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New Insights into Pre-Columbian Plant Use from Excavations at two Late-Ostionoid Sites in Eastern Puerto Rico

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Abstract - Pre-Columbian Jamaica: the sites in the landscape
Through the identification of starch grains, this study constructs direct associations between artifacts and human actions in the realms of plant procurement, processing, and use at two late-period habitation sites located on the former Roosevelt Roads Naval Facility in eastern Puerto Rico. Results highlight the use of plants in two different contexts – domestic (cooking) and medicinal (e.g., plants used for healing, as stimulants, and/or part of ritual or religious activities). Tentative identification of the hallucinogen cohoba (Anadenanthera peregrina) within the context of a small habitation site offers new insights into how this plant functioned in Antillean societies. An additional nine plants were identified from both wild and domesticated species that include various tubers (including manioc), beans, maize, and the red colorant annatto (Bixa orellana). This glimpse of the botanical cultures of two small occupations expands our understanding of how plants were obtained, processed, and cooked in this region in pre-Columbian times.
Key words : starch, food plants, hallucinogenic plants, cohoba, Ostionoid, Puerto Rico

Resumen
A través de la identificación de granos de almidón, el presente estudio desarrolla asociaciones directas entre artefactos y acciones humanas en el contexto del procuramiento, procesamiento y uso de plantas en dos sitios habitacionales tardíos localizados en lo que fue la Base Naval Roosevelt Roads en el oriente de Puerto Rico. Los resultados enfatizan el uso de plantas en dos escenarios diferentes – uno doméstico (cocina) y otro medicinal (e.g., uso de plantas para sanar, como estimulantes, o como parte de rituales o actividades religiosas). La identificación tentativa del alucinógeno conocido como cohoba (Anadenanthera peregrina) en el contexto de un pequeño sitio de habitación ofrece nuevas perspectivas acerca de la función de esta planta en las sociedades antillanas. Adicionalmente, fueron identificadas otras nueve plantas, tanto silvestres como domésticas, entre las cuales se documentaron varios tubérculos (incluyendo la yuca o mandioca), frijol, maíz y el achiote (Bixa orellana). Este atisbo a la cultura botánica de dos pequeñas ocupaciones humanas amplía nuestro entendimiento de cómo las plantas fueron obtenidas, procesadas y cocinadas en esta región en tiempos precolombinos.
Palabras claves : almidones, plantas alimenticias, plantas alucinógenas, cohoba, Ostionoide, Puerto Rico

Résumé
Par l'identification des grains d'amidon, cette étude construit des associations directes entre les artefacts et les actions humaines dans les domaines de l'acquisition des plantes, le traitement, et l'utilisation à deux emplacements d'habitation de tard-période situés sur le Roosevelt Roads Naval Facility dans l'est du Porto Rico. Les résultats accentuent l'utilisation des plantes dans deux contextes différents – domestiques (faisant cuire) et médicinaux (par exemple, des plantes utilisées pour guérir, comme stimulants, et/ou partie d'activités rituelles ou religieuses). L'identification tentative de l'cohoba hallucinogène (Anadenanthera peregrina) dans le contexte d'un petit emplacement d'habitation offre de nouvelles perspicacités dans la façon dont cette plante a fonctionné dans les sociétés Antillean. Des neuf plantes additionnelles ont été identifiées des espèces sauvages et domestiquées qui incluent de divers tubercules (manioc y compris), haricots, maïs, et l'annatto rouge de colorant (Bixa orellana). Cet aperçu des cultures botaniques de deux petites occupations augmente notre compréhension de la façon dont des plantes ont été obtenues, traitées, et faites cuire dans cette région dans des périodes précolombiennes.
Mots clefs : amidons, plantes alimentaires, plantes hallucinogènes, cohoba, Ostionoïde, Porto Rico

Introduction

In 2008, in collaboration with the U.S. Navy, archaeologists with Southeastern Archaeological Research, Inc. investigated four sites on the grounds of the former Roosevelt Roads Naval Station in eastern Puerto Rico at the Phase III level (SEARCH 2011) *(Figure 1)*. Two of these sites are prehistoric hilltop habitations (CE-11 and CE-33) that contain midden refuse and artifacts with the potential to reveal botanical remains. This paper focuses on the paleoethnobotanical aspect of this multidisciplinary research project. Using a microbotanical/microarchaeological approach, this study constructs direct associations between artifacts and human actions and thus has the potential to provide information on site function and other social dynamics. The new information gained from this work reveals internal ethnobotanical dynamics at each site (e.g., subsistence, plant procurement, plant processing), which can be incorporated into our understanding of prehistoric plant use for eastern Puerto Rico and for the cultural periods represented by both sites.

CE-11 is a hilltop habitation (10 m above mean seal level [amsl]) containing Cuevas, Santa Elena, and Esperanza-style pottery, as well as shell tools, animal bone, and lithics deposited within dense shell middens. CE-33 is a habitation located on a hillside terrace (20 m amsl) containing almost entirely Esperanza-style ceramics and a remnant shell midden. Both these small sites are proposed to have supported a single family household. It was not uncommon in the later Ostionoid period in this region for even very small hilltops to support habitation sites. The plants identified in this study come from small household contexts.

This paper discusses the results derived from the analysis of eight starch residue samples (five from CE-11 and three from CE-33) obtained from one coral tool, two stone tools, and five ceramic sherds (both bowls and griddles). The time frame pertinent to this starch-grain study can be bracketed by radiocarbon dates between approximately AD 1000 and 1450. This small sample produced both firm and provisional identifications of 10 different plant species and provides a glimpse of the botanical cultures at these two Ostionoid communities.

