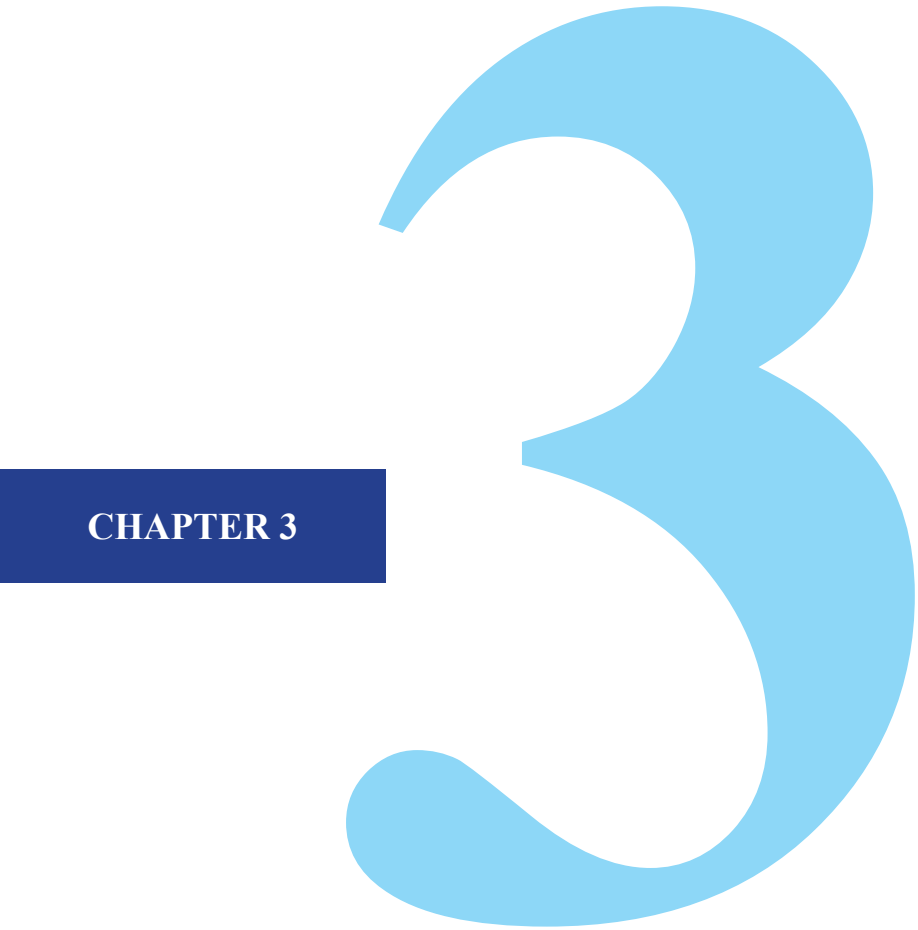
CHAPTER 3

Starchy Shells: Residue analysis of precolonial northern Caribbean culinary practices

Andy J. Ciofalo[1*], Peter T. Sinelli[2], and Corinne L. Hofman[1]

[1]Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333 CC Leiden, Netherlands

[2]Department of Anthropology, University of Central Florida, Orlando, FL 32816

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[1]Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333 CC Leiden, Netherlands
[2]Department of Anthropology, University of Central Florida, Orlando, FL 32816

Abstract
Determining culinary practices is critical for understanding phytocultural complexes, transported landscapes, and human niche constructions. Starch analysis is an exemplary method for reconstructing human-plant dependencies. However, certain types of artefacts from the Greater Caribbean region, such as flaked lithics, lithic griddles, coral artefacts, and shells, have not been extensively analysed for starch remains. Moreover, there has been no comparison of culinary practices between the Bahama archipelago and the Greater Antilles (the presumed origin of foodways transported to the Bahama archipelago). The paper investigates 60 bivalve shell artefacts for starch remains, which were recovered from three archaeological sites: El Flaco and La Luperona (Dominican Republic), and Palmetto Junction (Turks & Caicos Islands). In contrast to ethnohistorical narratives that characterize shell tools exclusively as manioc peelers, the starch remains recovered in this study suggest a broader suite of plants and functions. The results provide evidence that a diversity of plants (*Dioscorea* sp., *Dioscorea trifida* L., Fabaceae, *Ipomoea batatas* L., *Manihot esculenta* Crantz, cf. *Zea mays* L., cf. *Acrocomia media* O.F. Cook, and Zingiberales) were prepared with these shells. This new evidence contributes to ongoing discussions regarding culinary practices in the Caribbean and other related late precolonial (c. 800-1500 CE) foodways.

Resumen
El estudio de las prácticas culinarias es esencial para comprender los complejos fitoculturales, el transporte de paisajes vegetales y la construcción de nichos humanos. En particular, el análisis de almidones es un método ejemplar para la reconstrucción de las interacciones entre humanos y plantas. A pesar de ello, los residuos amiláceos depositados en ciertos tipos de artefactos provenientes del Gran Caribe –como la lítica tallada, las posibles planchas [de cocción] líticas, los corales modificados y las herramientas en concha– no han sido examinados exhaustivamente. Asimismo, no se han efectuado trabajos comparativos de las prácticas culinarias entre el archipiélago de las Bahamas y las Antillas Mayores (el posible lugar de origen de las tradiciones alimentarias a Bahamas). Con el objeto de remediar esta limitación, el presente estudio ha sido diseñado para investigar los residuos (almidones) extraídos de 60

herramientas de bivalvos. Estas herramientas fueron recuperadas en tres sitios contemporáneos: El Flaco y La Luperona (noroeste de la República Dominicana), y Palmetto Junction (Islas Turcas y Caicos). Los almidones recuperados explican el posible uso de los bivalvos, estableciendo que las herramientas de concha etnohistóricamente asociadas exclusivamente al raspado de la yuca fueron incorporadas en el procesamiento de una gama más amplia de especies y funciones. Nuestros resultados proveen evidencia empírica de que una diversidad de plantas (*Dioscorea* sp., *Dioscorea trifida* L., Fabaceae, *Ipomoea batatas* L., *Manihot esculenta* Crantz, cf. *Zea mays* L., cf. *Acrocomia media* O.F. Cook, and Zingiberales) fueron procesadas o preparadas con las herramientas de concha. En particular, los nuevos datos ayudan a ampliar los debates en curso en torno a las prácticas culinarias y las dimensiones de la alimentación en el norte del Caribe precolonial (c. 800-1500 CE).

