Author: Ciofalo, A.J.
Title: Starchy foodways: Surveying Indigenous Peoples’ culinary practices prior to the advent of European invasions in the Greater Caribbean
Issue date: 2020-03-25

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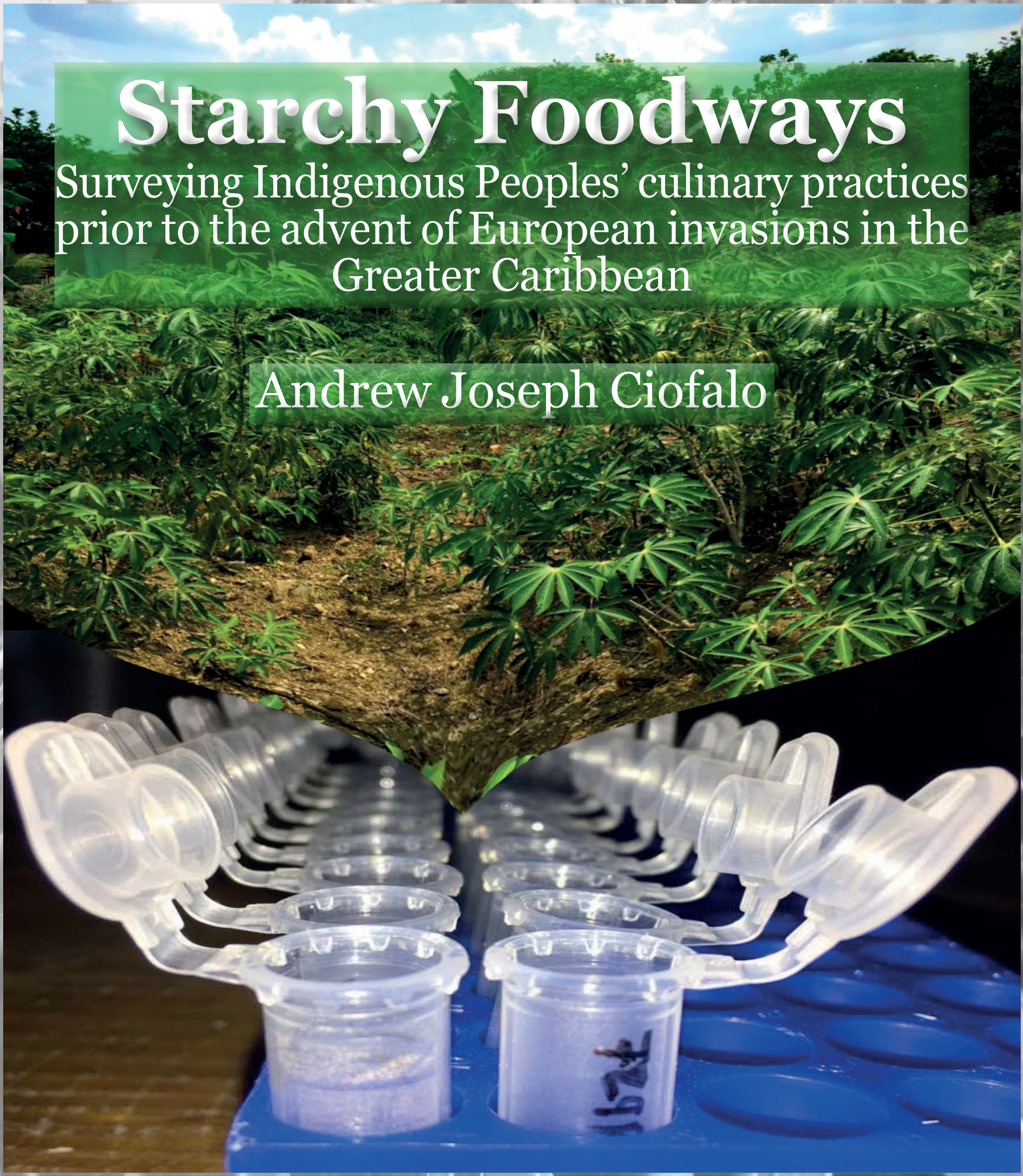
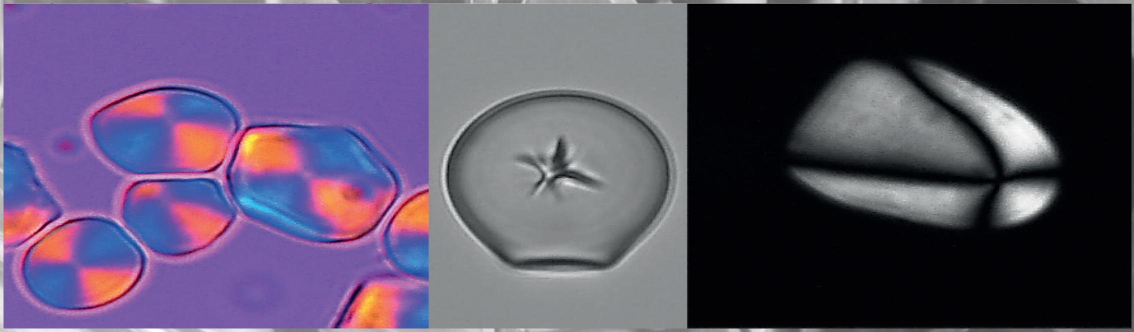
Surveying Indigenous Peoples' culinary practices prior to the advent of European invasions in the Greater Caribbean

Andrew Joseph Ciofalo





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Proefschrift
ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 25 maart 2020
klokke 13.45 uur

door

Andrew Joseph Ciofalo
Geboren te Colorado, Verenigde Staten
in 1984

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Preface

They tried to bury us. They didn't know we were seeds.