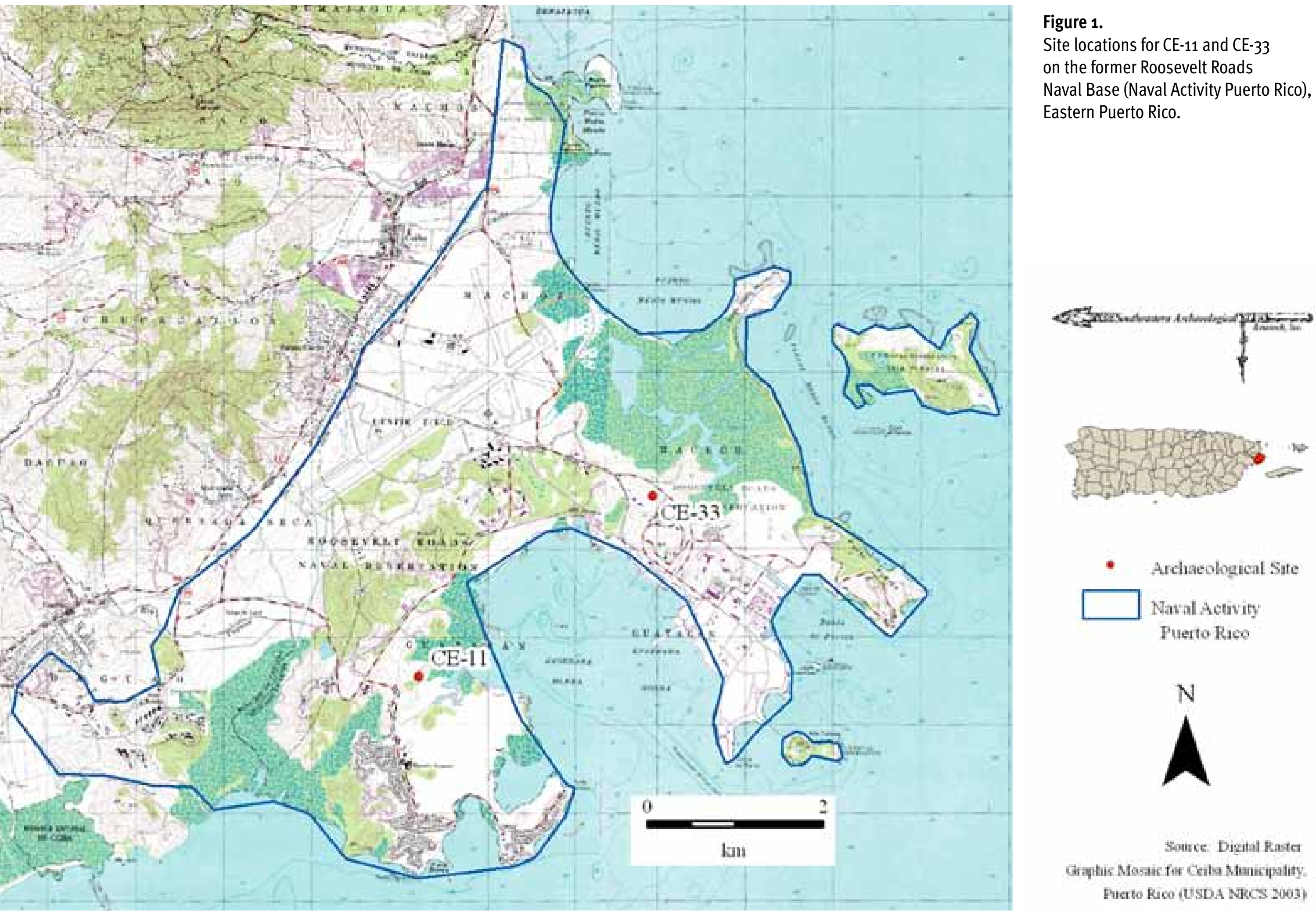

Figure 1.
Site locations for CE-11 and CE-33 on the former Roosevelt Roads Naval Base (Naval Activity Puerto Rico), Eastern Puerto Rico.

Results - Starches Identified

Artifact Sample-1

Artifact Sample 1 is as fragment of a small milling base made of elkhorn coral (Acropora palmata) that has an obvious use-wear pattern and a marked concavity on one of its surfaces *(Figure 2)*. Although such concavities can be natural in this species of coral, this specimen is heavily modified along its borders, and individual polyps within the concavity have been ground smooth. Because of its small size, 5.5x5.4 cm (reconstructed at 9 cm across), it is likely that this tool was not used to produce plant derivatives (e.g., flour, vegetable pastes) in large quantities. It is possible that the tool has been used to process plant materials used as condiments (seasoning items), or to produce plant derivatives used for medical, ritual, or magical-religious purposes. Another possibility for such a small grinding surface is the processing of minerals, although there are no visible pigmentation signs on the used surface. Having no doubt that the coral artifact was a tool, we extracted sediment samples from the used surface.

Sixty-nine starch grains, all from a legume, were recovered; 64 granules were documented in a cluster, and the remaining five occurred individually *(Table 1)*. Three of the four starch grains documented outside of the cluster showed surface fissures and thin striations that are consistent with features produced by grinding and processing seeds (Henry et al. 2009). All the granules on this object appear to be from the same legume species.

These recovered starch grains do not match domesticated legumes such as Phaseolus (common bean), due to differences in many important features including lamellae, size, fissure, striations, and conspicuous shapes (see Piperno and Dillehay 2008). The average starch grain size for our archaeological sample is 14µm, with shapes that are frequently transovate-obtuse. These characteristics are consistent with those starch grains recognized in seeds of the hallucinogen cohoba (Anadenanthera peregrina) with matches that are quite clear. Knowing that the archaeological granules generally coincide with those produced by a legume, while not matching any of the known domestic or wild species used for food, we tentatively ascribe all the starch grains recovered in the coral milling base to A. peregrina.

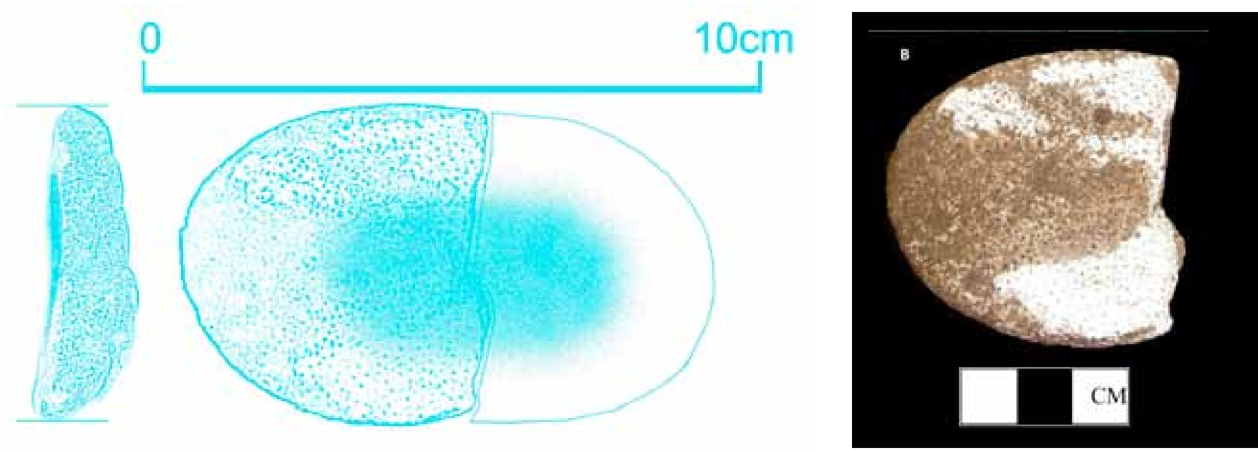

Figure 2. Coral *(Acropora palmata)* artifact from CE-11. A). Hypothetical form of the complete coral milling base in top and side views. Drawing by J. Pagán Jiménez. B). Coral milling base, top view. Note the abraded, rounded edges and used facets within the concavity. White sections were produced during the excavation process. Photograph by J. Pagán Jiménez.