Keywords: starch analysis, Caribbean, archaeology, culinary practices, shell artefacts, foodways, archaeobotany

3.1 Introduction

Based upon macroscopic and microscopic analyses, the presumed use of shells by Indigenous Caribbean Peoples was diverse, including bodily adornments, butchery knives, celts, chisels/gouges, fish hooks and descalers, hammers, knippers, net weights, perforators, and more, (Boomert 2000:324; O'Day and Keegan 2001; Petitjean-Roget 1963; Van Gijn et al. 2008). Lammers-Keijsers (2007) carried out extensive use wear and experimental work to better understand the functions of archaeological shells. Suggestions of bivalve shell functions embedded within botanical foodways include adzes, axes, cutters, scoops, peelers, and scrapers (Boomert 2000; Sauer 1966:51). However, because European written sources suggested bivalves were used to peel manioc (Fernández de Oviedo 1851 [1535]:270; Las Casas 1876 [1561]:147), the predominant assumption in the Caribbean had been that they were used primarily or even exclusively for this purpose (Keegan 2007:149; Loven 1935:359; Sturtevant 1969). Previous research that investigated starchy residues recovered from two shell artefacts from The Bahamas provided evidence that they were used to process or prepare maize, zamia, and manioc (Ciofalo et al. 2018). Worldwide, only two published studies have investigated more than two shell artefacts for starch remains (Allen and Ussher 2013; Barton and White 1993). Thus, shell artefacts should receive more attention to reveal their potential roles within ancient foodways.

3.2 Archaeological Background

Determining botanical foodways (Welch and Scarry 1995) has been critical for understanding phytocultural dynamics (Pagán-Jiménez 2013), transported vegetal environments (Berman and Pearsall 2008), and human niche constructions. Human Niche construction describes processes in which practices effect changes to their environments that modify the selection pressures on themselves and their descendants and foodways is a major component of these practices (Laland et al. 2007; Wollstonecroft 2011). Berman and Pearsall (2000) provided evidence for the use of domesticated geophytes and interpretations of maize agriculture on San Salvador, The Bahamas. While their studies focused on a time frame predating the present study, their questions and answers about transported landscapes to The Bahamas have provided avenues for us to extend these investigations (Berman and Pearsall 2008). The shell artefacts analysed in the present study were recovered from three chronologically contemporaneous archaeological sites in these regions. The two sites located in the northern Dominican Republic, which is an area of the Greater Antilles for the presumed origin of foodways transported to the Bahama archipelago (Berman and Pearsall 2008; Keegan 1992:47). Thus, this region is worthy for a comparison of foodways.

El Flaco (FL) (Fig. 3.1) was interpreted as a large hamlet with some permanent households and cooking huts (Keegan and Hofman 2017:129). This site has cultural sequences dated between cal 1309 ± 81 CE (Table S3.1). FL's bivalve shell remains are characterized by *Chione cancellate, Crassostrea rhizophorae, Brachidontes exustus, Donax denticulatus*, and *Codakia orbicularis* in descending order of frequency based on MNI. Zooarchaeological evidence suggests that the inhabitants of FL focused on consumption of terrestrial animals, based on the prevalence of bird, reptile, and mammal remains in the faunal assemblage, compared to that of marine-sourced animal remains (Shev 2018:177). Mollusk meat may not have been a common ingredient at FL, but several shells were modified and used for bodily adornments (Guzzo Falci et al. 2020); and are prevalent enough to have possibly been used as tools for agricultural activities, processing plants (including wood), and working clay.

Both Dominican Republic sites in this study were interpreted as hamlets of permanent households operating in a network of settlements (Hofman et al. 2018). La Luperona (LU) (Fig. 3.1) (cal 1352 ± 60 CE, Table S3.1) lies 9 km north of FL, across the Northern mountain range. LU is situated approximately 11 km from the coastal zone. Dwelling structures appear to have been surrounded by food preparation areas with hearths and there were land snails, marine

vertebrate, and sea shell remains along with terrestrial fauna all which characterized the subsistence remains (Hofman and Hoogland 2015a).

Palmetto Junction (PJ) (Fig. 3.1) is located on a cape along the western end of Providenciales, Turks & Caicos Islands, roughly 225 km from the northern coast of Dominican Republic. This archaeology site has cultural sequences dated between cal 1391 ± 41 CE (Table S3.1), and has been interpreted as a large village, which possibly functioned as a trading hub. This site is directly adjacent to both a creek and a bay, which provide access to a large fringing reef and open ocean to the west and the Caicos Bank to the south, respectively. Palmetto Junction is one of the largest sites in the Bahama archipelago encompassing approximately 2 ha of habitation and activity areas. More than twenty individual middens, which appear to be contemporaneous with each other based on the radiocarbon dates and material culture remains so far, have been archaeologically investigated and each contained a high frequency and density of pottery fragments and faunal remains, including fish, mollusks, and mammals. With less frequency, reptile remains were recovered from the middens. Palmetto Junction's bivalve shell remains are characterized by *Codakia orbicularis*, *Tellina* sp., *Liophora paphia*, and *Chione* sp. in descending order of frequency based on MNI. With an abundance of marine resource remains, apparently a substantial amount of seafood was prepared at Palmetto Junction (DuChemin 2005).

Table S3.1
The ^{14}C dates for these sites were provided by the authors, calibrated using OxCal 4.3 software (Ramsey, 2009) and the IntCal 13 atmospheric curve (Reimer et al., 2013).

Beta nr.	Site	Unit / Find nr.	Level	Material	^{14}C dates BP(±1σ)	Cal CE (±2σ)	Services
384425	Palmetto Junction	C	2	charred organic material	660 ± 30	1335 ± 58	radiometric
384428	Palmetto Junction	D	5	charred organic material	600 ± 30	1353 ± 56	radiometric
384427	Palmetto Junction	D	2	charred organic material	460 ± 30	1440 ± 28	radiometric
424979	Palmetto Junction	K	3	charred organic material	470 ± 30	1434 ± 23	AMS
374083	La Luperona	NA	NA	charred organic material	660 ± 30	1335 ± 58	AMS
374082	La Luperona	NA	NA	charred organic material	560 ± 30	1368 ± 61	AMS
374080	El Flaco	NA	NA	charred organic material	520 ± 30	1384 ±59	AMS
374081	El Flaco	NA	NA	charred organic material	700 ± 30	1324 ± 63	AMS
420874	El Flaco	2365	NA	bone collagen	430 ± 30	1519 ± 97	AMS
420891	El Flaco	2307	NA	charred organic material	1030 ± 30	1009 ± 107	AMS

Figure 3.1
Map of the northern Caribbean showing locations of El Flaco, La Luperona, and Palmetto Junction archaeological sites. Courtesy: Dr. Eduardo Herrera Malatesta.

