 6 (or CE-11) within Puerto Rico and the West Indies.

to establish direct links between this plant and the different human groups that were thought to use it. With this scenario in mind, this report describes the identification of archaeological starches highly consistent with those stored in modern cojoba seeds.

Archaeological starches were directly recovered in a coral grinding artifact within a small habitation site (Playa Blanca 6 or CE-11) in eastern Puerto Rico chronologically situated between A.D. 1150 and 1270 (Figure 1). In order to understand the nature of the finding, we will first present an overview of cojoba and its purported uses and functions in the precolonial and postcolumbian West Indies and South America with the aim of creating an ethnographic base that supports the interpretation of the archaeobotanical data. Following is a description of the archaeological context of the findings. Next, we present the archaeobotanical data recovered and microbotanical information that was gathered through an experiment processing modern cojoba starches using protocols described ethnographically. It is by these various means that we ultimately propose that in the household where the cojoba was identified, the plant was not necessarily used as part of the formal cojoba ritual, as has been widely described by chroniclers and ethnographers. Based on the quality of the preserved starch grains and their morphometric characteristics, these particular cojoba seeds appear to have been ground during their mature state without being subjected to heating or parching. This characteristic, in addition to the context of the find, suggests that this cojoba may have been used in the context of healing treatments (divination of illness) or as a stimulant possibly associated with other types of religious activities, rather than being part of the formal *ritual de la cojoba*.

The Genus *Anadenanthera* (Cojoba) and Its Uses

Species Distribution

Cojoba (also called *cojóbana* in some parts of Puerto Rico) is an exotic tree species of South

Figure 2. Cojoba (*Anadenanthera peregrina*) mature pods from an adult tree located at the Universidad de Puerto Rico, Río Piedras (left). Seeds dried naturally (right). (Photographs by Jaime Pagán-Jiménez.)

American origin that was humanly introduced to the Antilles during the precolonial era (Figure 2). There are two recognized species of the genus *Anadenanthera* in the Americas (*A. peregrina* and *A. colubrina*) that have been historically used by indigenous peoples in ritual ceremonies and magical-religious activities due to the chemical components, or tryptamines (alkaloids),[1] contained in its seeds, leaves, and bark (Reis Altschul 1972; Torres and Repke 2006). The current natural distribution of these species is restricted to South America, generally north of the southern limit of the Tropic of Capricorn. As an exotic plant, *Anadenanthera peregrina* is known today in Puerto Rico, Hispaniola, and some of the Lesser Antilles (e.g., Trinidad). Interestingly, its presence has never been clearly demonstrated in Cuba or Jamaica (Román 2007), where important paraphernalia associated with the cojoba ritual have been identified in precolonial contexts. In Puerto Rico, discrete populations of cojoba trees are currently known for the lowland semi-arid south of the island—from Salinas to Cabo Rojo—but also for middle elevation landscapes where rainfall is relatively abundant (e.g., moist subtropical forests in Carolina, Utuado, and Peñuelas municipalities). On the South American continent, cojoba trees generally grow in partially cleared, low- to mid-elevation forests and are commonly associated with transitional zones between the *cerrado* (savannah) and the semi-deciduous forests (Brito da Costa et al. 2003; Malhado and Petrere 2004).

In the precolonial Americas, hallucinogenic substances were considered intermediaries between the human and supernatural realms and, as such, participated in the interpretation and creation of cultural elements (Torres 1998). It has been proposed that cojoba was so important for precolonial indigenous people of the Andean Highlands and Pacific coast regions, where the plant does not grow, that people there acquired it through trade with people of the lowlands (Schultes 1998; Schultes and Hofmann 2000). Schultes and Hofmann (2000) suggest that cojoba, and the ritual associated with the cojoba snuff, originated in the Orinoco region of Venezuela. The wide distribution of this species, including its presence in the Antilles, is a direct consequence of the human dispersion of the plant (Reis Altschul 1972).

According to Torres (1998), smoking pipes associated with the use of cojoba (*cebil*) have been found in northwestern Argentina at the sites of Inca Cueva and Huachichocana, with the oldest archaeological examples dating to ca. 2100–1200 B.C. There are also several archaeological contexts in Peruvian, Chilean, and Argentinean sites that have yielded abundant paraphernalia and botanical remains (seeds and preserved snuff identified as *Anadenanthera peregrina*) directly associated with the inhalation of cojoba that date to ca. 1000–800 B.C. (e.g., Chavín de Huántar, Huaca Prieta, Asia, and Solcor 3 [Torres 1998]). Argentinean sites have revealed artifacts and botanical remains associated with the use of hallucinogenic cojoba in contexts dated from A.D. 500 to 1500, such as the case of the Alero I-La Matanza site in northwestern Argentina, where powdered material recovered in archaeological snuffing tubes was confidently identified as *Anadenanthera colubrina* (Pochettino et al. 1999). These are the only examples where direct archaeobotanical remains of cojoba seeds or snuff in South America have been clearly identified. In the West Indies, macrobotanical remains (charred wood) of *Anadenanthera* spp. have been identified to the genus level in the ceremonial archaeological site of Tibes in southern Puerto Rico (ca. A.D. 500–900) (Newsom 2010; Newsom and Wing 2004). This finding establishes the presence of the genus *Anadenanthera* in the precolonial Antilles at least by the Saladoid/Ostionoid transitional period. Prior to the current study, no evidence of processed cojoba snuff had been identified in this region.

The Use of Hallucinogenic Substances in the West Indies: Archaeological Evidence

The oldest archaeological evidence in the West Indies for the use of hallucinogenic snuffs (presumably cojoba, though other unknown hallucinogenic or medicinal snuffs are possible) come from early Saladoid and Huecoid sites (ca. 500–100 B.C.) in Puerto Rico and some of the Lesser Antilles (Chanlatte and Narganes 1983), although this practice continued through European contact (Fitzpatrick et al. 2009). The use of cojoba has been commonly ascribed to the inhalation of hallucinogenic powders through the nose with two types of instruments: nasal snuff bowls and inhaling tubes. Snuff bowls are crafted from ceramic or wood and are small globular or spherical containers with flattened bases and one or two inhaling spouts on one side. In the case of the early Saladoid/Huecoid materials, the snuffing vessels are usually finely decorated with geometric incisions or applications of white or red paint (Figure 3a). In the Antilles, this artifact type is restricted to Puerto Rico and Montserrat during the early Saladoid/Huecoid period (Fitzpatrick et al. 2009; Kaye 1999), but during the later Saladoid/Huecoid period (ca. 100 B.C.–A.D. 400), inhaling bowls were more dispersed, documented in Trinidad, Carriacou, and eight other islands (Fitzpatrick et al. 2009). Interestingly, a similar artifact type is documented in Costa Rica during the same time period. Snarskis (1982) relates the Costa Rican ceramic inhaling bowls to the snuffing of tobacco and for inhaling cojoba snuff, at least for the El Bosque complex during the first century B.C. However, no clear direct evidence for the function of this artifact type, or for the hallucinogenic substances used in the bowls, has been documented for this region of Lower Central America, which is an area where other hallucinogenic substances derived from mushrooms (liquids?) appear to have been common in precolonial times (Jones 1991).