Artifact Sample-2

This metavolcanic mano (pestle) fragment, made from tuff (greenstone), contains clear signs of pecking in one of its ends *(Figure 3-A)*. Sediment recovered from the pecked end of the tool yielded a total of 19 starch grains mostly of the genus Zamia (locally called marunguey). Other starches include a tentative identification of white cocoyam/yautía blanca (*Xanthosoma sagittifolium*) and an example of the genus Canna (locally called gruya or achira).

Marunguey is a cycad root, the edible portion of which is its subterranean stem, which can grow to 25 cm in diameter. It is pounded or grated and ground into flour, and contains toxins that must be eliminated before consumption. Starch grains ascribed to the genus Zamia were recovered in a cluster and share characteristics with documented modern specimens of the species Z. pumila, Z. erosa (syn. amblyphyllidia), and Z. portoricensis. Z. pumila starches were identified in another sample from CE-11, which advocates for this cluster being Zamia pumila.

The genus Canna was identified from a diagnostic granule. It was not possible to ascribe this sample to a particular species because the granule shows considerable damage on its surface (large cracks and striations); these are the result of food preparation that included pounding. Finally, two unidentified starch grains show evidence of gelatinization, which is a chemical/molecular change in the granules likely produced by the process of cooking the starch in a liquid base. The presence of these granules in a milling/pounding mano reveals that starches were processed with this tool after they had already been heated or cooked.

Table 1. Starch grains identified on five artifacts from CE-11.

Taxa	Sample-1 coral milling base	Sample-2 stone mano with a pecked end	Sample-3 griddle	Sample-4 pot fragment with charred residues	Sample-5 pot fragment with charred residues	Starch Count	Ubiquity[1] (%)
Tuberous roots, trunks, corms and rhizomes							
cf. *Zamia pumila*					1	1	20%
cf. *Zamia* sp.			1			1	20%
Zamia sp.		14				14	20%
Xanthosoma sagittifolium			3			3	20%
cf. *Xanthosoma sagittifolium*		2				2	20%
Calathea sp.				2		2	20%
Manihot esculenta					1	1	20%
Canna sp.		1				1	20%
Seeds							
Zea mays					3	3	20%
cf. *Zea mays*				1		1	20%
Leguminosae: cf. *Anadenanthera peregrina*	64 (cluster) + 5 isolated					69	20%
cf. *Phaseolus vulgaris*			1 (apparently gelatinized)			1	20%
Not Identified		2 (gelatinized)	5 (gelatinized)		1 (gelatinized)	8 (gelatinized)	----------
Starch Count	69	19	10	3	6	107	----------
Species Richness[2]	**1**	**3**	**3**	**2**	**3**		
Radiocarbon Dates (cal. 2-σ)	AD 1100-1120	AD 1030-1220	context not dated	AD 1150-1270	AD 1160-1270		
Cultural Association	Santa Elena Esperanza	Late Cuevas Santa Elena	Late Cuevas Santa Elena	Santa Elena Espe-ranza	Cuevas Esperanza		

[1] Ubiquity refers to the occurrence of the identified taxa between the sample spectra.
[2] Species richness combines both approximate ("cf.") and secure identifications.

Figure 3.
Artifacts from CE-11 and CE-33 sampled for starch grain study.
A). Mano (pestle) fragment with a pecked extremity (at left) (Sample-2) ; material is likely tuff (greenstone).
B). Ceramic vessel fragment with charred residue on interior surface (Sample-4)

Artifact Sample-3

This clay griddle produced a total of 10 granules from three plant species. Six of the granules are gelatinized indicating exposure to heat in a humid environment. One of the gelatinized grains could be tentatively identified as common bean *(Phaseolus vulgaris)*. An additional four starches were not gelatinized and could be positively identified as white cocoyam and marunguey. The three cocoyam granules showed some degree of damage caused by exposure to high temperatures or pounding. The remaining starch grain has sufficient morphological traits to ascribe it tentatively to marunguey (possibly Z. pumila). A pattern of thin striations runs from the center to the edges, which were likely formed by the action of pounding. All the starch grains recovered from this griddle were affected in one way or another by processes that are strictly cultural (heating or pounding).

Artifact Sample-4

One ceramic vessel fragment retained a thick, charred residue on its interior surface, which was subjected to both radiocarbon dating and paleoethnobotanical analysis *(Figure 3-B)*. Three starch grains were recovered, one tentatively identified as maize (Zea mays), and the other two ascribed to the genus Calathea (in the same family as arrowroot) ; Calathea zebrina (locally called zebra) or Calathea allouia (locally called lerén) are possible matches. The starch grain tentatively identified as maize has morphological and dimensional features found regularly in modern starches of this species, specifically in those flint varieties with hard endosperm such as some popcorns. In fact, the size of this grain is larger than all the varieties in our modern comparative collection except for Pollo, which is a primitive popcorn from Colombia and Venezuela.

Artifact Sample-5

A second ceramic vessel fragment with charred residue on its interior surface produced six starch grains, five of which could be identified to three different species—marunguey (cf. Zamia pumila), manioc (Manihot esculenta), and maize. One granule could not be identified due to gelatinization or heat damage.

Artifact Sample-6

Turning to CE-33, the clay griddle chosen for inclusion in this study showed clear patterns of having been subjected to heat. Analysis recovered 27 starch grains of which approximately 20 were found inside a package of cellulosic tissue. Four different plant species were identified from this griddle—marunguey, maize, arrowroot, and possibly the red dye annatto (Table 2). Two starches were identified as marunguey. The morphometric features documented in one of the grains allowed its confident identification as Z. pumila, thus allowing us to infer that the other starch grain comes from the same plant. Three individual starches have all the diagnostic traits of arrowroot. Similar features noted in the grains clustered together in the cellulosic tissue suggest these may also be arrowroot. Maize was identified from a single starch grain with all the diagnostic attributes for this species and especially those starches deposited in seeds of hard endosperm (flint) landraces (Cortella and Pochettino 1994; Pearsall et al. 2004). The final starch was tentatively ascribed to Bixa orellana (achiote or annatto), which can be used as a red colorant or as a cooking spice. This granule displayed a combination of features (shape, size, and lamellae) that resemble modern annatto starch grains. The grain displays a sort of roughness on its surface that has only been seen, to date, on annatto starches.

Table 2. Starch grains identified on three artifacts from CE-33.