3.3 Materials and methods

Table 3.1
Sample details. Zara Ali provided assistance identifying archaeological shells.

Lab ID	Shell taxa	Sample volume (ml)	Sample weight (g)
	El Flaco		
FL14	*Codakia orbicularis*	1.00	0.21
FL62	*Codakia orbicularis*	0.40	0.02
FL63	*Codakia orbicularis*	0.40	0.01
FL64	*Codakia orbicularis*	2.00	0.53
FL66	*Codakia orbicularis*	1.40	0.23
FL69	*Codakia orbicularis*	2.50	0.41
FL70	*Codakia orbicularis*	2.00	0.25
FL87	*Phacoides pectinatus*	1.50	0.31
FL99	*Codakia orbicularis*	1.20	0.25
FL104	*Codakia* sp.	1.00	0.28
FL134	*Codakia orbicularis*	2.00	0.23
FL135	*Phacoides* sp.	1.00	0.10
FL136	*Codakia orbicularis*	1.00	0.23
FL137	*Phacoides* sp.	1.00	0.06
FL138	*Phacoides* sp.	1.50	0.12
FL140	*Phacoides* sp.	1.00	0.05
FL309	*Codakia orbicularis*	0.50	0.05
FL311	*Phacoides pectinatus*	1.00	0.34
FL651	*Phacoides* sp.	1.20	0.34
FL652	*Codakia orbicularis*	1.00	0.37
	La Luperona		
LU27	*Codakia orbicularis*	0.80	0.04
LU28	*Chione cancellata*	0.50	0.01
LU55	*Codakia orbicularis*	2.50	0.33
LU58	*Codakia orbicularis*	1.50	0.45
LU63	*Codakia orbicularis*	0.50	0.12
LU66	*Phacoides pectinatus*	0.40	0.05
LU67	*Chione cancellata*	1.00	0.27
LU88	*Codakia orbicularis*	0.50	0.01
LU89	*Codakia orbicularis*	0.50	0.03
LU90	*Codakia* sp.	0.40	0.01
LU91	*Chione cancellata*	0.50	0.15
LU92	*Chione cancellata*	0.50	0.02
LU93	*Codakia orbicularis*	0.80	0.08
LU94	*Codakia orbicularis*	0.80	0.12
LU95	*Ctena orbiculata*	0.40	0.01
LU96	*Ctena orbiculata*	0.40	0.01
LU97	*Codakia orbicularis*	0.40	0.01
LU101	*Codakia orbicularis*	0.40	0.01
LU104	*Codakia orbicularis*	0.30	0.01
LU106	*Codakia orbicularis*	0.40	0.11

Palmetto Junction			
Lab ID	**Shell taxa**	**Sample volume (ml)**	**Sample weight (g)**
PJ3	*Codakia orbicularis*	0.10	0.10
PJ4	*Codakia orbicularis*	0.20	0.31
PJ5	*Codakia orbicularis*	0.05	0.11
PJ8	No ID	0.10	0.23
PJ30	*Chione* sp.	0.50	0.15
PJ31	*Chione* sp.	0.80	0.01
PJ32	Lucinidae	0.80	0.01
PJ34	No ID	0.50	0.04
PJ45	No ID	0.30	0.03
PJ46	*Liophora paphia*	1.00	0.09
PJ56	No ID	0.20	0.03
PJ57	*Liophora paphia*	0.20	0.05
PJ58	No ID	0.80	0.19
PJ97	*Liophora paphia*	0.60	0.06
PJ110	*Codakia orbicularis*	0.50	0.01
PJ111	*Codakia orbicularis*	0.20	0.01
PJ113	*Codakia orbicularis*	1.00	0.01
PJ115	*Codakia* sp.	0.50	0.09
PJ117	*Codakia orbicularis*	2.00	0.35
PJ147	*Liophora paphia*	0.40	0.02

The study examined 20 bivalve shells from each site, for a total sample of 60 (see examples Fig. 3.2 and details Table 3.1). At FL, the sampled shells were recovered from stratigraphic layers with contexts areas outside archaeological features (hearths, burials, post holes, etc.). At LU, shell artefacts were recovered from middens, habitation contexts, and areas outside archaeological features. At PJ, sampled shells were recovered from midden and habitation contexts.

Because scores of shells were recovered from each study site, a random selection of 20 was created to generate a representative sample of each of the three assemblages. The excavated shells were individually bagged in the field, handled minimally, and assigned a starch lab identification number that was entered into a random number generator on random.org (Haahr and Haahr 2018). Twenty integers were generated and the corresponding shells were sampled and analysed for starch content with the following procedure.