In addition to being used in snuff bowls, cojoba could be inhaled through tubes that were typically made from the hollow long bones of large birds; some of these tubes were polished and finely decorated. The apparatus could be simple or sophisticated, with the tubes occasionally embedded into a central piece carved of ceramic, wood, shell, or bone. The resulting compound Y-shaped artifact could be quite complex (Figure 3b and c). Other artifacts traditionally ascribed to the cojoba ritual in the Caribbean islands include intricate vomiting sticks made of manatee bone, wood, or shell (Figure 3c); small wood platters with detailed decorations; and elaborate wooden idol tables (Conrad et al. 2001; see also Rouse 1992:120, Figure 30). Additionally, special artifacts have been identified that relate to the processing and preparation of cojoba and include small- to medium-size stone mortars and manos that are finely decorated and sometimes carved as effigies (Cassá 1995:117).

Ethnohistorical Documentation for the Processing of Hallucinogenic Snuffs in the West Indies and South America

The European chroniclers Fray Ramón Pané (1999 [1571], 2004), Cristobal Colón (see F. Colón 1892),

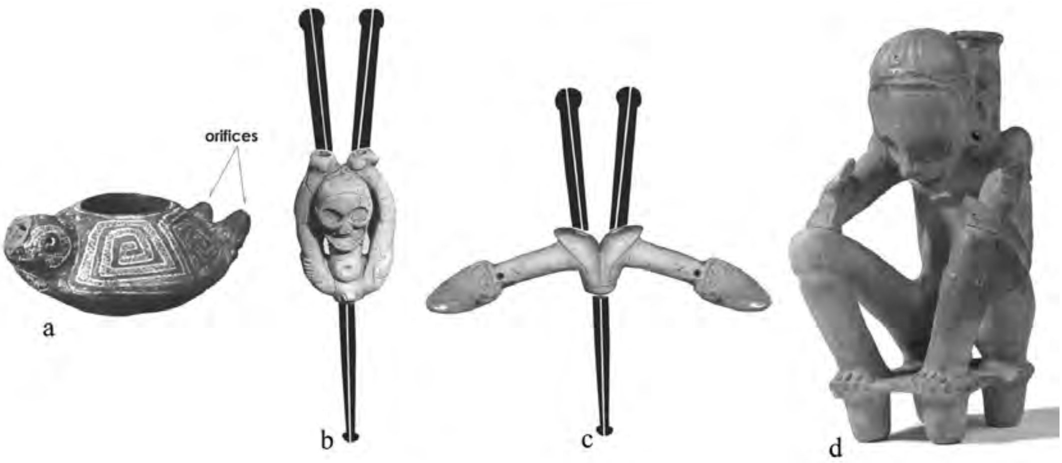

Figure 3. (a) Turtle effigy snuffing bowl from La Hueca culture, Puerto Rico (ca. 160 B.C.–A.D. 520); (b) Y-shaped inhaling device presumably used for snuffing cojoba and showing where tubes (possibly bird bones) are inserted (La Cucama, Dominican Republic); (c) combined spatula and tube holder made of *Strombus* spp. shell (very likely *S. gigas*, Coto Site, Isabela, Puerto Rico); (d) ceramic vessel representing a *behique* (medicine man) or a *cacique* (with highly decorated personal adornments) seated on a duho, with his head lowered and his arms on his knees, probably just after the inhalation of a hallucinogenic snuff (cojoba) as described by Pané (1999:26).[2] (Specimen (a): photo courtesy of Dr. Luis Chanlatte and Yvonne Narganes, Centro de Investigaciones Arqueológicas (Universidad de Puerto Rico, Río Piedras); specimens (b) and (c), images courtesy of Dr. José R. Oliver; specimen (d), ceramic vessel is from the Fundación García Arévalo (Dominican Republic); copyrighted photo courtesy of Jordi Más Lloveras.)

and Bartolomé de Las Casas (1909), among others, documented the use of cojoba in late fifteenth- and early sixteenth-century rituals across Hispaniola (present-day Haiti and the Dominican Republic). Those chroniclers made detailed descriptions of the social contexts (e.g., divine communication, divination, healing rituals) in which the hallucinogenic snuff was used (see Kaye 1999; Oliver 2009; Oliver et al. 2008; Román 2007; Sánchez 2005). Even so, only vague descriptions were made concerning the formulation of the hallucinogenic powder. In the following discussion, ethnohistorical descriptions are provided for the Antilles on the ways of processing the cojoba seeds into the hallucinogenic snuff. This information is compared with some ethnohistoric and ethnographic data from other regions where cojoba has been historically used in multiple ways—as a daily stimulant, in rituals, as medicine, and in magical-religious contexts. For additional information regarding the *ritual de la cojoba* in the Antilles from an ethnohistoric and anthropological perspective, see Cassá (1995), Lovén (1935), Ortíz (1987), Safford (1916), and Torres and Repke (2006).

Regarding the processing of cojoba and the resulting hallucinogenic powder, the only allusion that de Las Casas made (1909:469) is to leaves that "had made certain powders of certain very dry and well ground herbs, with a color like ground cinnamon or *alheña*; thus, they were of a *leonada* [golden] color." López de Gómara (1999:ch. XXVII) also referred to a powder, writing that "when they need to make divinations on what they are asked, then they eat an herb that they call cojoba, ground or in the process of grinding, or they take the smoke by their noses." Other important chroniclers, such as Fray Ramón Pané (1999 [1571], 2004), Fernando Colón (1892, son of Cristobal Colón), Gonzalo Fernández de Oviedo (1959 [1535]), and Diego Alvarez Chanca (see Tió 1966), made mention of the consumption, physiological effects, and ritual or ceremonial use of a plant that the indigenous people called cojoba. To the best of our understanding, none of these chroniclers ever explained clearly the true source of the hallucinogenic powder, with the probable exception of Fernández de Oviedo (see Kaye 1999), or the way in which this snuff was made. This confusing situation led important researchers such as Sven Lovén (1935) and Fernando Ortíz (1987) to postulate that tobacco (*Nicotiana tabacum*) was the only correct identity for the cojoba (see Boomert 2001 for a discussion of this issue).