Taxa	Sample-6 clay griddle fragment	Sample-7 stone mano with used facets	Sample-8 griddle rim	Starch Count	Ubiquity(%)[1]
Tuberous Roots, Trunks, Corms and Rhizomes					
Zamia pumila	1			1	33.3%
cf. *Zamia* sp.	1		1	2	66.6%
Maranta cf. *arundinacea*	3 and ~20 (cluster in cellulosic tissue)			3 and ~20 (cluster in cellulosic tissue)	33.3%
Seeds					
Zea mays	1	2		3	66.6%
Leguminosae-Fabaceae			1	1	33.3%
cf. *Bixa orellana*	1			1	33.3%
Not Identified			3 (gelatinized)	3 (gelatinized)	---------
Starch Count	~27	2	5	11 + ~20 (cluster) + 3 (gelatinized)	---------
Species Richness [2]	**4**	**1**	**2**		
Radiocarbon Dates (cal. 2-σ)	AD 1410-1470	context not dated	context not dated		
Cultural Association	Esperanza	Esperanza	Esperanza		

[1] Ubiquity refers to the occurrence of the identified taxa between the sample spectra.
[2] Species richness combines both approximate ("cf.") and secure identifications.

Artifact Sample-7

This complete metavolcanic mano (cf. tuff [greenstone]) contains various facets that show use-wear patterns related to the pounding or grinding of vegetables and perhaps other materials *(Figure 3-C)*. Testing yielded two starch grains, both identified as maize. This small number of recovered starches may be due to the low volume of sediment that could be extracted from the used facets. These minor facets contain few imperfections (cracks, fissures, etc.), which may indicate that this tool was used minimally before being discarded in this midden. The recovered maize starches both display features that are typical of maize races with hard endosperm (such as Pollo).

Artifact Sample-8

This griddle fragment displays post-production oxidation on both surfaces, showing its exposure to fire. The rounded and upwardly curved and thickened rim on this artifact may relate to a specific function for this type of griddle *(Figure 3-D)*. This form would more effectively contain foods with a high liquid content (Deboer 1975). Five starch grains were recovered from the griddle; two were tentatively identified as marunguey and a legume (possibly of the genus Phaseolus or Canavalia), and the other three were gelatinized. All five starches show different levels of alteration due to pounding, grinding, or boiling, resulting in the tentative identifications.

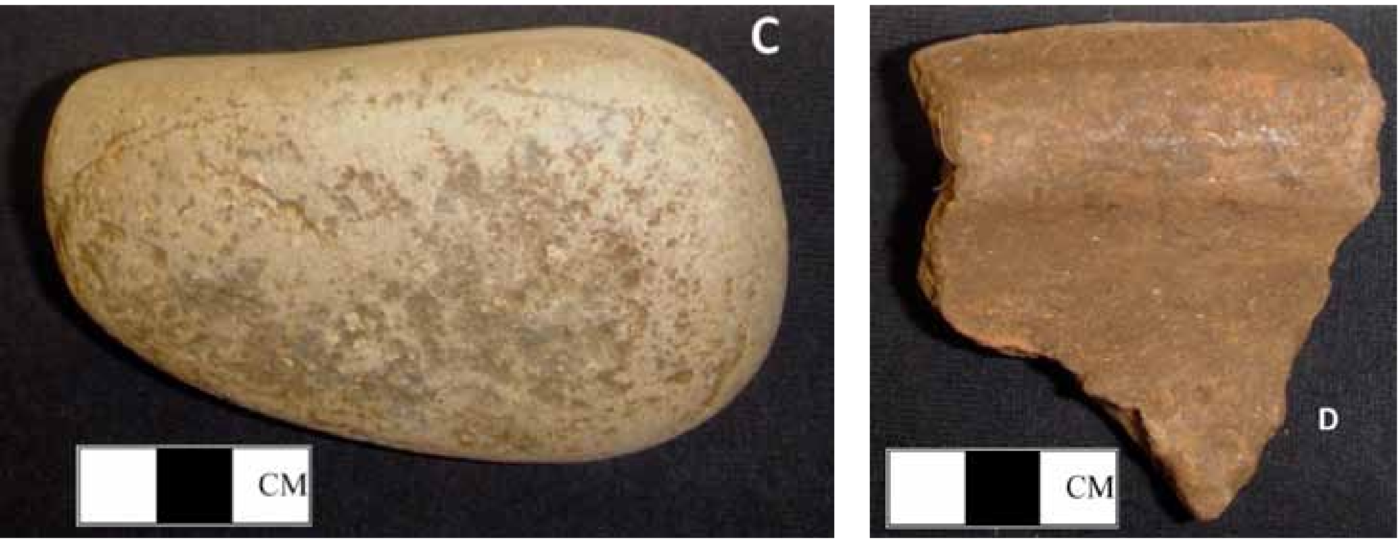

Figure 3.
Artifacts from CE-11 and CE-33 sampled for starch grain study.

C). Stone mano with multiple use-wear facets (on face, left end, and top) (Sample-7).

D). Clay griddle rim (Sample-8).
Photographs byJ. Pagán Jiménez.

Discussion - Plant Biographies

The plants identified in this study are mainly tubers, although edible seeds provide a significant portion of the subsistence items. Important food plants of the prehistoric Antillean people including manioc, maize, beans, cocoyam, arrowroot, and marunguey have been identified in this study. For the first time in American pan-tropical archaeology, the processing and/or handling of seed powders from cohoba have been tentatively identified. Previously, the only identification of this plant has been microscopic (Pochettino et al. 1999) and chemical (Torres et al. 1991) signatures noted on preserved snuff found in the southern Neotropics. A discussion of the identified individual plants follows in order of the plant's commonness and assumed importance in the subsistence practices of the people who lived at CE-11 and CE-33.

Marunguey

Marunguey was the most commonly identified plant across the sampled artifacts, occurring in three of the five artifacts from CE-11 and two of the three artifacts from CE-33. Every clay griddle sampled contained remnants of this plant; it also was found in the charred residue on the inside of one clay pot and on a stone mano.

This perennial belongs to the Zamiaceae family (order Cycadales) and grows wild and is native to Puerto Rico. Its natural distribution is associated mainly with the limestone (karstic) and serpentinite regions of the island. Two of the three Puerto Rican species of marunguey (Z. pumila and Z. erosa) grow in moist to dry forests and tend to form conglomerated populations as a result of their reproduction system (propagation by shoots or seeds). A third species (Z. portoricensis) does not form dense population clusters and is currently only found in southwestern Puerto Rico, a semi-arid region of the island characterized by karstic and serpentinite geology. It is possible to imagine that in the past at least two of the Puerto Rican marunguey species would have been relatively abundant and vigorous in the wild.