—Mexican maxim/Dinos Christianopoulos

This proverb is a powerful statement regarding oppression and resilience, but it also resonates deeply with the forgotten and buried stories that archaeologists excavate and reconstruct. The human requirement and use of food is so intrinsic it forms the base and echoes throughout Maslow's hierarchy of needs. The facts presented in this dissertation help retell lost or forgotten stories, which were essential because there has been a curricular genocide—erasing the memory of Indigenous Caribbean Peoples from many of our classrooms. Because Spanish policies of enslavement, genocide, and in due course mass murder are so egregious, it is tempting to only fixate on Indigenous Peoples' deaths, but they can seem chronogeographically distant and abstract unless we learn something about their lives. Therefore, even if this dissertation only makes one reader realize something about the worlds history it will contribute a reconstruction of a past that was forgotten, ignored, and destroyed. The power from these words may breathe life back into exhausted lungs.

My story begins from lasting memories that were forever imposed during my childhood from fresh breaths of the sweet air and experiences on my family's farm in Colorado, USA. It was here that I learned to love plants and understand that dietary plants can be medicinal as well. Twenty-five years away from that farm, I had a crisis. Visiting the University of Oregon for an interview to become a PhD student, I was asked a simple question: What topic do you want to study for your PhD? At the time, I was unprepared to answer this question other than a general statement about archaeological research in the Caribbean. On that trip to Oregon, I hiked the Eugene Mountains and had an epiphany while gazing up at the tall trees. Andy you were a vegetarian for 25 years, you grew up around plants, love nurturing plants, and watching them grow—become an archaeobotanist. It would take another year actualize that dream when beginning my PhD at Leiden University. Prof dr. Corinne Hofman introduced me to the renowned Dr. Jaime Pagán-Jiménez, or as he prefers simply Jaime. He taught me techniques used to address questions of human-plant interactions and how to research phytocultural dynamics. Before beginning this quest, I never imagined the beauty of looking through the microscope at ancient plant remains and the ensuing interpretations of culinary practices. The foodways approach for archaeobotanical investigations is knowledge I am now able to share with the world and take an immense pleasure with this responsibility.

Acknowledgments

The niche I have constructed would not have been possible without the context it was manifested from and that is why I first want to thank my supervisor; Professor dr. Corinne Hofman who has successfully challenged the boundaries of her discipline. Her influence, guidance, and charisma have caused me to reach for the moon and land amongst the stars. I am also thankful for the encouragement, input, advice, motivation, and intellectual support of my co-promotor, Dr. Jaime Pagán-Jiménez. Without his guidance, this dissertation would not have materialized, but more importantly the hours of conversations, family dinners, and comradery helped me persist through the trials and tribulations of attaining a PhD.

I have been indebted to the faculty of archaeology and the Caribbean Research Group at Leiden University for their countless hours of shared intellectual experiences, riveting debates, and advice. To Dr. Pete Sinelli, ten years ago he agreed to take on a daring task—converting a previous business student, then Maya archaeologist, into a Caribbean archaeologist, thank you Dr. Sinelli for sharing time with me chewing the mud in the field and showing me the ropes for providing education to future archaeologists.

I thank the present-day people of the Greater Caribbean for the opportunities to carry out this research. Their historical legacies are passionately admired. More specifically, I have a big thank you to the Antiquities, Monuments, and Museum Corporation in The Bahamas, Eric Salamanca, from the Department of Environment and Coastal Resources (DECR) in Providenciales. I am forever grateful to the many participants of the excavations in Dominican Republic, The Bahamas, Turks & Caicos Islands, and Nicaragua. Also, I thank the Nicaragua government administration facilitated by the Instituto Nicaragüense de Cultura, under the technical supervision of the Dirección Nacional de Arqueología.

Much of this work was made possible through funding from the ERC-Synergy NEXUS1492 project that received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 319209. This dissertation was also made possible due to a study trip fund from Leiden University, which was sponsored by the Leiden University Fund/ Byvanck Fonds. The Naturalis biodiversity center was helpful by providing samples to add to the starch reference collection, they deserve a lot of praise for their tedious task of maintaining an enormous national collection.

I am grateful the members of the reading committee—Prof. dr. Annelou van Gijn, Dr. Amanda Henry, Prof. dr. Corie Bakels, Prof. dr. Tinde van Andel, Dr. Mary Jane Berman, and all the anonymous reviewers of the articles for their insightful and constructive feedback.

A considerable thank you goes to the people who played a significant role in the coordination and administration of my education Dr. Arelis Arocho Montes (also, for her delicious home cooking and guidance based upon her own research and life experiences), Ilone, Dr. Maribel Adame, and Dr. Roswitha Manning. Dr. Mike Field took on the mission of providing an overview of archaeobotany for which my (at the time) green ears were thankful. Erica van Hees always provided words of encouragement, kept a clean lab, lead fun bike rides to Meijendel for botany excursions, and provided many essential cookies during coffee breaks. A special place will always be held for friends who became coauthors and coauthors who became friends- Natalia Donner, Dr. Bill Keegan, Dr. Alex Geurds, and Mike Pateman. My paranymphs Dr. Joseph Sony Jean and Weiya Li will always hold a special place in my experiences at Leiden University for being outstanding colleagues, amazing archaeologists, and dear friends.