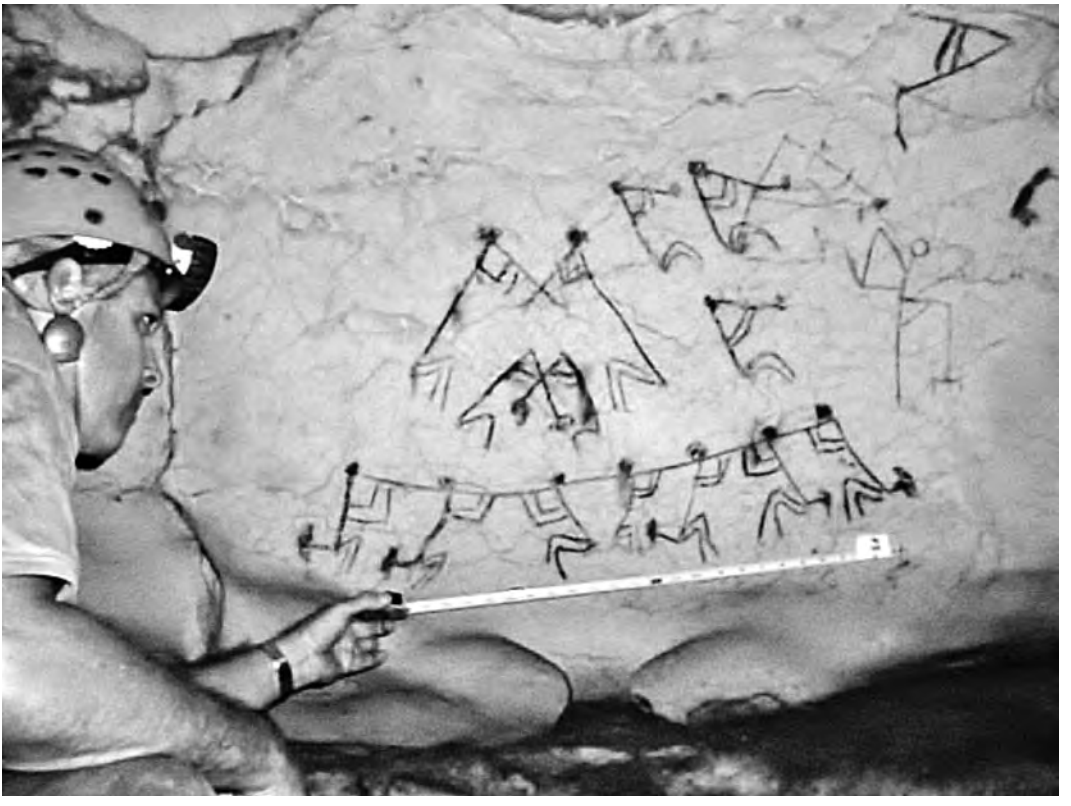

Figure 4. Pictograph of precolonial origin (Cueva del Pomier or Borbón, Dominican Republic) showing some individuals seated on duhos and/or their own heels and snuffing unknown powders (presumably cojoba) with inhaling tubes (copyrighted photo courtesy of Divaldo Gutiérrez Calvache).

The previous arguments in favor of tobacco as the true identity of cojoba (e.g., Ortíz 1987) were based mainly on the absence of clear evidence for *Anadenanthera peregrina* in the Antillean precolonial era (its presence has since been established), as well as chronicler accounts that mention the use of leaves or herbs, rather than seeds, in the preparation of the hallucinogenic snuff (specifically Las Casas and López de Gómara). However, during the second decade of the twentieth century, Safford (1916) demonstrated the differences in the effects caused by snuffs made from tobacco and those made from the ground seeds of *Anadenanthera* spp. Cojoba seed snuff was the only one that caused the effects described by the chroniclers in the Antilles, namely, violent sneezing, perspiration, salivation, loss of balance, physical heaviness, bloodshot and watery eyes, headaches, and significant mucus production. Descriptive images of the *ritual de la cojoba* have been identified in petroglyphs and on carved wooden idols from the Antilles (see Rodd 2002) (Figure 3d and Figure 4).

Oliver (2008), following Safford (1916), has proposed that in the Antilles the hallucinogenic substance used in the cojoba ceremony came from the seeds of *A. peregrina*. He describes the process of preparing the seeds, which are "slightly roasted to remove moisture and later they are crushed with a mortar pestle to obtain a fine powder of a color of the cinnamon" (Oliver 2008:175). He continues, "[to] it is added an alkaline substance (lime) to accelerate its absorption through the mucous membrane ... the resulting mixture is then placed on a plate and, after that, inhaled." Lime can be extracted from heated and crushed sea shells or coral. Senior (2003) proposes that the cojoba seeds should be first dried and then crushed and mixed with lime. It should be noted that these interpretations are not based on the fifteenth- and sixteenth-century texts, but on ethnobotanical data from various South American indigenous people.

Table 1. Radiocarbon Results from CE-11, Puerto Rico.

Unit (FS)	Level/ Depth (cmbs)	Conventional radiocarbon age	$^{13}C/^{12}C$ ratio	Calibrated A.D.date range 2-σ (95%)	Material dated	Beta sample no.	Analysis type
EU 18 (FS 333)	4 (30-40)	840 ± 40 B.P.	-24.6 ‰	A.D. 1060–1080 and A.D. 1150–1270	charcoal	283564	AMS
EU 11 (FS 281)	3 (20-30)	910 ± 40 B.P.	-24.8 ‰	A.D. 1030–1220	charcoal	283562	AMS
EU 13 (FS 297)	3 (20-30)	1020 ± 40 B.P.	-24.0 ‰	A.D. 970–1040 and A.D. 1100–1120	soot off sherd	283563	AMS
EU 15 (FS 300)	2 (10-20)	840 ± 40 B.P.	-23.0 ‰	A.D. 1060–1080 and A.D. 1150–1270	charred crust off sherd	268066	AMS
EU 16 (FS 327)	4 (30-40)	830 ± 40 B.P.	-23.3 ‰	A.D. 1160–1270	charred crust off sherd	268067	AMS

Note: Coral milling base found in EU 13, Level 1.