At present, natural populations of marunguey are unknown for eastern Puerto Rico, with the nearest documented populations in the south-central portion of the island. Several discrete limestone lenses in the south and west portions of Vieques, in the Loíza region in northern Puerto Rico, and in the region south of Naguabo could have supported natural populations of this plant in the past (Briggs and Akers 1965). If these plants never occurred naturally in eastern Puerto Rico, it is possible that its derivatives (e.g., flour) could have been integrated into regional trade networks (Rodríguez Ramos and Pagán Jiménez 2006). Alternately, this plant could have been transplanted and maintained in agricultural plots or house gardens along with other cultivated species.

Marunguey is a wild, high-yield food source of not only carbohydrates but also protein. However, powerful neurotoxins (cycasin) are found in all parts of this plant that require complex processing. After the underground, tuberous stems are grated, the pulp is submitted to various processes to remove the toxins. At least two different techniques for eradicating the toxic substance have been documented (Sturtevant 1969; Veloz Maggiolo 1992:137); one of these is biological (the action of enzymes and larvae), and the other involves multiple washes and squeezing of the pulp. The resulting flour is then made into bread called bollos (buns). Las Casas (1909) described the use of this plant on the island of Hispaniola in the 16th century and referenced the consumption of bollos cooked in pots with larvae :

> "Hácese el pan [de guáyiga o marunguey] de esta manera, conviene a saber, que en unas piedras ásperas como rallo, las rallan como quien rallase un nabo o una zanahoria en un rallo de los de Castilla, y sale luego una masa blanca y hacen della unos globos o bollos redondos, tan grandes como una bola, las cuales ponen al sol, y luego pónense de color de unos salvados o afrechos; están al sol uno y dos y tres días y al cabo dellos se hinchen de gusanos [larvas] como si fuese carne podrida, y quedan eso mismo tan negros poco menos que una tizne, como un negro algo deslavado que tira a pardillo; después que ya están en esta disposición, negros y hirviendo de gusanos tan gordos como piñones, hacen una tortilla dellos, que ya es masa cuanto a la blancura y ser correosa como la de nuestro trigo, y en una cazuela de barro que tienen ya sobre unas piedras, y fuego debajo, caliente, ponen sus tortillas, y desde un rato que están cociendo de un lado las vuelven del otro, donde bullendo con el calor los gusanos se fríen y mueren, y así quedan allí fritos."
>
> "The bread [of guáyiga or marunguey] is made thus, convenient to know, that on rough stones such as rallo [possibly pumice], you grate them as you would grate a turnip or a carrot on a grater from Castille [Spain]. This results in a white dough that is then formed into globes or round buns, as big as a 'bola' [possibly a reference to the balls used in the game bola], which are put out in sunlight until they attain the color of bran; if left out in sunlight one and two and three days at which time they will be swollen with maggots (larvae) as if it were rotten meat, and turn as black as soot, or a washed out black more brownish; once they reach this condition, black and boiling with maggots as fat as pine nuts, shape them into flat cakes, that are like dough already as to the whiteness and toughness, like our wheat, and in a hot clay pot that is already on rocks with fire beneath it, you place the cakes to cook on one side and then the other, where simmering with the heat, the maggots fry and die, and thus are cooked" (translation by the authors).

At CE-11, marunguey starch grains were recovered in a stone mano, in a griddle fragment, and in the charred crust of a ceramic pot. This suggests the maceration of the tuberous stem, followed by baking of bollos in pots and on griddles. Bollos made from marunguey have been documented from starch-grain studies at several late Saladoid (Cuevas) archaeological localities (Pagán Jiménez 2006, 2008a, 2008b), identified on griddles, cooking pot fragments, and lithic microflakes used as grater-board teeth. Marunguey continued to be a staple food through the late Ostionoid, as confirmed by its identification on two griddle fragments from CE-33 in addition to two later-period sites on Cuba (Rodríguez Suárez and Pagán Jiménez 2008). Recent studies continue to document the economic and dietary importance of marunguey (including its increased protein component provided by the insect larvae) to the prehistoric inhabitants of the Greater Antilles, securing its place among the more widely known dietary staples of this region (e.g., legumes, maize, and probably cassava).

Maize (Maíz)

After marunguey, the second most common plant in this study is maize, found in two artifacts from CE-11 (both clay pots) and two artifacts from CE-33 (one griddle and one stone mano). These findings show both grinding and pounding of the seeds from this plant and the cooking of the processed maize both on griddles and in ceramic bowls. Maize is a domesticated plant species that depends exclusively on humans for its reproduction and dispersal. Once the initial domestication began in Mexico (Piperno et al. 2009; Staller et al. 2006), maize was dispersed by humans in a relatively short span of time to other regions of the Americas. Maize entered the Antilles with the "Archaic" or Pre-Arawak peoples by at least ca. 3000 BC and has been documented for all the subsequent cultural periods in this region (Pagán Jiménez 2009, 2011). Although it is generally accepted that maize requires exceptional soils and climatic conditions for its successful production, it can be grown in rocky soils and specifically in silty clays, silty sands, and slightly plastic clay soils. Open or cleared spaces and sufficient water are key to its successful cultivation. Such an agricultural pursuit would have required consistent oversight of the cultivated plots.

The maize starch grains recovered in this study suggest multiple processing and cooking methods. The stone mano from CE-33 attests to the grinding of raw maize seeds. This conclusion is based on the fissures documented in the starches, which could only be produced by grinding the seeds when they were still hard. Ground maize flour could have been formed into a paste and baked on griddles as suggested by the starch findings at CE-33. Because multiple plant varieties are often identified on a single griddle, it is likely that recipes combined different foods. For instance, corn tortillas or bread may have been combined with other ingredients (plant, animal, or condiments) during the cooking process. An annatto starch grain, probably used as colorant or flavoring, was documented on the same griddle as the maize in CE-33. The finding of maize in charred crusts on two ceramic vessel fragments at CE-11 suggests a second cooking method. Both charred crusts produced multiple species: one vessel contained Calathea and maize; the other contained manioc, marunguey, and maize. It is possible that mixed vegetable pastes were being cooked in a water-based environment (boiled) in these pots. During the course of water evaporation, the plant paste forms a gelatinous mass that is susceptible to charring. An alternative to cooking the paste directly in boiling water is to wrap the paste in leaves and steam them like tamales (Rodríguez Ramos 2005).

White Cocoyam (Yautía Blanca)

Cocoyam starches were documented only in CE-11, found in a stone mano and a griddle. Cocoyam is native to northern South America and produces corms (the swollen base of an underground stem) with high nutritional value. But because it has abundant raphides (calcium oxalate crystals) in its corms that can cause suffocation in humans, pretreatment is required in the form of pounding and cooking. At least three species of cocoyam have been identified previously in Puerto Rican sites, found on coral milling bases, stone manos and mortars, and griddles (Pagán Jiménez 2007; Pagán Jiménez et al. 2005). Cocoyam can be grown both in fully cleared fields and in plots partially covered with vegetation (trees and bushes), where it develops with little care. Although this crop has been phenotypically modified by humans due to selection pressures, it has retained the ability to reproduce itself and thrive outside of cultivation.