The people I have shared an office with Dr. Jana Pesoutová, Dr. Tom Breukel, Gene, Carlos, Nacho, Marlieke, and Zara constantly encouraged me and provided significant comradery. As did the rest of my friends in the Netherlands: Alex, Alice, Alvaro, Dr. Amy Strecker, Ana (I've just seen a face), Dr. Andrew Sorensen, Dr. Andrzej Antczak, Angus Martin, Dr. Angus Mol, Anika, April, Dr. Arie Boomert, Arlene, Dr. Becki Scott, Cameron, Catarina, Christian, Dr. Csilla Ariese, Daniel, Devon, Dominique, Dr. Eduardo Herrera-Malatesta, Dr. Eldris Con Aguilar, Dr. Eloise Stancioff, Emma de Mooij, Dr. Emma Slayton, Eric, Dr. Felicia Fricke, Femke, Finn, Floris, Dr. Genner Ortiz, Dr. Hayley Mickleburgh, Heidi, Irini, Iulian, Dr. Jason Laffoon, Dr. Jay Haviser, Jay, Dr. Jimmy Mans, Dr. Jorge Ulloa-Hung, Katarina Katarina, Kaz, Kirsten, Kwinten, Dr. Lewis Borck, Lorenzo, Loe, Lou, Dr. Marlena Antczak, Dr. Meliam Gaspar, Dr. Menno Hoogland, Mireia, Dr. Noa Corcoran-Tadd, Dr. Olivier Carraz, Dr. Pauline Kulstad Gonzalez, Riia, Sahirine, Sam, Simone, Sjors, Sophie, Sven, Tibisay, Dr. Till Sonnemann, Tomomi, Dr. Uditha Jinadasa, Uli, Valerio, Wouter. Thank you also to my friends outside the Netherlands: Kurt, Dr. Arlen Chase, Tr3, Swamburger, Jeff, Brandon, Justin, Alex, Ashley, Nick, Samantha, Paul, Micah, and Jen.

Andy learning culinary practices

Finally, a huge thank you is due to my parents and sister, Gretchen, Joe, and Kellie all of them provided love, support, and guidance during times where I may have fallen but they were there to encourage me to get back up and keep going to challenge the limits of the unknown.

Contents

CHAPTER 1

1

Setting the Scene

Chapter 1 Setting the Scene

1.1 Introduction

Intangible dimensions of foodways such as culinary practices leave lasting impressions on memories and help form elements of group identities. Through starch recovery and analysis, archaeologists can reconstruct some of these culinary practices and view a picture of them through a window of time. There is a great view when you stand on the shoulders of giants. This dissertation was partially designed to enrich our understanding of Indigenous Caribbean Peoples' starchy food histories. This endeavor serves to add to what was known conceptually and methodologically from previous microbotanical analyses (Barton and Torrence 2015; Berman and Pearsall 2008; Pagán-Jiménez 2007a; Perry 2005; Piperno 2009).

Analysing cultural material remains that came from contexts prior to the advent of European invasions in the Greater Caribbean was ideal because one of several research objectives of the ERC- synergy NEXUS1492 project[1] has been to determine the "immediate and lasting effects of the colonial encounters on Indigenous Caribbean cultures and societies and what were the intercultural dynamics that took place during the colonisation processes" (Hofman et al. 2012). Reconstructions of late precolonial (800-1500 CE) Caribbean foodways have been pushed beyond relying on ethnohistorical texts and ethnographic analogies, to include direct evidence from isotopic dietary analyses, microbotanical remains, and zooarchaeological studies (Giovas et al. 2012; Laffoon et al. 2016; Mickleburgh et al. 2019; Pagán-Jiménez and Oliver 2008; Pestle and Laffoon 2018). Stable isotope evidence (from human remains) have reflected individual diets and large-scale changes of dietary regimens, although this innovative approach cannot provide evidence for similarities or variations in the selection of specific botanical food items and entangled culinary practices (Laffoon et al. 2016). It has been demonstrated that when utilizing starch recovery and analysis there is the possibility to accurately make taxonomic identifications of plant remains and infer the culinary practices which modified plants (Beck and Torrence 2006; Pagán-Jiménez et al. 2015; Pearsall et al. 2004; Perry 2005; Piperno 2006a).

Microbotanical research on samples of artifacts from the insular Caribbean region has exposed a diversity of plants prepared on griddles (food preparation platters) during the Late Ceramic

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[1] The NEXUS1492 project was funded by the European Research Council under the European Union's Seventh Framework Programme (FP7/2007–2013)/ERC-NEXUS1492 grant agreement n° 319209. The project was led by Profs. Corinne Hofman, Gareth Davies, and Ulrik Brandes from Leiden University, Free University of Amsterdam, and University of Konstanz.