In the early decades of the nineteenth century, the German geographer Alexander von Humboldt recorded the processing of cojoba seeds among the Otomacos of the Orinoco region in Venezuela (Humboldt and Bonpland 1881). He described that after the seeds were harvested, water was added to encourage the fermentation process until the seeds turned black. The seeds were then ground to a powder and a final addition of manioc flour and lime (from crushed shells) was made. In 1851, a British botanist known as Spruce (cited in Schultes 1998:5) recorded among the Jivi people (also named Guahibo) of the Orinoco that the cojoba seeds were toasted, pulverized, sifted, and then mixed in equal parts with the alkaline ashes of certain barks or leaves. The modern E'ñepa people (also named Piaroa) of southern Venezuela grind the raw cojoba seeds with mortars and wooden *manos*, adding alkaline ashes of a tree bark and then exposing the resulting paste to indirect heat until dehydration occurs (Rodd 2002). Schultes and Hofmann (2000) note that some indigenous people use the cojoba snuff without any addition of alkaline substance.

Context of the Archaeobotanical Recovery: The Site of Playa Blanca 6 (Ceiba [CE]-11) in Eastern Puerto Rico

Playa Blanca 6 (CE-11) is a hilltop habitation site in eastern Puerto Rico that contains large amounts of pottery, primarily Esperanza and Santa Elena styles of the Ostionoid series (Rouse 1992), as well as shell tools, animal bone, and lithics deposited within dense shell middens. The site is located on the grounds of the former Naval Station Roosevelt Roads and although Irving Rouse (1936) was aware of the site as early as 1936, it was not formally identified by the Navy until 1977. Based on radiocarbon dating, CE-11 was settled at the midpoint of the eleventh century, but the majority of the cultural deposition occurred slightly later, approximately A.D. 1150–1250 (Table 1).

The hilltop location sits at an elevation of 10 m asl and overlooks Ensenada Honda Bay, which leads into Vieques Sound (see Figure 1). The topography consists of a central saddle area situated between two exposures of large boulders. The entire ridgetop measures only 50 x 50 m. The flat central area of the saddle measures 25 x 25 m and would have been the living area for the occupants. It was not uncommon in the later Ostionoid period in this region for even very small hilltops to support habitation sites. These small sites contained structural remains (one or two houses) and burials (see Rivera and Rodríguez 1991) and abundant and diverse artifact types in thick shell middens. Site CE-11 would have contained only one or two households, and the community to which these occupants belonged would have been spread out across the landscape surrounding the bay and sound. The archaeobotanical identifications at CE-11, including that of cojoba, come from a small household context.

These hilltop sites often contain dense shell middens, even though the shells had to be transported to these upland locations. The shell mid-

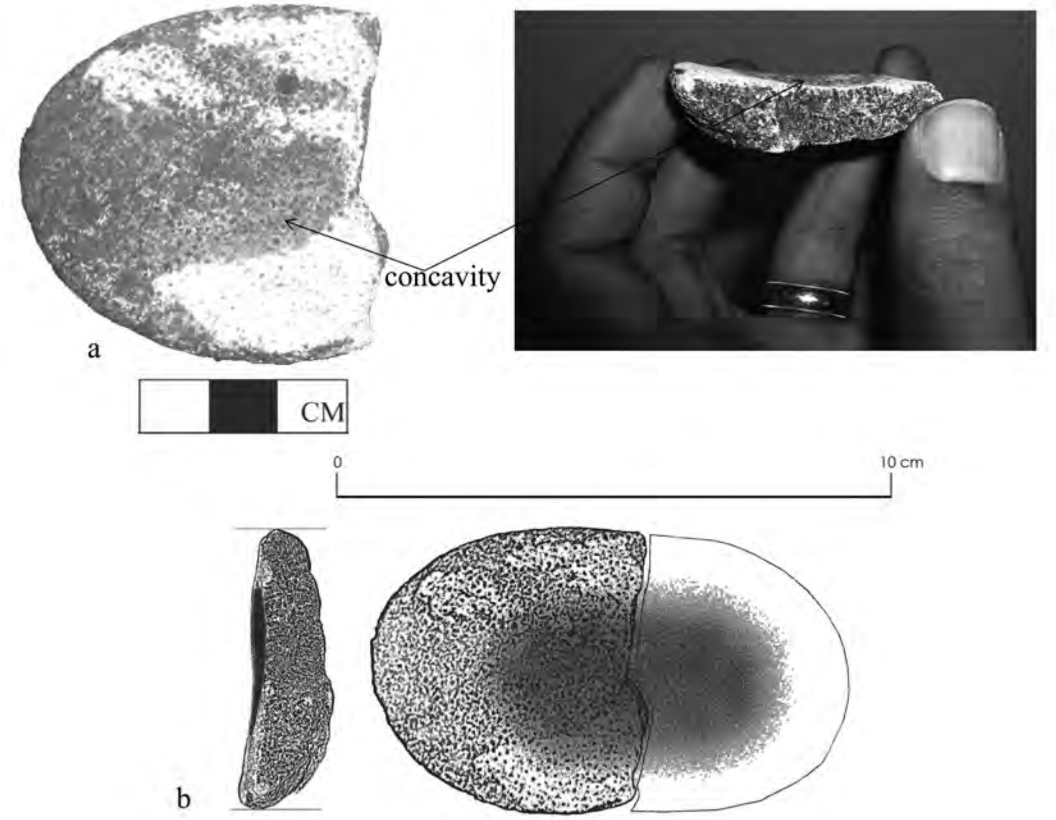

Figure 5. (a) Milling coral base, top and side views. Note the abraded, rounded edges and used facets within the concavity. White sections were produced during the excavation process. (b) Hypothetical form of the complete coral milling base in top and side views. (Drawings and photos by Jaime Pagán-Jiménez.)

dens at CE-11 were deposited on either side of the central flat, pushed slightly upslope against the two large boulder outcroppings. While the former living area in the flat was obliterated through later occupation and agricultural practices, the shell middens deposited around and between the boulders were protected and remained intact. As such, the midden contained undisturbed evidence of site activities (sequences of shell dumping episodes), a rich subsistence refuse deposit, and abundant artifacts (e.g., decorated ceramics, shell and stone and coral tools, ornaments, spindle whorls). Tools for processing plants were common in the midden and included elkhorn coral grinding slabs, stone *manos*, bivalve shell scrapers to peel root crops, and staghorn coral rasps (cylindrical abraders) to shred *henequen* (a species of agave) into workable fibers that were spun into cord.

The cojoba was identified in a small milling base made of elkhorn coral (*Acropora palmata*). This artifact has an obvious use-wear pattern and a marked concavity on one of its surfaces (Figure 5). Although such concavities can be natural in this species of coral, this specimen is rounded along its borders, and individual polyps within the concavity have been ground smooth. The artifact is quite small, measuring 5.5 x 5.4 cm, with one broken edge. As reconstructed, the complete oval artifact would have measured 9 cm across.