Cocoyam starches recovered in the stone mano from CE-11 show that this plant was ground. Although these starches did not show any signs of alteration by heat (gelatinization), there were unidentified gelatinized grains on this stone artifact. It is possible that the corms were boiled first and then pounded (possibly to treat the raphides). In addition, the presence of cocoyam starches in the griddle fragment shows that these corms were cooked in the form of cakes or pastes, or as an auxiliary ingredient in other recipes. Marunguey starch grains were recovered on the two artifacts that contained cocoyam, suggesting that they may have been processed/cooked together.

Manioc (Yuca)

A single grain securely identified as manioc starch was recovered in the charred crust within a ceramic pot from CE-11, found in association with maize and marunguey. Manioc was not identified on any of the griddles or on either of the stone manos in this sample, and was not found on any tested artifact from CE-33. Manioc is a perennial shrub that reproduces mainly through the planting of its stems, and there are more than 100 related species distributed from southern Arizona to Argentina. Most species are native to arid or seasonally dry regions such as the tropical deciduous forests (Piperno and Pearsall 1998). Two areas have been identified as main centers of domestication: the Guianas and central Brazil. Manioc may be produced in almost any soil type, and with very little work it will produce high yields. Cultivation requires open, cleared plots for its successful production, although it can also be grown in home gardens with a slight cover of dispersed trees and shrubs. Manioc is generally regarded as the most efficient energy source among all the lowland tubers and roots (Piperno and Pearsall 1998).

The introduction of manioc to Puerto Rico dates to the so-called "Archaic" era, based on starch grains recovered on grinding stone artifacts dated to ca. 1290–890 BC (Pagán Jiménez et al. 2005). Although considered a staple of the diet in this region through all cultural periods, the presence of manioc is extremely minimal in artifacts studied to date. Ancient manioc starches have only been documented in eight (4.9%) of approximately 164 tools sampled so far from Antillean sites (Pagán Jiménez 2009). All these identifications correspond with artifacts used for pounding or grinding (manos and mortars of stone or coral) and come from "Archaic," La Hueca, Ostiones, and Esperanza cultural tradition sites (Pagán Jiménez 2007, 2009; Pagán Jiménez et al. 2005; Pagán Jiménez and Oliver 2008; Rodríguez Suárez and Pagán Jiménez 2008). None of the griddles analyzed so far (seven in previous studies and three in the present study) have documented manioc starches, even though such artifacts have been attributed to the cooking of manioc bread (cassava). A limited number of stone grater teeth, traditionally associated with manioc processing, have also been studied, and no manioc starch has been found. Interestingly, the species that are found in these "manioc-processing artifacts" are consistently maize, bean, arrowroot, cocoyam, and marunguey, among others (Pagán Jiménez 2009; see also Berman and Pearsall 2008; Perry 2004).

Among the cultivated varieties of manioc, the bitter species has been historically more esteemed, at least in lowland South America, even though it contains extremely powerful toxic substances (cyanogenic glycoside) that must be removed prior to consumption. Manioc tubers must be peeled, grated, washed, and squeezed in preparation for cooking. The finding of manioc on manos from previous studies shows that the manioc starch was ground into flour or paste, but the manner in which it was cooked is not clear. Perhaps the manioc was cooked and/or consumed in ways that are virtually unknown to the West Indies but resemble other ways of processing that are known from outside the islands. For example, some common recipes in Brazil are farinha and tapioca, both made with the manioc starch previously extracted by traditional means (grated, washed, and squeezed). These recipes involve the use of pots to heat the food paste, which usually consists of several mixed ingredients and condiments. Traditionally, farinha and tapioca were side dishes that were combined with other food products (León 1987:305; Montaldo 1977:211).

The recovery of manioc in CE-11 within a ceramic pot is the first identification so far for the West Indies of this starch in any sort of cooking vessel. This is evidence that the cooking process is not destroying the manioc grains or making them unidentifiable in the sampled artifacts.

Secondary Plants

Starches of seeds and rhizomes of other important economic plants were processed and/or cooked in these sites, although they appear to be secondary in importance to the species discussed above; they include wild/domestic Fabaceae (bean), arrowroot, calathea, and canna. All of these plants have consistently been identified in previous studies, recovered on a wide range of artifacts and spanning many cultural periods in Puerto Rico (Pagán Jiménez 2009). In contrast, annatto (Bixa orellana) has only been recovered previously in a single grinding tool in a north-central Puerto Rican site dating to the Ostiones (Pure) time period (Pagán Jiménez and Oliver 2008). Its recovery on a griddle from CE-33 is a unique find.

Fabaceae (Legume Family). In the world of economic plants, legumes are a substantial source of vegetable protein widely used in the Neotropics. Wild plants of the genus *Canavalia* (jack beans) and others from the genus *Phaseolus* (bean, both wild and domestic) have been consistently identified in previous studies in the Antilles (Pagán Jiménez 2009) and beyond (see Piperno and Dillehay 2008). In this sense, the intentional introduction of *Phaseolus* and *Canavalia* plants into the Antilles very likely occurred by at least 3000 BC, based on data from the site of Maruca in Puerto Rico (Pagán Jiménez et al. 2005). Wild bean species can be used as a food after processing the seeds through various grinding and cooking techniques. Processing is necessary due to the presence of cyanogenetic compounds in some wild bean seed coats and endosperm, which are poisonous and can cause damage to the human central nervous system (Ayet et al. 1996).

Wild species of the *Phaseolus* genera (with about 275 species and/or accepted varieties), as well as other legumes of economic importance (e.g., *Canavalia* sp.), are mostly perennials that are easily reproduced without human intervention, accepting of many soil types, and tolerant of salinity, low fertilization, and water scarcity. However, the two species most commonly related to prehistoric human subsistence in the American hemisphere, *Phaseolus vulgaris* and *Phaseolus lunatus,* are annuals that require cultivation in partially or fully cleared plots. Domestication of *P. vulgaris* and *P. lunatus* occurred simultaneously in Central America and South America (Piperno and Pearsall 1998). In cultivation areas located on the periphery of sites, domesticated beans would have been planted in open plots (possibly together with maize), while wild beans could have been tended in either open or partially cleared plots.