Age (800-1500 CE), which included maize (*Zea mays* L.), sweet potato (*Ipomoea batatas* L.), beans (*Phaseolus* spp.), and coontie/guáyiga (*Zamia* spp.), among others (see Table 1.1). From a microbotanical viewpoint in the northern Caribbean[2], the understanding of botanical foodways is rather enigmatic, with notable exceptions from Cuba (Chinique de Armas et al. 2015; González Herrera 2016; Mickleburgh and Pagán-Jiménez 2012; Rodríguez Suárez and Pagán-Jiménez 2008) the central Bahamas (Berman and Pearsall 2000; Berman and Pearsall 2008), and Dominican Republic (Pagán-Jiménez in Ulloa Hung 2014 115, 138). In contrast, archaeobotanical studies of foodways in central Nicaragua have been absent. Thus, a focus of this dissertation is on ascertaining culinary practices in the Greater Caribbean from areas with few or no previous microbotanical studies. The Greater Caribbean (pan-Caribbean) region has been envisioned geographically as the seascape and continental areas proximally surrounding and including the insular Caribbean islands, and culturally speaking this includes the Bahama archipelago and the Central Americas, or at least the coastal regions of the surrounding continents (Berman 2011a; Hofman et al. 2010; Rodríguez Ramos 2010; Rodríguez Ramos 2011).

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[2] For the purpose of this dissertation, the definition of the northern Caribbean was areas of the insular Caribbean and Bahama archipelago north of the 19th parallel north latitude because this includes four of the case study sites and excludes areas that have previously been critically investigated by starch analyses (see Pagán-Jiménez, et al., 2005; Pagán-Jiménez, 2007; Pagán-Jiménez and Oliver, 2008; Pagán-Jiménez, 2008).

Table 1.1
Clay griddles analyzed for starch content and their identified taxa from insular Caribbean archaeological contexts.

Location	No. Griddles analyzed	Identified Taxa	Reference
Cuba	5	*Zamia pumila* L., *Phaseolus vulgaris* L., Fabaceae, *Zea mays* L., *Ipomoea batatas* L., *Maranta arundinacea* L., cf. *Xanthosoma* sp.	(Rodríguez Suárez and Pagán-Jiménez 2008)
Puerto Rico	1	*Canna indica* L.	(Pagán-Jiménez 2007b)
Puerto Rico	1	*Zamia amblyphyllidia* D.W.Stev, cf. *Zea mays* L., Fabaceae, *Ipomoea batatas* L.	(Pagán-Jiménez 2008)
Puerto Rico	3	cf. *Zamia* sp., *Xanthosoma sagittifolium* L. Schott., cf. *Phaseolus vulgaris* L., *Zamia pumila* L., *Maranta* cf. *arundinacea* L., *Zea mays* L., cf. *Bixa orellana* L., Fabaceae	(Pagán-Jiménez 2011a)
Puerto Rico	1	*Zamia pumila* L., cf. *Zamia pumila* L., cf. *Phaseolus vulgaris* L., *Zea mays* L., Fabaceae	(Pagán-Jiménez 2011b)
Dominican Republic	6	*Ipomoea batatas* L., cf. *Ipomoea batatas* L., *Zamia* sp., cf. *Zamia* sp., *Zea mays* L., cf. *Zea mays* L., Fabaceae	(Pagán-Jiménez in Ulloa Hung 2014:115,138)

To assess microbotanical remains and interpret culinary practices there is a focus on three types of artifacts—bivalve shells, clay griddles, and microliths. Traditionally, archaeologists working in the Caribbean have associated clay griddle and microlith artifacts with manioc processing (Berman and Pearsall 2008; DeBoer 1975; Dufour 1985; Hofman and Hoogland 2015a; Keegan 1992:18; Keegan 1997:59; Keegan and Hofman 2017:222; Loven 1935:359; Perry 2002b; Perry 2004; Perry 2005; Rouse 1992:12; Sauer 1966:241). Based on early European written sources and the abundance of these types of artifacts it was assumed that manioc was a dietary staple for precolonial Indigenous Caribbean Peoples (Allaire 1999; Castillo 1906; Fernández de Oviedo 1851 [1535]; Fernández de Oviedo 1959 [1526]; Keegan and Carlson 2008:4; Las Casas 1909; Newsom and Wing 2004:3; Rouse 1992:12; Sauer 1966; Sauer 1981; Sturtevant 1961; Sturtevant 1969; Wilson 2007). Extrapolations of the chronicles applied to the archaeological record from centuries before are problematic due to the magnitude of devastation and thus cultural changes (i.e. which plants were cultivated, managed, and processed) due to European invasions, systematic colonization, and enslavements (Cortés 1908 [1519]; Curet 2006; Deagan 2004; Denevan 1992; Figueredo 2015; Jennings 1975; Keegan 1996; Montenegro and Stephens 2006; Pagán-Jiménez 2009; Wilson 1993). Paleoethnobotany is a key route to reconstructing the archaeobotanical record without relying on European written sources.

1.2 What is paleoethnobotany?

Paleoethnobotany known otherwise as archaeobotany, in the first half of the 19th century, archaeobotany began by investigating exceptionally preserved macrobotanical remains from arid and waterlogged contexts (Heer 1866; Kunth 1826). Archaeological microbotanical analyses began in the 20th century with remains recovered from uniquely well-preserved contexts (Netolitzky 1900; Schellenberg 1908). This early research cast doubts on the applications of paleoethnobotany in tropical regions, which are notorious for limited organic preservation (Dickau 2010; Pearsall 2003). Yet, during the 1970s questions regarding agricultural origins and developments drove microbotanical analyses into the spotlight (Rovner 1971).