The area where the coral tool was found contained four additional elkhorn coral grinding tools, stone *manos*, a broken triton's trumpet shell, and abundant pottery dominated by Esperanza-style wares. Located on the northern edge of the midden, this area appeared to be a special-use processing area with the artifacts deposited near the end of the occupation (ca. A.D. 1250).

Because of the coral tool's small size, it was likely not used to process food items such as flour or vegetable pastes. Other possibilities include (1) the processing of minerals, although there are no visible signs, such as pigmentation, on the used surface; (2) the processing of plant materials as condiments (seasoning items); or (3) the processing of plant derivatives for medical, ritual, or magical-religious purposes, such as the preparation of hallucinogenic powders. The coral milling base was chosen as one of eight artifacts (two stone *manos*, three ceramic griddles, and two potsherds with preserved food crusts) subjected to sediment extraction for this starch grain study.

The Archaeobotanical Finding of Cojoba in Eastern Puerto Rico

For starchy organs such as tubers, roots, and seeds, it is known that the morphology, size, chemical composition, and basic structure of a starch grain are characteristic for each species (Bello and Paredes 1999; Cortella and Pochettino 1994; Czaja 1978; Gott et al. 2006; Reichert 1913; Trease and Evans 1986). As other studies have shown, starch residues can preserve for a long time in the imperfect, irregular surfaces (e.g., pores, fissures, cracks) of lithic, coral, and ceramic tools related to the processing of plants (Haslam 2004; Loy et al. 1992; Pagán-Jiménez 2007; Pearsall et al. 2004; Piperno and Dillehay 2008). If starch grains can be extracted from a tool and correlated to the starch of a known plant, then a direct link can be established between the implement and the plant or plants that it processed.

Commonly, starch grain analysis is used in archaeology for recovering and identifying starchy plants used mainly as food sources or as food condiments (e.g., Henry et al. 2011; Mercader et al. 2008; Perry et al. 2007). The processing of starchy plant organs by grinding, pounding, or grating occurs for various reasons, most commonly (1) to eradicate toxins and make the plant edible (e.g., in the case of bitter manioc [*Manihot esculenta*] and marunguey [*Zamia* sp.]); (2) to make the plant organs malleable for producing single or compound recipes (e.g., pastes, *tortillas*); or (3) to separate starch from the resulting mass in order to create specific foodstuffs (e.g., breads). The case of cojoba provides a very different scenario. Cojoba seeds possess starch grains, as do other legumes, but, more importantly, they can be processed to create hallucinogenic substances. Cojoba starch grains are released from the seeds in the process of producing the fine powder destined for inhalation. In this sense, recovery and identification of cojoba by its starches is 'incidental' in archaeological artifacts, considering that the true object of the many processes for manipulating cojoba seeds is the creation of the hallucinogenic substance found in the chemical compounds of the seeds. Although different from traditional interests of starch grain analysis in archaeology, in which subsistence is the main goal for interpretations, the same principles apply here for the recovery and identification of ancient starch grains derived from the production of hallucinogenic snuffs of vegetal origin.

Description of Modern Cojoba Starches Compared to Other Legume Starches

In comparing the morphometrics of modern cojoba starches with other species from the bean family Leguminosae, this study used the following published sources in addition to Pagán-Jiménez' own published reference collection (Pagán-Jiménez 2007): (a) three species commonly found in the Caribbean islands (*Phaseolus vulgaris*, *Canavalia rosea*, *Macroptilium lathyroides* [Pagán-Jiménez 2007:Appendix B]); (b) 8 different *Phaseolus* spp., 4 *Arachis* spp., 3 *Canavalia* spp., 2 *Vigna* spp. and numerous varieties within these species published by Piperno and Dillehay (2008:Supplementary material); (c) the starch grain description of *Phaseolus lunatus* published by Reichert (1913:386–388); and (d) six different specimens of *Phaseolus vulgaris* published by Babot (2007:154). For the analysis and quantitative discrimination of shapes among Leguminosae specimens, we used Pagán-Jiménez's database on his modern reference collection of starch grains, as well as images (qualitative discrimination) published by Piperno and Dillehay (2008) and Piperno and Holst (1998).

Starch grains from the mature (but not dried) seeds of modern cojoba (Figure 6) were collected by Pagán-Jiménez from an adult tree located at the Universidad de Puerto Rico, Río Piedras. The cojoba starches are mostly oval (61.9 percent regular oval, double-oval, irregular-expanded oval,

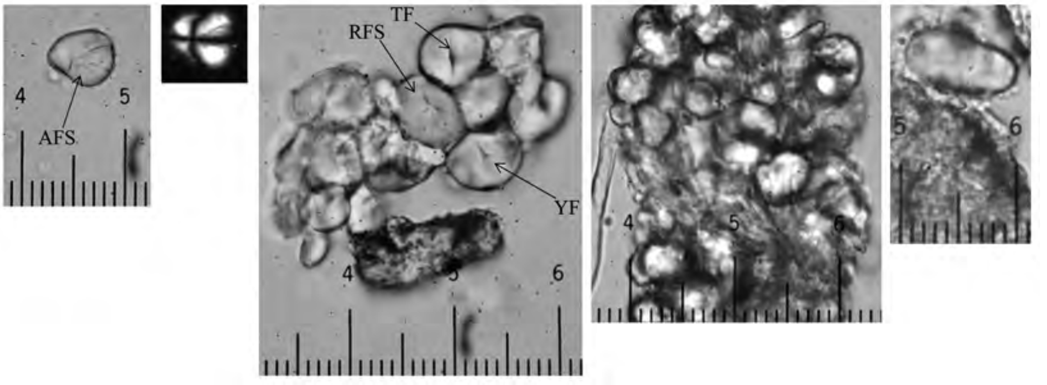

Figure 6. Modern starch grains from *Anadenanthera peregrina*. Starch grain from mature seeds and starch grain cluster showing shapes, dimensions, and types of fissures that are common in *A. peregrina*. AFS = asymmetrical fissures and striations; RFS = radial fissure and striations; TF = transversal fissure; YF = "Y" shaped fissure. Note: oval starch grain at the extreme right; transovate-obtuse starch grain at the extreme left. Scale for all microphotographs: space between major units (numbers) = 37.5 μm.

and irregular-oval) to spherical (17.5 percent) in shape. Less common shapes registered are the truncated or bell-shaped (9.5 percent), the transovate-obtuse (4.8 percent), some polygonal variants (3.2 percent), and the elliptical and the triangular (1.6 percent each). In contrast, other Leguminosae species such as *Phaseolus vulgaris*, *Phaseolus lunatus*, and *Canavalia* spp. have starches that are often oval-to-ovoid or spherical in shape, but also commonly include the diagnostic oval-kidney shape (Babot 2007; Pagán-Jiménez 2007:Appendix B; Piperno and Dillehay 2008; Piperno and Holst 1998), which is totally absent in the cojoba starches. Other shapes, such as the elliptical, the truncated, the enlarged transovate-obtuse, the transovate-obtuse, the triangular, and the polygonal, have been registered in very few cases for these legume starches (Babot 2007; Pagán-Jiménez 2007).