Two bean starch grains were identified in this study: one wild legume (Fabaceae) was recovered from a griddle in CE-33, and one gelatinized bean starch (cf. *Phaseolus vulgaris*) was recovered also from a griddle in CE-11. This gelatinized starch was recovered in association with marunguey and cocoyam. In CE-33, the wild bean was recovered in association with marunguey. It is possible that multiple vegetables were combined into mixed pastes prior to cooking, but it is also possible that as the griddles were used repeatedly, starches of various species were deposited over time within the cracks on its working surface. Compared to other archaeological sites studied in this region where legumes have been commonly identified on griddles in association with marunguey, maize, arrowroot, and sometimes sweet potato, the presence of legume starches in this study is surprisingly minimal (see Pagán Jiménez 2008a, 2008b; Rodríguez Suárez and Pagán Jiménez 2008).

Marantaceae (Arrowroot Family). Arrowroot was recovered from CE-33 and calathea was recovered from CE-11. Arrowroot *(Figure 4)* is a perennial plant that originated in the northern lowlands forests of South America (Montaldo 1977; Piperno and Pearsall 1998). It has a high nutritional value and, unlike many of the other foods identified in this study, is easily digested. Arrowroot has been used to treat people with stomach problems (especially diarrhea) and in some cases used as a food specifically for infants because of its easy digestion (DeFilipps et al. 2004). Arrowroot has medicinal properties as well, and is used in the treatment of wounds or irritated skin. Sturtevant (1969) suggested that this plant was used by the Caribbean indigenous people as an antidote for poisoned arrows.

Calathea is similar in its characteristics to arrowroot. Although it was not possible to assign specific taxa to the documented calathea starch, any of the approximately 250 species of this genus have rhizomes or tubers that are edible or contain important healing components (DeFilipps et al. 2004). Both arrowroot and calathea thrive in partially cleared plots or even under light canopies within silty sand or sandy loam soils. The cultivation of arrowroot and/or calathea may have occurred in a small house garden on the periphery of the site that would have also contained useful medicinal plants and herbs, or both plants could have been maintained at the edges of nearby forested areas. Calathea was recovered along with maize in the charred crust within a ceramic pot, while the arrowroot was recovered along with maize, marunguey, and annatto in a griddle. This suggests that both these species were processed and cooked and used as food (probably combined with other ingredients) rather than used solely for medicinal purposes.

Figure 4.
The edible rhizomes of arrowroot (Maranta arundinacea).
Photograph by J. Pagán Jiménez.

Cannaceae (Canna Family). Canna was identified on a stone mano from CE-11. Canna is an herbaceous perennial that does not require human intervention for its reproduction, although it can be propagated by seeds or by planting the rhizomes. It grows in various climates and elevations and can tolerate full sun or partially covered settings (León 1987; Piperno and Pearsall 1998). Its economic importance is based on the easy management and minimal care that this plant requires, but also on the high content of starches in their rhizomes, which can be eaten boiled or roasted. Like arrowroot, canna starches are used in the preparation of food for infants and sick people due to its easy digestion. At CE-11, the raw rhizomes of this plant were processed by pounding with a mano. In CE-11, canna was found in association with marunguey and cocoyam; this along with the presence of gelatinized starches (cooked) in the stone tool points to the use of canna in the preparation of mixed culinary recipes.

Annatto. *Bixa orellana* (annatto) starches were recovered on a griddle fragment from CE-33, found in association with maize, arrowroot, and marunguey. The annatto plant is a perennial shrub that produces ovoid fruits containing seeds of economic interest *(Figure 5)*. It can be grown in all types of terrain in the lowland and middle tropics, and is often grown in home gardens in association with other fruit trees.

The most common use of annatto among the indigenous people of the West Indies was as an insect repellent, with an extract from the ground seeds applied to the skin (Las Casas 1909). Las Casas also reported the application of annatto coloring to the skin for ritual activities and in preparation for battle against enemy groups. Ground annatto seeds are currently used in Colombia as a colorant and flavoring ingredient in food preparations (Fonnegra and Jiménez 2007) and as a healing remedy for numerous conditions (e.g., inflammation, burns, diarrhea, gastritis), in which it is made into a poultice.

Because of the many documented uses of annatto, it is informative that this starch was recovered in a cooking utensil, found along with the greatest diversity of food plants identified in this study. In this context annatto was being used as colorant and condiment for other food items. This is the first such identification for the West Indies. In fact, the only other condiment or flavoring item identified to date in this region is the recovery of chili pepper starches (Capsicum sp.) (Berman and Pearsall 2008; Newsom and Wing 2004:155). Annatto seeds and a single starch grain have been recovered in Ostiones contexts from the Finca Valencia site and Cueva de los Muertos (both in Puerto Rico); in the latter case the identification of annatto starch from a spherical mano was tentative and related to a funerary ritual context.

Figure 5 : Annatto (Bixa orellana) shrub with its flowering fruits. Photograph by J. Pagán Jiménez.

Cohoba

Cohoba is an exotic tree species of South American origin that was introduced to the Antilles at an unknown date during the prehistoric era. 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 contained in its seeds, leaves, and bark. The current natural distribution of these species is restricted to South America, generally north of the Tropic of Capricorn. As an exotic, the *Anadenanthera peregrina* species is known today in some of the Lesser Antilles, Puerto Rico, and Hispaniola. Interestingly, specialized botanical literature reveal that it has never been introduced in Cuba or Jamaica. In Puerto Rico, discrete populations of cohoba 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 and Utuado). Generally, cohoba trees grow in partially cleared, low- to mid-elevation forests and are commonly associated with transitional ecozones (Brido da Costa et al. 2003). Macrobotanical remains (charred wood) of the genus *Anadenanthera* have been identified in the ceremonial archaeological site of Tibes in south-central Puerto Rico (ca. AD 500–900) (Newsom 2010; Newsom and Wing 2004). This finding establishes the presence of the genus *Anadenanthera* in the prehistoric Antilles at least by the Saladoid/Ostionoid transitional period.

According to Torres (1998), smoking pipes associated with the use of cohoba are found in northwestern Argentina, with the oldest archaeological examples dating to ca. 2100 - 1200 BC. There are also several archaeological contexts in Peruvian sites with abundant paraphernalia and botanical remains (seeds and preserved snuff) directly associated with the inhalation of cohoba that date to ca. 1000–800 BC. It has been proposed that cohoba was so important for prehistoric 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) suggest that cohoba, and the ritual associated with the cohoba snuff, originated in the Orinoco region of Venezuela. The wide distribution of this plant, including its presence in the Antilles, is a direct consequence of the human dispersion of the species.

In the prehistoric 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). European chroniclers Fray Ramón Pané (2004), Cristobal Colón (Colón 1892) and Bartolomé de Las Casas (1909), among others, documented the use of cohoba in rituals across Hispaniola. Those chroniclers made detailed descriptions on the social contexts (e.g., divine communication, divination, healing rituals) in which the hallucinogenic snuff was used (Oliver 2009; Oliver et al. 2008). The use of hallucinogenic substance in the Antilles dates from at least 500 BC through European contact (Fitzpatrick et al. 2009).