3.3.1 Starch extraction

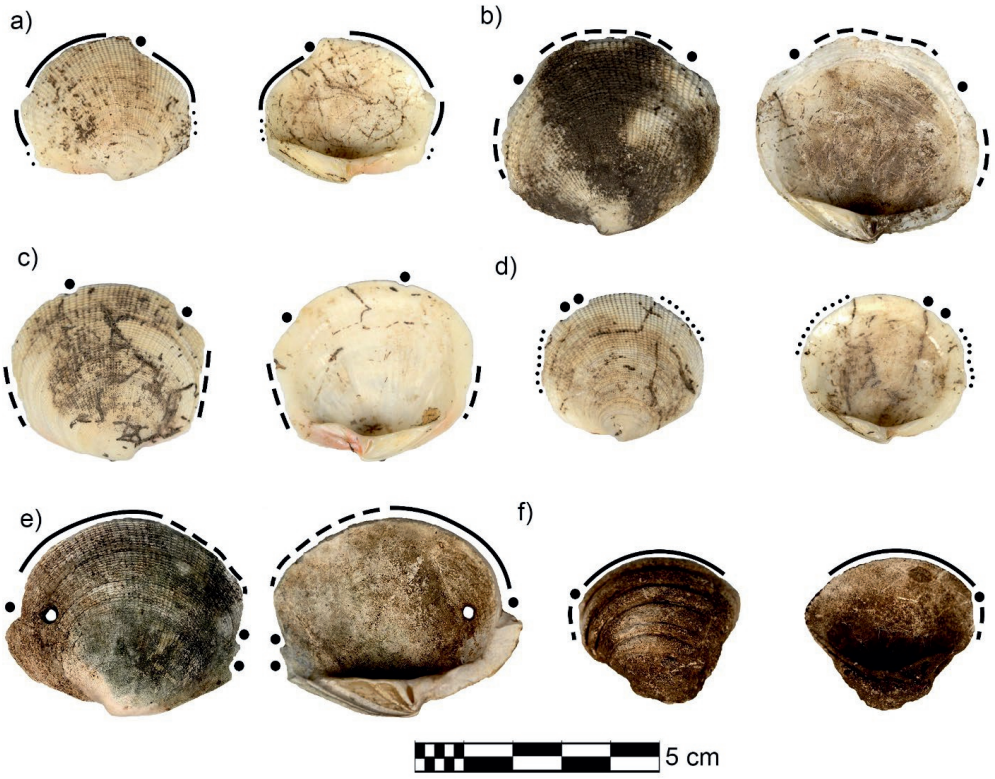

Figure 3.2
Selected shell artefacts from this study. Macroscopically visible wear produced relief of radial ribs and grooves at the ventral margins, which produced polishing (solid line), micro detachments (dots), and combinations of polishing, and micro-detachments (dashed lines). **a** FL66; **b** FL69; **c** LU27; **d** LU104; **e** PJ110; **f** PJ57.

To help comprehend how starch grains may accumulate on bivalve shells used for plant processing (and therefore, hone our extraction method), we used a *Donax* sp. shell to peel modern yam. The experiment displayed in Fig. 3.3 was designed to better determine where starchy residues collected during tool use and to demonstrate that even small shells (2.5 cm wide) could effectively peel underground storage organs. The shell used in this experiment was then sampled with the same protocols employed for the archaeological shells. The results indicate that small shells can function as geophyte peelers. In addition, it was observed that plant material collected on interior ventral margins and significantly in the interior aspect of the umbo. The plant material in the interior aspect of the umbo has the potential to counter claims that only botanical residues from the edge of a shell with demonstrated use-wear resulted from

ancient plant processing (Barton and White 1993). Indeed, the results demonstrate that a shell tool can retain thousands of diagnostic starch grains from across much of its surface.

The protocols used to extract starch from our bivalve samples were derived from Pagán-Jiménez (2007a), and modified from Barton et al. (1998); Dickau et al. (2012); Pearsall et al. (2004); Piperno et al. (2004). Each artefact was handled separately and lightly washed with ultra-purified water. This washing procedure removed much of the loosely adhered sediment, which was less likely to have been a part of the artefact's use-history (Barton and Torrence 2015). Each shell was then placed into a new plastic bag, covered with ultra-purified water, and allowed to soak for a period of 24 hrs. The bagged shells were then placed into an ultrasonic bath and sonicated for 9 min. After sonication, the aqueous sediments were transferred to new 50 ml tubes. As the shells were removed from the bags, particular attention was given to the interior aspect of the umbo and interior ventral margins, which means when macroscopically visible residues remained after the ultrasonic bath, those areas were scraped directly into the tubes with a sterilized dental pic, because those sections were where starchy tissues were visibly concentrated during our experiment (Fig. 3.3). The tubes that contained the samples were centrifuged at 3400 rpm for 6 min and the excess water was decanted. Samples were allowed to dry in a controlled lab environment, then volumes and weights were measured (Table 3.1).

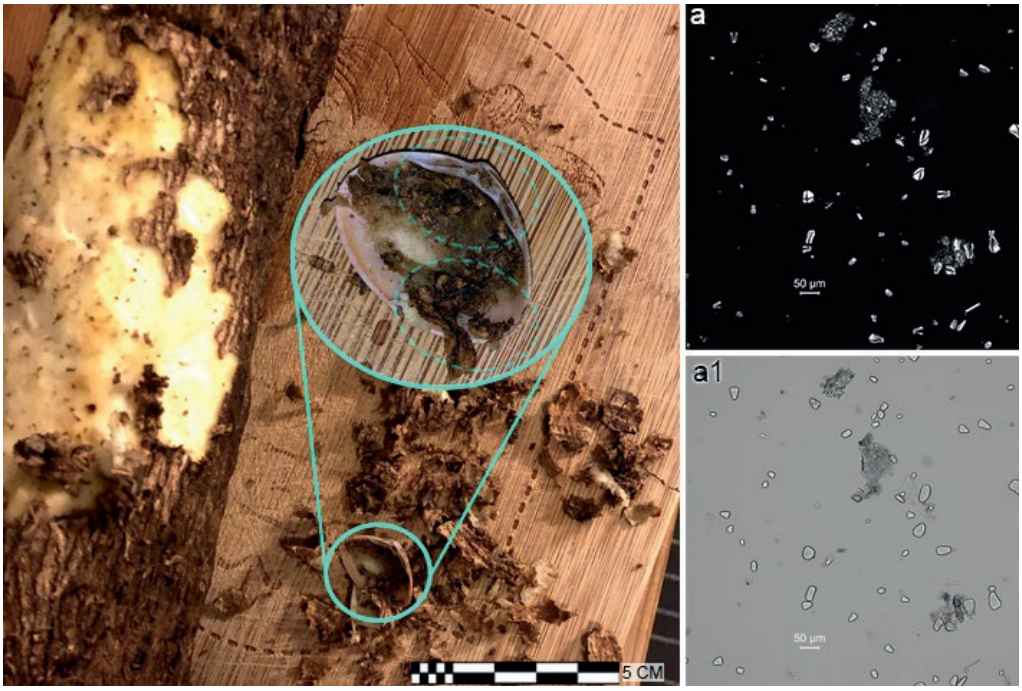

Figure 3.3
Bivalve shell used to peel modern yam (*Dioscorea cayennensis* subsp. *rotundata* (Poir.) J.Miège). Dashed ellipses highlight visible areas of concentrated starch collection in magnified image of used shell. **a** Sample of starch grains recovered from experimental bivalve shell tool under polarized light and dark field view. **a1** the same Sample of starch grains recovered from experimental bivalve shell tool under bright field view.