Range in starch grain size of cojoba is from 4 to 38 μm, but the average size of the granules is 22 μm with a standard deviation of 5.7 (Table 2). Only *Phaseolus vulgaris* is close in size range and standard deviation to cojoba (Pagán-Jiménez 2007, but see Babot 2007; Piperno and Dillehay 2008).

The hilum, or central point, of the granule in cojoba starches is regularly visible, primarily in the smallest starch grains (34.9 percent of our modern sample). In other legume species such as *Canavalia maritima*, and *Phaseolus vulgaris*, the hilum is almost imperceptible. It has been clearly observed in only 11.1 percent and 3.2 percent of their starches, respectively (Pagán-Jiménez 2007). The position of the hilum is predominantly centric (55 percent) in cojoba, both in cases in which it was directly discernible and in cases in which the extinction cross was used to establish its position. The same tendency is observed with the position of the hilum in *Canavalia maritima*, *Phaseolus vulgaris*, and *Macroptilium lathyroides* (Pagán-Jiménez 2007), and in other legume starches (Babot 2007; Piperno and Dillehay 2008).

Less than 10 percent of the cojoba starches (primarily the larger ones) show any type of lamellae (concentric rings and symmetric circles made up of amylose and amylopectin). In contrast, *Canavalia maritima*, *Phaseolus vulgaris*, and *Macroptilium lathyroides* possess discernible lamellae (asymmetric circles) in 60.3, 36.5, and 90.5 percent of their starches, respectively (Pagán-Jiménez 2007). Margins in cojoba starches are characterized by a soft undulating line around the bodies in more than half of the modern grains studied. A similar tendency is observed with the margins of *Canavalia maritima* and *Macroptilium lathyroides* starches, while *Phaseolus vulgaris*, in contrast, has very regular or unaltered margins (Pagán-Jiménez 2007).

The fissures documented in our modern starches of cojoba show some diversity, different from other legume starches (see Piperno and Dillehay 2008), but this variability is restricted to the oval shapes. The radial (or asymmetrical) fissure (Figure 6) is the most common of all those

Table 2. Size Range, Mean, and Standard Deviation of Starch Grains from Different Plant Sources Mentioned in the Paper.

Taxa	Range of measures in μm[a]	Mean in μm[b]	No. of measures considered	Reference
Cojoba (*Anadenanthera peregrina*)	4–38	22 (± 5.7)	111	Pagán-Jiménez 2007
Common bean (*Phaseolus vulgaris*)	10–40	20 (± 6.1)	111	Pagán-Jiménez 2007
Lima bean (*Phaseolus lunatus*)	8–48	30 (Std.dev., unknown)	unknown	Reichert 1913
Jack-bean (*Canavalia maritima*)	10–53	28 (± 8)	109	Pagán-Jiménez 2007
Phasemy bean (*Macroptilium lathyroides*)	3–28	17.5 (± 3.9)	122	Pagán-Jiménez 2007

[a]Minimum and maximum.
[b]Standard deviation of the mean in parenthesis.

documented and occurs primarily in two of the oval shape variants. This type of fissure, which can be composed of a set of deep lines and/or thin striations projecting from the center to the edge of the granules, seems to be diagnostic of *Anadenanthera peregrina*, when compared to other Leguminosae (see Babot 2007; Piperno and Holst 1998). The second most common fissure registered in the oval cojoba granules is the transversal (see Figure 6), which is also the most common fissure registered in other legumes (see Pagán-Jiménez 2007; Piperno and Dillehay 2008; Piperno and Holst 1998). Finally, the third important fissure variant is the "Y" type (see Figure 6), which also occurs in oval-shaped cojoba granules, but is unnoticeable or nonexistent in other legume starches (Babot 2007; Pagán-Jiménez 2007; Piperno and Dillehay 2008). Other two minor fissure types were identified in the cojoba samples that are not registered in other legume starches (i.e., "T" type, expanded "m" type).

There is a frequent shape in our modern starches of cojoba that is almost imperceptible in many of the other legume starches cited above (except in *Macroptilium lathyroides*), and that is the transovate-obtuse shape (see Figure 6, left). Starches with this particular shape in our modern cojoba sample range in maximum size from 13 to 19 μm and typically show "T" and expanded "m" fissure types. However, outside the group of modern cojoba starch grains counted and analyzed for this morphometric characterization, but within the same sample preparation, it was possible to associate the transovate-obtuse shape with larger maximum dimensions (between 22 and 27 μm), as well as with radial fissures or thin striations that extend from the center to the margin of the starches. In *Macroptilium lathyroides*, this shape occurs in only 1.6 percent of the starches, has a maximum size of 15 μm, and is associated only with the transversal fissure type (Pagán-Jiménez 2007:226–227).

Ancient Cojoba Starch Identification in Coral Tool from CE-11

After carrying out basic protocols for extracting samples and separating starches from their soil matrix (following Pagán-Jiménez 2007), starch grains consistent with those stored in cojoba seeds were identified in the coral milling base from CE-11. Sixty-nine legume starch grains were recovered (Figure 7) with 64 granules documented in a cluster and the remaining five granules occurring individually. The predominant shape of the granules was oval or oval-to-spherical (Figure 7a, b, and d); however, elliptical and some truncated shapes also were documented. The maximum size of the granules ranged between 2 and 41 μm. In the better represented granules within the cluster, the common maximum size was 14 μm, while the less common but better distinguished starches ranged in maximum size from 27 to 34 μm. Only four starches, each larger than 30 μm, showed either of the typical lamellae variants of the Leguminosae family (symmetric and asymmetric circles).