Although ethnohistorical references to the use of cohoba exist, only vague descriptions were made concerning the formulation of the hallucinogenic powder. Oliver (2008) has proposed that in the Antilles the hallucinogenic substance used in the cohoba ceremony came from the seeds of A. peregrina. He describes the process of preparing the seeds (Oliver 2008:175): the seeds 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." 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."

From a paleoethnobotanical point of view, starches that correspond well to those produced by cohoba seeds were identified in this study. In contrast to suggestions that the seeds were toasted prior to their grinding (Oliver 2008), our archaeological starches were not subjected to direct heat or accelerated dehydration produced by parching or toasting. Various experiments performed by the author indicates that the grinding of cohoba seeds in the coral milling base from CE-11 was done without previously subjecting them to parching or toasting.

Due to its size, the coral milling base could not have been used to produce large quantities of food. In contrast to all the other artifacts analyzed for this project, which contained multiple foods species, only one species was found on this coral tool. This in itself suggests that the coral milling base had a defined (restricted) use. Considering the contextual association of the coral milling base (within a domestic household) as well as the expectations for highly elaborate decorations of those artifacts traditionally related to the cohoba ritual, it is feasible to suggest that the seeds of this plant were used here in two possible scenarios: (1) as a medicinal component (for the diagnosis of diseases and/or for healing) or (2) as an everyday stimulant, as has been described ethnographically (Schultes 1998 : 5).

In the first scenario, it has been documented that cohoba snuff was used by healers (behiques) to diagnose disease, using the hallucination effect of the drug as a vehicle to confer with the 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, cohoba could be used on a daily basis as a stimulant, outside of ritual or religious activities, and even as an ingredient in the preparation of some food recipes (cassava, see Schultes and Hofmann 2000). Considering the small size of the artifact used to prepare the cohoba and its restricted use (processing one species only), it seems more feasible that the function of this cohoba snuff was medicinal. Because of this specialized use, the ritual (religious) or ceremonial (initiations, celebrations, consultation) uses of cohoba at CE-11 cannot be disregarded, even though the overall artifact assemblage did not contain sumptuary, high-status, or obviously ritualistic artifacts.

CONCLUSION

Specific functions for the artifacts in this study have been proposed, based on the physical characteristics noted in the recovered starches and observed in the tools that were produced by human action. In general terms, the artifacts analyzed from CE-11 and CE-33 show the following patterns of use and plant processing: (1) a small coral milling base was used exclusively in the maceration of raw cohoba seeds, or in the handling of cohoba powder previously processed with other tools; (2) stone manos were used to process (macerate/grind) both raw and cooked starchy stems, corms, and rhizomes of marunguey, cocoplum, and canna, and were used to grind maize seeds; (3) ceramic vessels were used for cooking mixed vegetable pastes containing maize, manioc, marunguey, and calathea; and (4) griddles were used for cooking bread, tortillas, and bollos made from maize, marunguey, cocoyam, arrowroot, and beans; annatto was integrated as a condiment or colorant. Two different culinary processes were identified—the direct cooking of the vegetable pastes in pots, and the baking of bread, tortillas, or bollos on griddles. In a broader sense, this study highlights that the processing of plant tubers and seeds existed in two different, but mutually influential, social settings—domestic (cooking) and medicinal (and possibly ritual), as seen in the identification of cohoba.

When we put the paleoethnobotanical information gathered here in the broader context of the studied archaeological sites across the Antilles, new knowledge is added about the sociocultural practices of the human groups who made use of these plants at the site, including information on subsistence and culinary regimens. Marunguey was the most common plant identified on the analyzed artifacts. Although this does not necessarily imply that marunguey was the main economic food plant, it does indicate that its use was consistent and "versatile," as it was recovered in multiple food processing and cooking contexts. This wild plant must have been integrated in the broader cultivation systems of these sites. We cannot discard the possibility that marunguey derivatives (e.g., flour) may have been part of regional exchange networks.

Maize was the second most common plant identified, and this demonstrates that the processing and consumption of maize goes well beyond previous assumptions about this plant. Maize has been interpreted as a "high-status" food resource in this region, supposedly consumed green or boiled by the indigenous elite (Newsom 2006, 2010; Newsom and Wing 2004). This species has been clearly and securely identified in 14 of the 15 Antillean archaeological sites studied by the author to date (including this study), and the contexts of its recovery include domestic (communal, ordinary, everyday use) and ritual and/or magical-religious situations and/or artifacts.

From the microbotanical perspective, manioc is almost imperceptible, not only in this study but in all others studies that have been completed so far in the Antilles (Berman and Pearsall 2008; Dickau et al. 2007; Pagán Jiménez 2007, 2009; Perry 2001, 2004). It is important to remember that the preservation of starch grains in artifacts that have been subjected to extreme heat has been proven over and over again (Babot 2006 ; Haslam 2004 ; Henry et al. 2009). It cannot be the case that all the manioc grains are being destroyed simply through the process of cooking. Even so, ancient manioc starch grains have been recovered from artifacts of almost all the cultural periods defined so far in the Greater Antilles, although its occurrence within each assemblage is slight and it has not yet been found on griddles. Manioc has been documented on stone manos, showing that the tubers were pounded or macerated, and it has been identified on coral graters. The presence of a starch grain positively identified as one from manioc in the charred crust attached to a cooking vessel fragment from CE-11 is the first archaeological microbotanical evidence for the cooking of manioc in the Antilles. Variable processing methods of this plant, beyond the usually accepted beliefs (grating, squeezing, and cooking on griddles), are starting to be established, and here we add data on a new way of preparing and serving manioc, until now unknown for the Antilles: either as part of a mixed vegetable paste, or with the end product being a purée.

Finally, the tentative identification of cohoba and its potential uses at CE-11 move us into areas that go beyond economic concerns. The possible use of cohoba within the context of a small habitation site dating to the Chican Ostionoid period opens new avenues for understanding cohoba use in the prehistoric Antilles, noting a broader range of situations where cohoba may have been utilized—in healing, as a stimulant, and as part of ritual or religious activities.

The plant assemblage identified in CE-11 and CE-33 can be viewed along with phytocultural practices connected through time and space across the island of Puerto Rico. While generally consistent with previous findings, the results of this study point toward what may be distinct culinary traditions determined by local cultures. Although similar plant products are used across the island, they can be created into locally distinct cuisine combinations, especially when considering the wealth of highly valued and accessible zoological ingredients that could be included into these recipes. This study provided new ethnobotanical information that allows us to better understand the people who made use of the spaces we now know as CE-11 and CE-33.

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