For this study, sediment samples from the artefactual contexts were not investigated for starch content. If residues recovered from artefacts are not also evident in the proximal soil, then starches extracted from the artefact's surfaces were more likely to have resulted from use of the artefact than depositional contamination. However, based on other studies, it is the authors' understanding that starches recovered from sediments surrounding artefacts were more related to transference from the artefact to the depositional contexts than vice versa (Pearsall et al. 2004). Alternative to investigating soil for starch content, a few ordinary objects (lithics lacking macroscopic wear traces) from the middens at Palmetto Junction were sampled and analysed for starch content. There were no detected starches from these control samples. In addition, 34 (57%) of samples extracted from the shell artefacts contained no recovered starch content (Table 3.2), which is an additional argument against ancient soil contamination and modern lab contamination.

Contamination both archaeologically and in particular, within the laboratory, are always possible issues (Barton et al. 1998; Crowther et al. 2014; Hart 2011; Loy 1994). Work surfaces

were consistently cleaned between each sample by thoroughly scrubbing with ultra-purified water and a new washcloth. Because starch has the potential to "piggy-back" (be transferred) on human hair, hairnets, facemasks, and gloves should be worn frequently (Crowther et al. 2014). However, during a routine contamination test on powder-free nitrile gloves, an unidentifiable starch was recovered (Ciofalo et al. 2018). Thus, no gloves were worn during laboratory procedures; instead, we thoroughly washed our hands throughout all laboratory protocols. In addition to gloves, the following all lab consumables were routinely tested for starch content, which produced negative results.

The dried samples were submitted to a flotation procedure to separate starches from other particles not of interest for this study. We prepared a solution of heavy-liquid cesium chloride (CsCl) to 1.79 g/cm^3, because starches were demonstrated to have an average specific gravity of 1.5 g/cm^3 or greater (Banks and Greenwood 1975). We subsequently added the same volume of solution as sample volume per 50 ml tube. We placed each tube into an ultrasonic bath for 1 min. This step in the procedure was deemed necessary for two reasons. First, because it has been inferred that plants were cooked prior to shell tool processing, the sonication presumably assisted in breaking apart any carbonized or conglomerated residues (Ciofalo et al. 2018). Second, the ultrasonic bath aided mixing the CsCl solution and residues. To further mix the solution and solid residues, cleaned separate glass-stirring rods were used to agitate the mixture per sample. The samples were then centrifuged at 2500 rpm for 8 min during the first phase of flotation. We decanted the supernatant into new 2 ml microcentrifuge tubes and filled them with ultra-purified water to initiate dilution. We then centrifuged the tubes at 9000 rpm for 8 min and the excess liquid was decanted. We added more ultra-purified water and carried out two more centrifuge cycles but operated the centrifuge for 5 min. During this phase, any recovered starches began to move down. After the last cycle, we added no water; instead, a small drop of glycerol (~.1 ml) was added. We slide mounted the remaining residue and glycerol solution. Finally, each sample was microscopically observed with a cross-polarized Leica DM2700 P at 400 X.

3.3.2 Starch identification

We counted, photographed, and described starches and then compared our findings with our modern starch reference collection for taxonomic identification. The utilized reference collection was established by Dr. Jaime Pagán-Jiménez and added to by Ciofalo, is currently housed at the Faculty of Archaeology, Leiden University, and consists of modern starches representing 140 individual specimens from 70 genera and 63 species of economic crops and

wild plants from the Antilles, the Bahama archipelago, and tropical continental Americas, as well as parts of the Old World. To aid in identification, published sources were also assessed (Pagán-Jiménez 2007a; Pagán-Jiménez 2015a; Pearsall et al. 2004; Perry et al. 2007; Piperno and Holst 1998; Reichert 1913). Particular attention was given to describing the starch characteristics of border, extinction cross arm morphology, compression facets, fissure, hilum, lamellae, size, and three-dimensional shape. When a starch did not have a qualified number (six) of diagnostic and/or distinctive features that matched our reference collection and published sources, the term "cf." was employed, categorizing that starch as an unsecure but probable identification. Damage patterns observable on the starches were compared to published food processing and other related starch damage experiments (Babot 2003; Babot 2006; Ge et al. 2011; Henry et al. 2009; Liu et al. 2018; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2015b; Pagán-Jiménez et al. 2017). Considering that 87% of the recovered individual starches were damaged, this was an integral part of the analysis and interpretations of the starch recoveries.

3.4 Results

Approximately, ~437 starches were recovered from 26 of the 60 shells (43%). Of these 26 shells with recovered starches, two had no macroscopically visible wear traces (Table 3.2). Because of starch clusters, only 329 individual starches were counted (Table 3.2). There were 32 unidentified starches, thus, 302 starch grains could be identified to various taxonomic levels. The broad spectrum of plants used at these sites includes: beans (Fabaceae), the flowering and rhizome producing order (Zingiberales), manioc (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L.), yam (*Dioscorea trifida* L. and *Dioscorea* sp.), as well as possibly maize (cf. *Zea mays* L.), and corozo palm (cf. *Acrocomia media* O.F. Cook).

Table 3.2
Identified starches per sample. [a] CL= starch cluster. Clusters were not included in the individual starch totals because they could not always be counted. [b] Minimum species richness combined both tentative ("*cf.*") and secure identifications, which excluded starches that were not identified because they could have been produced by some of the already identified taxa. [c] Heat damage is a presence/absence indicator of at least one starch recovered from the sample that was affected by heat, where Y=yes and N=no. [d] Macroscopic wear is a presence/absence indicator of visible wear produced relief of radial ribs and grooves at the ventral margins, micro detachments, or combinations of polishing and micro-detachments Y=yes and N=no.

	El Flaco																				
	FL14	**FL62**	**FL63**	**FL64**	**FL66**	**FL69**	**FL70**	**FL87**	**FL99**	**FL104**	**FL134**	**FL135**	**FL136**	**FL137**	**FL138**	**FL140**	**FL309**	**FL311**	**FL651**	**FL652**	**Total**
Manihot esculenta											1										1
Ipomoea batatas						1															1
cf. *Ipomoea batatas*						4															4
Fabaceae									1												1
cf. Fabaceae									1												1
cf. *Zea mays*			1														1				2
Unidentified	1	2	1			3 + [a] CL 5			1					1					[a] CL 3		9 + [a] CL 8
Individual Starches	1	2	2	0	0	8	0	0	3	0	1	0	0	1	0	0	1	0	0	0	19
[b]Minimum species richness	1	1	1	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1	0	--
[c]Heat damage	Y	N	Y			Y			Y		N			N			Y		Y		6
[d]Macroscopic wear	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	20