Dolores Piperno (1998) provided novel evidence of plant utilization from Neotropical residue studies on the origins of agriculture using a combination of evidence from multiple microremains (pollen, phytoliths, and starch grains). Residue studies have sought to investigate a variety of research topics such as early dispersals of domesticated plants (Nieuwenhuis 2008; Pagán-Jiménez 2011c; Pagán-Jiménez et al. 2015; Perry et al. 2007b; Piperno et al. 2009), variability of Neandertal subsistence activities (Henry et al. 2011), and reconstructions of hunting technology (Barton et al. 2009). Promising research has also been generated from directly dating recovered botanical residues (Zarrillo et al. 2008) and by assessing extensive cultural change and stability (Fullagar and Field 1997). However, the integration of cutting-edge analytical techniques to provide new lines of evidence to old research questions, such as the domestication origins of key agroeconomic crops using multiple proxies from trace-elements, starch, and aDNA, have provided richer understandings of ancient human-plant interactions on a scale and eminence previously inconceivable (Zarrillo et al. 2018).

Starch grain morphology was first investigated more than one hundred years ago and continuously helps to classify and identify plant taxa (Meyer 1895; Nägeli and Nägeli 1858; Reichert 1913). Compared to other plant microfossils, such as phytoliths or pollen, the analysis of starch for archeological purposes is relatively new. The initial works of Ugent et al. (1982) and Loy et al. (1992) initiated a surge of interest in ancient starch research. More recently, ancient starch analyses have been applied to studies of stone tool functions, which has helped to track the emergence of plant domestication, ranges of human mobility, evolution of human diets, land use patterns, and vegetation histories (e.g. Field et al. 2009; Fullagar et al. 2006; Henry et al. 2011; Herzog 2014; Liu et al. 2010; Piperno and Holst 1998; Therin et al. 1999). Over the last 20 years, ancient starch analyses have helped to better understand technological developments and human behaviors in many areas of the world (Barton and Torrence 2015). There are still a diversity of methodological approaches to recovery, analysis, and identification of starch and to interpreting culinary modifications of plants (Atchison and Fullagar 1998; Barton and Torrence 2015; Barton et al. 1998; Lentfer and Boyd 2000; Liu et al. 2014; Pearsall et al. 2004; Piperno 2006b; Torrence and Barton 2006; Torrence et al. 2004). However, comprehensive descriptions of starch grain characteristics is still the core of most analyses, which include starch size, shape, angularity, facets, and surface features (Loy et al. 1992; Mercader et al. 2018a; Pagán-Jiménez 2015).

1.3 A brief synopsis of Greater Caribbean archaeobotanical investigations

It is out of the scope of this dissertation to provide a systematic report of the entire Greater Caribbean region's archaeobotanical investigations. Instead, several significant and relevant studies are summarized. It has been established there was long-term use and consumption of manioc in continental Neotropical areas (Piperno 2006a; Piperno and Pearsall 1998; Sheets et al. 2012). However, in the insular Caribbean, the recovered microbotanical remains of manioc have been limited or practically nonexistent (Berman and Pearsall 2008; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007a:127; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Pagán-Jiménez 2016). Thus, current archaeobotanical data is still inadequate to reconstruct insular Caribbean contexts surrounding the dispersal and use of manioc.

Earlier in Caribbean archaeological research, isolated finds of zamia plant remains from a domestic cave in the Dominican Republic contributed to reports of macroremains (Veloz Maggiolo and Vega 1982). Although, considering the plant presently grows in front of the same cave, the interpretations and validity of these ancient remains are dubious. However, pollen recovery and analysis identified the presence of zamia and several other economically important plants including tobacco (*Nicotiana* sp.) and maize at the Sanate site in eastern Dominican Republic (Fortuna 1978). Zamia pollen was also identified at the site of Rio Jobá in northern Dominican Republic (Fortuna in Veloz Maggiolo et al. 1981). Notably this was important because currently zamia is unknown in northern Dominican Republic, thus this is more evidence that it is problematic to extend modern environmental records into the past.

Deborah Pearsall's (1983; 1985) research of macroremains initiated full-fledged systematic paleoethnobotanical analyses in the Caribbean. Subsequently, Lee Newsom (1988; 1991; 1992; 1993) began to identify archaeological macro plant remains from Haiti, followed by Puerto Rico, Bonaire, and the Lesser Antilles. Macrobotanical research in the Greater Caribbean region provided useful information, particularly about arboriculture, but did not recover empirical evidence for many of the presumed key agroeconomic plants (Dickau 1999; Newsom 1988; Newsom 1991; Newsom 1992; Newsom and Wing 2004; Piperno and Pearsall 1998). During this time, Deborah Pearsall (1989) expanded her research area into The Bahamas combining macroremains and phytolith analyses.

More recently, other plant microfossils have been studied in the Greater Caribbean. Typically, pollen does not preserve well in arid regions and buried archaeological deposits of humid tropical areas, but waterlogged deposits can hold substantial paleoecological information (Burney et al. 1994; Castilla-Beltrán et al. 2018; Higuera-Gundy et al. 1999; Hodell et al. 1991; Jones 1997; Lane et al. 2014; Pagán-Jiménez 2016; Siegel et al. 2015). Pollen from sediments recovered from two archaeological sites El Curro and Puerto Alejandro in the Dominican Republic provided early evidence of maize approximately dating to 3450 BP (Fortuna in Sanoja 1989).

From more recent archaeological contexts (1000-1500 CE), Linda Perry (2004), analyzed traditionally associated manioc related tools—ground stone tools and flaked microlith artifacts for starch content from the Los Mangos del Parguaza site in Venezuela. She did not recover manioc remains, but did recover evidence of other geophytes—arrowroot (*Maranta* sp.) and ginger (Zingiberaceae) from some of these tools and maize was recovered from every sampled artifact from her study. This study illustrates some of the consequences of generating inferences regarding plant use from artifact form alone.