The hilum was observed in the few cases (n = 12 or 17.3 percent) where it was possible to discern features with confidence, mainly in the truncated (bell-shaped) or spherical bodies measuring less than 10 μm. The number of starches with clear hilum features exceeds those recorded for the other comparative legume species. The position of the hilum, mostly centric, was determined mainly by the presence of the extinction (Maltese) cross. Birefringence of the starch grains was varied, with some reflecting high birefringence while others, mainly those bigger than 20 μm, showed

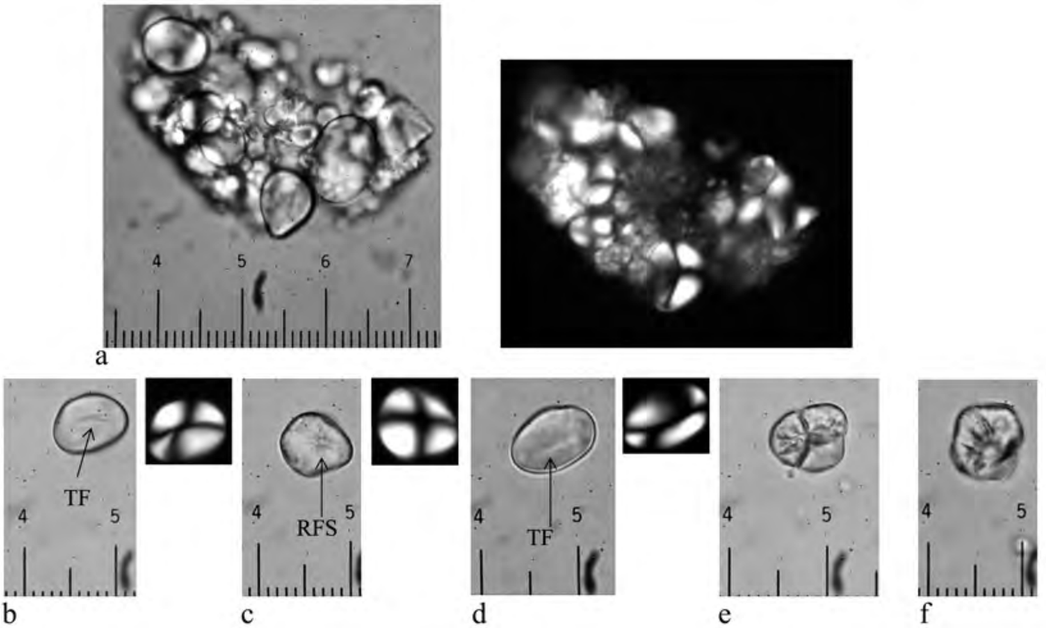

Figure 7. Starch grains recovered from the coral milling base from CE-11: (a) starch grain cluster from cojoba or *A. peregrina* (to the right is the same cluster cross-polarized in dark field); (b) oval starch grain with a transversal fissure (the same cross-polarized); (c) transovate-obtuse starch grain with thin striations and radial fissure that are typical of *A. peregrina* (the same cross-polarized); (d) oval starch grain (the same cross-polarized); (e) and (f) broken starch grains, probably broken by the grinding process. TF = transversal fissure; RFS = radial fissure and striations. Scale for all microphotographs: space between major units (numbers) = 37.5 μm.

limited birefringence and almost imperceptible extinction crosses.

Three of the four starch grains documented outside of the cluster showed surface fissures that are consistent with those documented in normal (unaltered) cojoba starch grains (Figure 7b and d), but also in starches altered by pressure (e.g., grinding). Some of the recovered starches revealed striations and cracks produced by grinding and processing seeds (Henry et al. 2009). Observed within the cluster was one broken starch grain and other granules with subtle extinction crosses; such alterations to the granule's structure may also have been the result of grinding (Figure 7e and f). Fissures observed were the "T" type and the radial (asymmetrical) type (Figure 7c), both of which were registered only in modern cojoba starch grains, as well as the cross type and abundant, thin striations that ran between the center and the edge of the starch grains. These last two cases (cross type fissures and thin striations) are here likely related to anthropogenic disturbance processes (e.g., grinding). This is why the cross type fissure is not registered in normal (unaltered) cojoba starches.

The granules found individually all share similar characteristics and also share characteristics with some of the granules observed in the cluster. All the granules identified on the coral milling base appear to be from the same legume species. The archaeologically recovered starch grains definitely do not match domesticated legumes such as *Phaseolus* spp. (common bean), or wild species such as *Canavalia* spp. or *Macroptilium lathyroides*, due to differences in many important and combined features including lamellae, general size range, fissure types, striations, and conspicuous shapes. The average starch grain size for this archaeological sample is 14 μm, with shapes that fluctuate between spherical and oval. Some of the more clearly visible starch grains within the sample were larger, between 27 and 34 μm, but some of them were probably enlarged due to grinding action. Table 2 provides specific grain size comparisons for legumes referenced in this study, but this same information was reviewed for other legume specimens in order to compare size ranges of starch grains from plants distributed across the Americas.

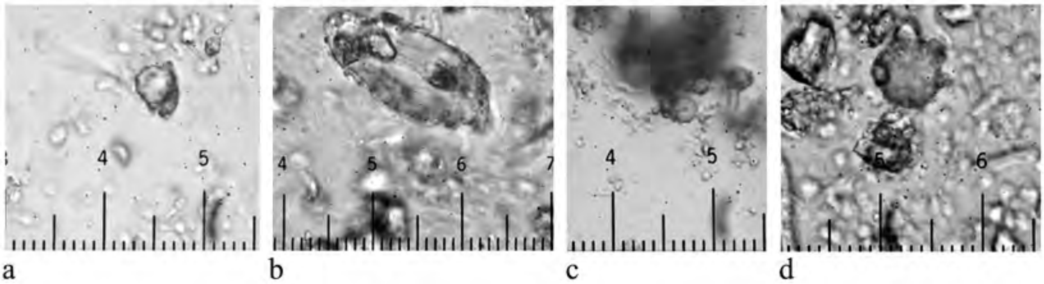

Figure 8. Modified and/or damaged starch grains from modern *Anadenanthera peregrina* (cojoba) seeds after parching (toasting). All the starches lost their extinction crosses, some of them (b) quadrupled their size due to the gelatinization process, and others (c) revealed a small circumscribed central depression ("scoop"). Scale for all microphotographs: space between major units (numbers) = 37.5 μm.

The combination of the smaller starch grains recovered from the cluster (with an average maximum size of 14μm) and the recurrence of spherical-to-oval granules (with no legume diagnostic kidney-shaped grains) that registered a size range between 25 and 35μm, together with the identification of transovate-obtuse starch grains found almost exclusively in cojoba rather than in other legumes (Figure 7c, compare with Figure 6, left), and the presence of "T" and asymmetrical fissures, are all characteristics widely consistent with those starch grains stored in the seeds of *Anadenanthera peregrina*—cojoba.