La Luperona

	LU27	LU28	LU55	LU58	LU63	LU66	LU67	LU88	LU89	LU90	LU91	LU92	LU93	LU94	LU95	LU96	LU97	LU101	LU104	LU106	Total
cf. *Manihot esculenta*																			1		1
Ipomoea batatas																	1				1
Zingiberales																			2		2
Fabaceae										1										1	2
Unidentified						[a]CL 7					2										2+ [a]CL 7
Individual Starches	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	3	1	8
[b]Minimum species richness	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	0	2	1	--
[c]Heat damage						N				Y	N						Y		N	Y	3
[d]Macroscopic wear	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	19

	Palmetto Junction																					
	PJ3	PJ4	PJ5	PJ8	PJ30	PJ31	PJ32	PJ34	PJ45	PJ46	PJ56	PJ57	PJ58	PJ97	PJ110	PJ111	PJ113	PJ115	PJ117	PJ147	Total
Manihot esculenta																		1			1
***Dioscorea* sp.**			1					1				206							45	9	262
Dioscorea trifida								1													1
cf. *Dioscorea* sp.												5							8	3	16
cf. *Acrocomia media*								1													1
Fabaceae		1								1									1		3
cf. Fabaceae													1						1		2
Unidentified		3+[a]CL~65						3	1	1		2	6	4					1		21+[a]CL~65
Individual Starches	0	4	1	0	0	0	0	6	1	2	0	213	7	4	0	0	0	1	56	12	307
[b]Minimum species richness	0	2	1	0	0	0	0	2	1	1	0	1	2	1	0	0	0	1	2	1	--
[c]Heat damage		Y	N					Y	N	Y		Y	Y	N				N	Y	Y	7
[d]Macroscopic wear	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	16

The recovered starches from FL's assemblage totaled 19 individual starches, of which 10 were identified as manioc, sweet potato, bean, and possibly maize (Table 3.2). From Sample FL69, there were four possible sweet potato starches identified and one securely identified sweet potato starch (Fig. 3.4 a, a1). This sweet potato starch measured 21.4 µm x 18.9 µm and had a polygonal shape with four flat compression facets with distinct margins. There was a diagnostic extinction cross that had two arms that appeared depressed. No lamellae were visible. These morphological features are consistent with sweet potato starches from our reference collection and published sources (Horrocks and Rechtman 2009; Pagán-Jiménez 2015a:54-57; Perry 2002; Piperno and Holst 1998). From Sample FL99, there were two starches identified as originating from beans, one was identified as Fabaceae (Fig. 3.4 b), and another was identified as cf. Fabaceae (Fig. 3.4 c). The securely identified bean starch grain measured 24.6 µm x 19.1 µm and had an elliptical shape with no compression facets. An eccentric, 'X'-shaped extinction cross, with curved arms was visible. Light and concentric lamellae were also visible. The diagnostic characteristics are consistent with Fabaceae starch grains of our reference collection

and published sources (Pagán-Jiménez 2015a:70-87; Piperno and Dillehay 2008). This starch had partial loss of birefringence and it was encrusted in particles, which are damage signs that have been associated with alterations from a dry cooking environment (Henry et al. 2009). From sample FL63, a cf. maize starch is shown in (Fig. 3.4 n, n1). The tentatively identified starch measured 13.7 µm x 13 µm and had a quadrangular shape with no compression facets. A centric, 'X'-shaped extinction cross, with two angular arms was visible. No lamellae were visible. However, a prominent double border was visible. The surface of the starch appeared bumpy. These features are found within our modern starch reference collection and published sources (Pagán-Jiménez et al. 2016; Pearsall et al. 2004). This starch is noticeably different, particularly the size, shape, and extinction cross from the LU sweet potato starch (Fig. 3.4 d, d1) described below.

The starches recovered from LU's sampled shells totaled eight individual starches, of which six were identified. We identified two starches as bean, two as Zingiberales, one as sweet potato, and one as potentially manioc (Fig. 3.4 f). This starch from Sample LU104 tentatively identified as manioc measured 33.5 µm x 27.0 µm and had a truncated bell shape with an undulating 'X'-shaped extinction cross. No lamellae were visible. There was a diagnostic stellate fissure. Most of these features fit diagnostic characteristics of bell-shaped manioc starches of our reference collection and published sources (Ciofalo et al. 2018; Ciofalo et al. 2019; Pagán-Jiménez 2007a:220-221; Pagán-Jiménez 2015a:68-69; Perry 2002; Piperno 2006:56-58). From Sample LU97, there was one starch securely identified as a sweet potato starch grain (Fig. 3.4 d, d1), which measured 10 µm x 8.8 µm and had a triangular shape with two flat compression facets displaying distinct margins. There was a diagnostic 'T'-shaped extinction cross that had two thin arms and two arms that appeared depressed in the distal areas. No lamellae were visible. The hilum was open and centric. These features are consistent with sweet potato starches of our reference collection and published sources (Horrocks et al. 2004; Pagán-Jiménez 2015a:54-57; Perry 2002; Piperno and Holst 1998). There was also an observed large central depression, known as a 'fold'; which occur as a part of the starch gelatinization process, and only occur in the presence of both humidity and heat (Biliaderis 2009; Henry et al. 2009). In addition, this starch had a border crack, which is evidence of exerted pressure or heat on the plant organ that generated this starch (Babot and Apella 2003; Vinton et al. 2009).

We recovered 307 individual starches from the Palmetto Junction samples. We identified the majority as yam (*Dioscorea* spp.) followed by beans (Fabaceae) (Table 3.2). We tentatively identified one starch (Fig. 3.4 j, j1) as palm (cf. *Acrocomia media*) coming from the pith (the