Not only maize, but also manioc, sweet potato, achira (*Canna indica* L.), chili pepper (*Capsicum* sp.), beans, and guáyiga starch remains have been recovered from pre-Saladoid ('Archaic Age') contexts in the Caribbean (Chinique de Armas et al. 2015; Pagán-Jiménez 2007a; Pagán-Jiménez 2009; Pagán-Jiménez 2011c; Pagán-Jiménez et al. 2005; Pagán-Jiménez et al. 2015). Evidence of early plant use in the Caribbean has been highlighted in much of Dr. Jaime Pagán-Jiménez's research (Pagán-Jiménez 2011c; Pagán-Jiménez 2012; Pagán-Jiménez et al. 2005; Pagán-Jiménez et al. 2019; Pagán-Jiménez et al. 2015). Contexts with Ostinoid (600-1550 CE) material remains have revealed the use of the some of the same plants previously listed in adition to leren (*Calathea allouia* (Aubl.) Lindl.), arrowroot (Marantaceae), palms (Arecaceae), and yams (Dioscoreaceae) (Pagán-Jiménez 2009). The later three plant families of which remains have been recovered across all periods investigated by Dr. Pagán-Jiménez (Pagán-Jiménez 2007a; Pagán-Jiménez 2009; Pagán-Jiménez 2011c; Pagán-Jiménez and Oliver 2008; Pagán-Jiménez et al. 2005; Pagán-Jiménez et al. 2015). Analysis of starch recovered from dental calculus from both pre-Saladoid and Ceramic Age contexts allowed Mickleburgh and Pagán-Jiménez (2012) to demonstrate a prevalence of maize remains, which was interpreted as consistent and unrestricted use of maize as well as a diversity of root crops used by Indigenous insular Caribbean Peoples.

Starch analyses to investigate botanical culinary practices will not provide indications of staple dietary plants, but they can help us interpret "cultural" staple plants (i.e. which plants were favored, targeted, or used ubiquitously). There were a few starch analyses carried out in the central Bahamas, Cuba, and Dominican Republic, these analyses suggested that starchy plants were brought to the central Bahamas as part of a phytocultural complex (Berman and Pearsall 2008), that "fisher-gatherers" in precolonial Cuba actively managed exotic plants (Chinique de Armas et al. 2015), and that precolonial Indigenous Peoples of Dominican Republic transformed starchy plants into pastes then cooked them in clay vessels (Pagán-Jiménez in Ulloa Hung 2014) (Table 1.2).

Table 1.2
Previous starch analyses in the northern Caribbean.

Sites and artifact types	**Plant types identified**										**Reference**
Three dog, The Bahamas, chert microliths		maize	cf. manioc			chili		cf. cocoyam			(Berman and Pearsall 2000; Berman and Pearsall 2008; Perry et al. 2007b)
Macambo 2, Cuba, clay griddles	zamia	maize		sweet potato	bean			cf. cocoyam			(Rodríguez Suárez and Pagán-Jiménez 2008)
Canímar Abajo, Cuba, dental calculus	zamia	cf. maize		cf. sweet potato	bean		cf. arrowroot				(Chinique de Armas et al. 2015)
El Popi, Dominican Republic, clay griddles and *ollas*		maize		sweet potato	bean						(Pagán-Jiménez in Ulloa Hung 2014)
Edilio Cruz, Dominican Republic, clay griddles, bowl, and millstones	zamia	cf. maize	manioc	sweet potato	bean	chili	arrowroot		cannaceae	cf. hypoxis	(Pagán-Jiménez in Ulloa Hung 2014)

Equally essential to his empirical evidence are Dr. Jaime Pagán-Jiménez's contributions towards archaeological practice and anti-colonial conceptual frameworks (Pagán-Jiménez 2003; Pagán-Jiménez 2004; Pagán-Jiménez and Rodríguez Ramos 2008). His most resonant written contributions towards this dissertation were his early insights regarding precolonial human-plant interactions (Pagán-Jiménez 2007a; Pagán-Jiménez et al. 2005). His main contentions to the archaeological establishment allowed him to indicate: 1) human population movements were coupled with plant dispersals in the Antilles and continued with long-distance exchange networks of phytocultural practices; 2) early use of processed and cooked plants predated Ceramic Age Sites (i.e. plants were transformed into meals prior to the use of clay vessels); 3) clay griddles were multipurpose and not indicators of manioc cultivation; 4) wild plants were systematically and consistently used; 5) maize was introduced earlier than believed and had unrestricted access and use (Pagán-Jiménez 2007a; Pagán-Jiménez 2008; Pagán-Jiménez 2013; Pagán-Jiménez et al. 2019; Pagán-Jiménez et al. 2015; Rodríguez Suárez and Pagán-Jiménez 2008). This list of insights is continuously evolving.

Dr. Mary Jane Berman and Dr. Deborah Pearsall have also been largely influential for this dissertation. Their early work together has provided evidence for the use of domesticated geophytes in The Bahamas as well interpretations of maize agriculture on San Salvador (Berman and Pearsall 2000). In addition, their questions and answers about transported landscapes to The Bahamas have provided avenues for more questions extending these investigations (Berman and Pearsall 2000; Berman and Pearsall 2008). Dr. Berman’s consistent call for systematic use of botanical analyses was a pleasure to read and inspirational (Berman 2011b; Berman et al. 2013; Berman et al. 1999).