Based on these characteristics, we ascribe all the starch grains recovered in the coral milling artifact to cojoba or *Anadenanthera peregrina*, knowing that the granules generally coincide with those produced by a legume but do not match any of the known domestic or wild food species evaluated in this study. Matches between the retrieved ancient starches and those described for modern cojoba are quite clear.

An Assessment of the Processing of Modern Cojoba Seeds and Starches for Producing Hallucinogenic Powders

In order to create comparative starch grain samples of cojoba seeds that have been modified into cojoba snuff according to ethnographic accounts previously mentioned, the following process was undertaken. The primary author took mature cojoba seeds and submitted them to dehydration in two ways: (1) by slow, natural drying (in an indoor environment) and (2) by parching. In the first case, the seeds were set aside for three days to allow partial dehydration and then were macerated together with the seed coat using a mortar and pestle to create a paste. In the second case, the seeds were placed on a metal griddle for 40 seconds until they became partially toasted. The seed coats were withdrawn and the seeds were ground with a mortar. To produce the cojoba snuff, a mixture was created of equal parts parched cojoba seeds and heated and ground marine shells, which was added to 1.5 ml of distilled water and gently mixed. The resulting color of the paste was a clear gray to light brown. After being placed into an open container, the paste was left to dry naturally in the shade for four days, then subsequently ground to a powder that retained its clear gray color. The sample of naturally dehydrated seeds was similarly treated and, upon grinding, produced a fine, whitish powder with light green tonalities.

General observations were documented with an optical polarizing microscope (Figure 8) and clearly show an extremely high degree of alteration and destruction to the starches in the snuff that was subjected to heat. Very few starches retained their morphology and, of these, none retained their extinction crosses. Some starches gelatinized and multiplied in size (Figure 8b), and most of them were dramatically affected, making their identification nearly impossible (compare with unmodified modern *Anadenanthera* starches in Figure 6). Other features observed in the starches affected by heat were the formation of scoops (Figure 8c) and the prominence of multiple radial striations perpendicular to the edge of the starch (Figure 8d). Among the preserved diagnostic remains of cojoba within the seed after parching, we documented fragments of the microscopic structure of the seed coat, which is a microbotanic element with unique features that could serve to identify cojoba at the species level in future studies (see Pochettino et al. 1999). Based on this assessment, it is clear that the cojoba identified in the coral tool of CE-11 had not been toasted prior to grinding.

Conclusions: New Interpretations on the Use of Cojoba by the Inhabitants of CE-11

All the starch grains recovered in the coral milling base from CE-11 were ascribed to those produced in cojoba seeds. The small size of the coral milling base would have prevented it from producing large quantities of food, indicating a specialized use. In contrast to all the other artifacts analyzed in the CE-11 archaeobotanical study, which produced identifications of multiple food species on each artifact, this coral tool contained evidence of only one species. This in itself suggests that the coral milling base had a defined (restricted) use, and the fact that it is an alkaline substance (coral) may also have contributed to its specific function in processing cojoba (at least symbolically, if not literally). Based on the assessment described above, no sign of seed toasting was evident in the making of the cojoba snuff in CE-11. Considering that no highly decorated artifacts traditionally related to the cojoba ritual were found in the site, that the context of this find is within a small domestic household midden, and most importantly, that the seeds were not toasted as has been documented for the *ritual de le cojoba,* it is possible to suggest that the seeds of this plant were not used as part of the cojoba ritual, as we currently understand it. The evidence from CE-11 suggests two alternative scenarios for the use of this plant: (1) as a medicinal component (e.g., for the diagnosis of diseases and for healing); or (2) as an everyday stimulant (Schultes 1998:5).

In the first scenario, it has been documented both ethnographically and by early chroniclers that cojoba snuff was used by healers (*behiques* in the Antilles) to diagnose disease, using the hallucinatory effect of the drug as a vehicle for conferring with supernatural entities about the condition of the sick (Cassá 1995; Las Casas 1909; Pochettino et al. 1999; Schultes and Hofmann 2000). In the second scenario, the use of cojoba as an everyday stimulant has been documented ethnographically among the Jivi of the Orinoco (Schultes 1998; Schultes and Hoffman 2000), and this use is specifically outside of ritual or religious activities. Schultes and Hoffman (2000) have also described the inclusion of cojoba as an ingredient in the preparation of some food recipes (e.g., cassava).

Considering the small size of the artifact used to prepare the cojoba at CE-11 and its restricted use (processing one species only), it seems more likely that the function of this cojoba snuff was medicinal. Because of this specialized use, the ritual (religious sphere) or ceremonial (initiations, celebrations, consultation) uses of cojoba at CE-11 cannot be completely disregarded, even though the overall artifact assemblage did not contain sumptuary, high-status, or obviously ritualistic artifacts typically linked to the *ritual de la cojoba* by West Indian archaeologists and ethnohistorians (although large stone beads, red ochre, and fine pottery were recovered). It should be remembered that the midden-only excavations at CE-11 recovered just a sample of the total spectrum of artifacts that must have existed in the locality; and, it is likely that religious artifacts did not get discarded in the refuse midden.

This study resulted in the first identification of microbotanical remains consistent with cojoba in the West Indies. Because of the context of this find— a small habitation site dating to the Chican Ostionoid or Taíno period in eastern Puerto Rico—the identification has opened new avenues for understanding cojoba use in the precolonial Antilles, suggesting a broader range of situations where cojoba may have been utilized (e.g., in healing, as a stimulant, in food preparations) in addition to its most commonly documented use as an important part of ritual and religious activities. As a result, the discussion has moved us into areas that go beyond the economic concerns that generally permeate the phytocultural approaches developed by tropical paleoethnobotanists.

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Notes

1. The hallucinogenic tryptamines of the cojoba are dymethyltryptamine (or DMT), 5-hydroxydimethyltryptamine (or bufotenine) and 5-methoxydimethyltryptamine (5-MeO-DMT) (Blackledge and Phelan 2006).

2. "That cohoba is used to pray to it and to please it and to ask and find out from the aforesaid zemi good and bad things and also to ask it for riches... And their [cacique] is the first one to begin to prepare cohoba, and he plays an instrument; and while he is making the cohoba none of those who are in his company speaks until the [cacique] has finished. After he has finished his prayer, he stays awhile with his head lowered and his arms on his knees; then he lifts his head, looking toward the heavens, and he speaks ... and he relates the vision he has had" (Pané 1999:26).

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