living tissue inside of the tree trunk). This starch from Sample PJ34 measured 9.6 µm x 9.1 µm, had a truncated bell shape with a slightly eccentric, three angular arms, 'X'-shaped extinction cross. No lamellae were visible. The hilum was open. There was a single, distal flat compression facet. Two examples of the recovered yam starch grains can be found in Fig. 3.4 k, k1, l, l1. The starch in Fig. 3.4 k, k1 from Sample PJ57 measured 11.8 µm x 9.6 µm, had an oval shape with an eccentric, undulating, X-shaped extinction cross. No lamellae were visible. The hilum was open and eccentric. There was a diagnostic distal concave compression facet. A different starch in Fig. 3.4 l, l1 identified as yam from Sample PJ57 measured 8.1 µm x 7.1 µm, had an oval shape with an eccentric, undulating, 'X'-shaped extinction cross. No lamellae were visible. The hilum was open and eccentric. There was a diagnostic distal concave compression facet. These two starches are exceptionally different from the yam species of *Dioscorea trifida*, so, we postulate that many of the yam starches identified from the Palmetto Junction samples were from a variety of yam that is absent from our reference collection. However, morphologically similar starches of archaeological and modern wild yam are present in published sources (Berman and Pearsall 2008; Dickau et al. 2012:193; Piperno and Holst 1998; Piperno et al. 2000). The starch in Fig. 3.4 m identified as domesticated yam (*Dioscorea trifida*) from Sample PJ34 measured 74.5 µm x 40.2 µm, had a triangular shape with a highly eccentric, undulating, 'X'-shaped extinction cross. A soft projection of angular, concentric lamellae was visible. These diagnostic features are consistent with our reference collection and published sources (Corteletti et al. 2015; Loy et al. 1992; Piperno and Holst 1998). In addition, this starch had a crack in its border, which is evidence of exerted pressure on the plant organ that generated this starch (Babot and Apella 2003).

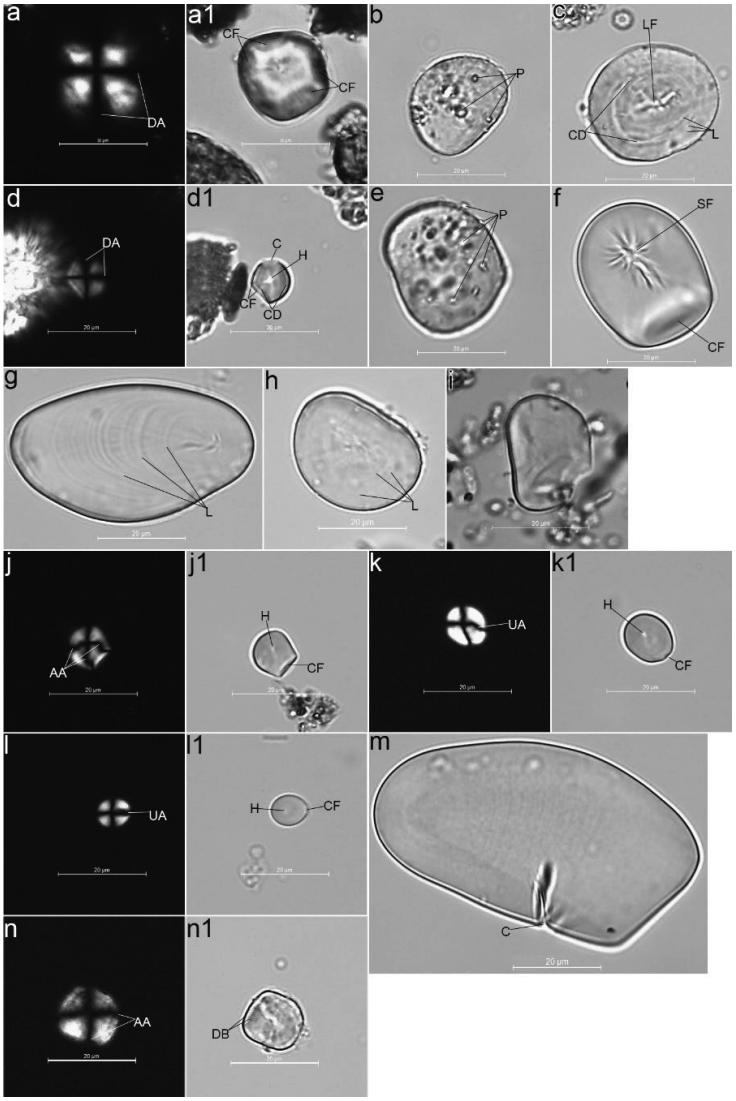

Figure 3.4
Examples of starch residues recovered from the 60 sampled shells. Grey background pictures are starches under bright field view and black background images are starches under polarized light and dark field view. **a** FL69, sweet potato starch. **a1** FL69, sweet potato starch. **b** FL99, bean starch. **c** FL99, cf. bean. **d** LU97, sweet potato starch. **d1** LU97, sweet potato starch. **e** LU90, bean starch. **f** LU104, cf. manioc starch. **g** LU104, Zingiberales starch. **h** PJ4, bean starch. **i** PJ46, bean starch. **j** PJ34, cf. palm starch. **j1** PJ34, cf. palm starch. **k** PJ57, yam starch. **k1** PJ57, yam starch. **l** PJ57, yam starch. **l1** PJ57, yam starch. **m** PJ34, domesticated yam starch (*Dioscorea trifida*). **n** FL63 cf. maize starch. **n1** FL63 cf. maize starch. Scale bar= 20 µm. Figure legend: "AA" angular extinction cross; "C" crack; "CD" central depression; "CF" compression facet; "DA" depressed extinction cross; "DB" double border; "H" hilum; "L" lamellae; "LF" lineal fissure; "P" particles; "SF" stellate fissure.

3.5 Discussion

Of the 334 recovered individual starches, 20 had signs of enzymatic degradation (including symmetric or irregular surface fractions, furrowing lines, pits) (Liu et al. 2018; Pagán-Jiménez

2015b; Vinton et al. 2009; Wang et al. 2017). The starches with signs of enzymatic degradation were possibly altered during storage of the plants when they naturally became degraded by enzymes before being manipulated with these shell artefacts. This process may have been intentional as in the case of certain recipes (Elias et al. 2000; Ray and Sivakumar 2009), or as a method of preservation (Flibert et al. 2016).