Peter Siegel et al. (2015) has also encouraged the systematic use of paleoenvironmental analyses. Their dynamic and robust investigations across nine islands of the southern Caribbean effectively added another demonstration of how microbotanical data can be used to provide information regarding human mobility and early transported landscapes (Siegel et al. 2015). However, from their interpretations of phytolith data they stated, “There is no evidence that first colonists introduced new cultigens or exotic plants in general” yet importantly they also add that only through interdisciplinary research will we further the understanding of landscape including plant use (Siegel et al. 2015).

Lee Newsom was a pioneer for her area of research. It cannot be ignored that the study of macrobotanical remains was brought to the Caribbean via Lee Newsom’s research, where it produced useful information and interesting interpretations regarding plant use, particularly arboriculture (Newsom 1988; Newsom 1991; Newsom 1992; Newsom and Deagan 1994). She set out to investigate diet and human adaptations in the insular Caribbean and the comprehension of plant use laid out in her dissertation was nothing short of monumental (Newsom 1993). While not a novel approach, the combination of botanical and faunal analyses provided a robust picture of Caribbean lifeways (Newsom and Wing 2004). The researchers mentioned in this section are some of the giants I referred to earlier that have helped provide a great view for the case studies in this dissertation. As the last frontier of initial human-plant migrations and the first place in the Americas to experience the full effects of European colonization, the Greater Caribbean region offers a unique opportunity for an examination of intercultural dynamics and culinary practices.

1.4 Approaching archaeobotanical investigation to reveal culinary practices

An aim of this dissertation is to comprehend tangible relationships between Indigenous Caribbean Peoples and plants woven within their culinary practices. Interpretations of these human-plant interactions contribute to understanding Greater Caribbean legacies. Another goal of this project is to refine our understanding of Indigenous Caribbean culinary histories during the late precolonial period. There is also an endeavor to add to what was known conceptually and methodologically from previous microbotanical analyses (Berman and Pearsall 2008; Pagán-Jiménez 2007b; Perry 2004). Providing views of botanical foodways has been critical for understanding phytocultural dynamics (Pagán-Jiménez 2013), transported botanical environments (Berman and Pearsall 2008), and cultural niche constructions (Pearsall 1988; Perry et al. 2007a).

1.5 Theoretical framework

For the purpose of this dissertation, foodways was defined as the foods consumed and the profusion of related behaviors including production, preparation, and presentation of such foods (Welch and Scarry 1995), in addition to forest management, the collection of wild plants, and ultimately the use of kitchenware and the bodily gestures necessary for culinary practices. These include learned behaviors for slicing, pounding, mixing, grinding, and baking etc. Because the majority of case studies that form this dissertation work with artifacts from the Bahama archipelago and incorporate ideas of transported landscapes, an approximate date of 800 CE was chosen as the beginning of the late precolonial period, which is when there is evidence for established occupations in The Bahamas (Berman et al. 2013). To help understand transported vegetal environments an importance of this dissertation lies on the identifications of exogenous botanical species that require human assistance for propagation. The perspective of cultural niche construction (Smith 2016; Zeder 2016; Zeder and Smith 2009) is another axis which is central to discussions in the case studies, but it is incorporated and interlaced with ideas of transported landscapes (Anderson 1967; Berman and Pearsall 2008; Pagán-Jiménez 2013; Pagán-Jiménez et al. 2019), and practice theory (Bourdieu 1977; Lave and Wenger 1991; Wenger 1998). The correlation of these theories makes it possible to reveal the agency of food in processes of adaptations and as elements of culinary identities.

Transported landscapes provide many benefits for the transporters; perhaps above all, the humanization and consistent supplies of food motivated the transportation of botanical landscapes (Anderson 1967; Berman and Pearsall 2008; Pagán-Jiménez et al. 2019; Rodríguez Ramos et al. 2013). The identifications of exogenous plants imply at least mobility and exchange; or when exogenous plant complexes are consistently identified, they could be a part of a predetermined mental plan for reconstructing consistent humanized vegetal niches.

Foodways is one part of lifeways that deeply entangles cultural niche constructions. Cultural niche construction explains processes where human practices cause changes to their environments that modify evolutionary selection pressures (Laland et al. 2007; Wollstonecroft 2011). The human-plant interactions in the case study areas must have been influenced by both environmental constraints and affordances; as well as cultural practices such as plant management strategies, exchanges with other human groups, and culinary practices. However, because of the limited diachronic perspective allowed by the investigated archaeological sites, this dissertation is unable to comment on long term evolutionary components and had to take the following stance on cultural niche construction. If a cultural niche is considered the way humans make a living (Lambert 2018), then an epitome for human niches are food products, which culinary practices created.