The culinary practices that caused damage to the starches were primarily from heat and pressure. Regarding the starches with identified folds, which can occur when food is cooked in clay vessels (Pagán-Jiménez et al. 2017), but they can also result from baking entire geophytes (Henry et al. 2009). Baking geophytes that have natural water content generates a partially humid cooking environment, yet, not all starches are gelatinized. Damage signs in the appearance of folds and loss of birefringence result from the starch gelatinization process, and only occur in the presence of both humidity and heat (Biliaderis 2009). The temperatures that starch typically completely gelatinizes range from 50-80 °C in humid cooking environments (Barton et al. 1998). At no point post-excavation, were the starches exposed to water and heat near these temperatures. If the folds were caused by lab processing, we would expect more than 11 of 334 starches to exhibit this type of heat damage. This leaves ancient culinary processes as a probable explanation for folds observed on the recovered starches. In these cases, some starches exhibit a range of damage signs due to various degrees of gelatinization including folds. Therefore, we put forth the possibility that some sweet potatoes were lightly baked before being peeled or further processed for incorporation in meals. The advantage of lightly baking geophytes would make processing easier or conceivably to release/exterminate other substances or entities (Pané et al. 1999:26). Whereas damage signs from pressure were plausibly generated from the use of the shell as a plant modification tool, heat damage was possibly caused from cooking plant organs prior to processing plants with the shell. Because more than 50 percent of the shells from each site had at least one starch recovered with damage characteristics due to heat, heating plants before, with the shells, or after use of the shells (i.e., peel-cook-scoop) was possibly a regionally embedded culinary practice (Table 3.2).

We postulate two possible explanations for the presence of palm (cf. *Acrocomia media*) starch on a shell artefact from Palmetto Junction. Either the shell was used to process fiber from the pith of a tree (Barton 2007), or alternatively, it was prepared with food that was cooked in palm oil (Kiple and Ornelas 2000:1805). The use of oils in ancient Caribbean culinary practices is a relatively underexplored topic (see exceptions Rodríguez Suárez 2004; VanderVeen 2006). In any event, this starch resembled those from the pith more than starches from palm seeds because

of the size, shape, and smooth visual appearance, suggesting that palm fruit was not processed with this shell.

We also posit three possible interpretations for the presence of bean starch on shell artefacts. First, we propose bean pods were cut or prepared with the shells. Second, the shells were used to scrape bean pods, which would warrant further investigations of starch content of modern bean pods. Third, cooked bean products were prepared and shells were used to scoop/spoon the dish (Pagán-Jiménez 2007b). We should envision these shells not solely as scrapers, but rather as manipulators (collectors, movers) of both raw and cooked.

Because five out of the 20 shell artefacts from Palmetto Junction had starches identified as tentatively wild yam and wild yam was not naturally dispersed in the Turks and Caicos Islands, it is possible wild yam from the Greater Antilles meaningfully contributed to Palmetto Junction's culinary practices (GBIF.org 2018). Future research will focus on expanding our reference collection to include more wild varieties of yam and beans. Wild or semi-managed plants such as zamia, yam, and beans were likely embedded in the phytocultural complexes of the Indigenous Caribbean Peoples who prepared meals at these sites. It will enlighten future studies to compare faunal and archaeobotanical datasets from these sites to evaluate relationships between the procurement of faunal and botanical resources.

Because the recovered remains of bivalve shells from LU were more abundant than from FL's contexts (Hofman and Hoogland 2015b), and the shells from Palmetto Junction had both more starches and a higher minimum species average recovered (Table 3.2), it is possible that the distance from marine resources created a difference in the use of bivalve shells. Perhaps the proximity to the coast or a variation of culinary practices contributed to this difference of archaeological starch remains. In addition, the Bahama archipelago has poor quality lithic resources for making plant processing tools (Keegan 1997:45). Thus, it is possible shells were more frequently used and perhaps used for longer durations to process plants, which contributed to more recovered starches and a higher minimum species average at Palmetto Junction. Alternatively, there is a possible taphonomic dilemma regarding preservation of starch at the sites in Dominican Republic from this study. Because the two Dominican Republic sites in the present study, their clay griddles (Ciofalo et al. 2019) and shell artefacts have had fewer starches recovered than sites from the Bahama archipelago (Ciofalo et al. 2018), bacterial, fungal, enzymatic, and changed chemical depositional environments could have contributed to less preservation (Barton 2009; Hutschenreuther et al. 2017).

Identifying culinary practices may reveal one of the most vital junctures ever produced by a cultural niche construction-the humanization and devouring of the vegetal environment. For the present study, the examined cultural niche was the way humans processed or prepared starchy plants with shells. If the culinary practices were successful, they were likely positively reinforced through cultural transmissions in the communities or regionally (Eerkens and Lipo 2005). From the data, it appears that processing or preparing heated plants with shells was a successful and reinforced culinary practice spanning these three sites. This does not imply that all three sites were connected or interacting, but perhaps they were situated within a constellation of practice (Wenger 1998:126-130). Interpretations from this data offer explanations regarding how cultural niches were constructed and which foodways offered modes of stability in dynamic environments. Manioc, sweet potato, beans, certain types of yams, and maize, were exogenous to the Greater Antilles and the Bahama archipelago. In addition, they require human assistance for cultivation (Tian et al. 2009). Accordingly, recoveries of remains of these plants imply mobility and exchange or ultimately transported landscapes from different areas to these islands. The comparison of results has exposed particular human niche constructions, several exogenous plant taxa that were mobilized, and possibly situated these sites within a constellation of practice.

3.6 Conclusions

We systematically excavated and then analysed these shell artefacts to reconstruct elements of human-plant dependencies. It is evident that more than seven types of siliceous plants were processed or prepared with the shells from these sites. The difficulty for wear trace studies to determine differences between shells that processed siliceous or non-siliceous plants has been demonstrated (Lammers-Keijsers 2007). Further, analysing wear traces alone will never be able to indicate which plant species were processed by a shell tool. Expedient shell tools probably used as scrapers have been interpreted from artefacts recovered from coastal sites in the Bahama archipelago (O'Day and Keegan 2001), but tools used only once do not always preserve detectable use-wear traces (Lammers-Keijsers 2007:138). However, remains of the starchy plants, which expedient tools processed may preserve for archaeologists to discover. This is not to argue for the primacy of one analysis over another, instead, we agree that an interdisciplinary approach of wear trace and residue analyses to create richer understandings of past tool uses is the way forward (Van Gijn et al. 2008).

The novel information drawn out of the recovered residues from these shells argues for a wider application of this type of research, particularly in research areas with limited organic

preservation. This study has identified the remains of a diversity of cultigens that were exogenous to these islands, which adds to previous interpretations of transported landscapes of both the Greater Antilles and the Bahama archipelago, demonstrating provisioning, access, and processing of plants that were transported to these islands (Berman and Pearsall 2008; Pagán-Jiménez 2013; Rodríguez Ramos et al. 2013). The findings have provided more evidence for the deliberate use of plants and have contributed to the discovery of culinary practices at these sites. In addition, we have created a richer understanding of culinary practices, phytocultural complexes, transported vegetal environments, and human niche constructions that incorporated bivalve shells.

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