Botanical culinary practices include many behaviors and things used to create meals such as the selection of plants to cultivate, harvesting and foraging particular plants, cooking techniques, additional flavors, and food preparation technologies (Ayora-Diaz 2015; Debevec and Tivadar 2006). Ancient starch analysis is a method to reconstruct and understand some of these things and behaviors through the identifications of plants and interpretations of which and how culinary practices caused damage to the plant organs. Throughout the case studies, interpretations of culinary practices help to illuminate the nuanced ways plants were used in the past. One of the ideas to test is if the culinary practices were successful and positively reinforced through cultural transmissions in local or regional communities then there must be a patterned use of plants at multiple stages in the production process (Eerkens and Lipo 2005; Zeder 2016). Alternatively, if the culinary practices were unsuccessful, new culinary practices should have emerged and be archaeologically detectable such as the replacement of exogenous plant ingredients with endogenous ones or discontinuing the use of starchy plants. This is possible by investigating multiple types of artifacts at the same archaeological site. Thus, multiscalar analyses of clay griddles and shell artifacts were carried out (Ciofalo et al. 2019; Ciofalo et al. 2020). These types of artifacts were previously demonstrated to have processed starchy plants in other investigations (Allen and Ussher 2013; Pagán-Jiménez 2007b; Rodríguez Suárez and Pagán-Jiménez 2008). In addition, these types of artifacts have been archaeologically recovered from many Ceramic Age sites in the Greater Caribbean (Hofman and van Duijvenbode 2011; Keegan and Hofman 2017). The recovered and identified starchy plant remains help explicate associations drawn between ethnic identities and culinary practices. Furthermore, the identified culinary practices will tie the data together offering a view of cultural niche constructions and ancient foodways.

1.6 Methodology

Because of copious amounts of rainfall in tropical areas and consistent high temperatures, organic remains decompose quickly in humid soils (Babot 1996; Pearsall 2003). The varying environmental conditions in the Neotropics make it problematic for the successful recovery of preserved organic remains because there are varied local conditions of soil pH, temperature, and humidity (Carbone 1980; May and McLellan 1973). Macrobotanical remains are unlikely to preserve unless the archaeological contexts are anoxic (waterlogged), extremely arid (dry), carbonized, or possibly mineralized (Pearsall 2015:108). In contrast to macrobotanical preservation, microbotanical remains (spores, pollen, phytoliths, and starch grains) have had a higher success rate of preservation and recovery in the Greater Caribbean region (Pearsall 1989; Piperno and Holst 1998; Piperno and Pearsall 1998:217; Piperno et al. 2009; VanDerwarker et al. 2015). Ultimately starch analysis was chosen for this dissertation because it has the unique ability to infer culinary practices (human-plant interactions for creating and modifying dietary plants), as well as demonstrate the direct association between starchy plants and the sampled artifacts (Dickau et al. 2007; Pagán-Jiménez 2013). Thus, starch analysis has the ability to answer the research questions and starch preserves exceptionally well in tropical environments (Perry 2004).

Initial sampling of approximately 200 artifacts (presumed kitchenware made from clay, limestone, and bivalve shells) was carried out. Because of the nature of the raw materials of these artifacts, two different starch-sampling methods were employed. Clay artifacts are more likely to be damaged from soaking in water, so they were sampled using a dry scraping method detailed in Chapters 4 and 5. Shell and lithic artifacts are typically more durable and thus able to be soaked in water without damage, so they were submitted to ultrasonic sampling, which is described in Chapters 2 and 3.

Ubiquity analysis is one method commonly used to statistically understand and interpret results from botanical data (Dickau 2005; Newsom and Pearsall 2003; Pagán-Jiménez et al. 2015). The total number of samples that contain a plant taxon expresses the percentage presence (ubiquity) (Pearsall 2018). Using ubiquity analysis, the comparative use of certain plants over others may be projected. However, interpretations do not suggest a plant's contributions to overall diet.

Instead, the more a plant taxon was ubiquitously recovered amongst the sample spectra, the more likely it was frequently used and possibly integral for local culinary practices (Pagán-Jiménez et al. 2019). The only way currently to answer the research questions is through methods that have been constructed by several pioneers in paleoethnobotany over the last 200 years. Due to time constraints, reference collection availability, and the following aims discussed in the next section, the decision was made to prioritize starch analysis over other types of botanical analyses because it has an enormous potential for generating the data needed for a discussion of the research questions (Loy et al. 1992; Pagán-Jiménez 2011a; Perry 2004).

1.7 Aims

A key aim is to infer culinary practices within and amongst the case study sites. Plants are a crucial component of food choices throughout the world. Their multiple uses including their preparation contribute to formation of cultural memories (Pesoutová 2019). The ways people created meals contributes towards formation of self and group identities (Hastorf 2016:223). Bodily gestures are able to reaffirm shared cultural memories, which help people connect on a deep level with the people that share those bodily gestures and memories (Caballero-Arias 2015). In this case, gestures and movements, such as behaviors towards plant preparation constitute culinary practices. Understanding the connections between culinary practices and the technical choices past humans made allow for interpretations of plant processing and investigations of cultural niches.

Starch analysis is a unique archaeobotanical technique because it allows direct associations amongst plants, artifacts, and human practices (Pagán-Jiménez 2013; Pearsall et al. 2004). While starch recovery and analysis has started to solidify its techniques and protocols (Pagán-Jiménez 2007a; Pearsall 2015). However, doubt remains regarding authenticity of the results including if and why starch preserves in humid tropical regions (Barton and Torrence 2015; Collins and Copeland 2011; Mercader et al. 2018b). We may not fully understand the reasons for starch preservation but we have a clear understanding of human practices that make starch accessible and useful substances for different cultural needs (Beck and Torrence 2006; Oliveira et al. 2015; Pagán-Jiménez et al. 2017). Regardless of the many preservation biases affecting starch taphonomy, many studies have also demonstrated that starches survive after being exposed to variations in depositional contexts (tropical variations of moisture, temperature, acidic, and alkaline conditions) and culinary practices such as elevated temperatures (toasting, roasting, charring, baking, boiling), amylase digestion (fermenting), pressure (grinding, pounding, scraping), (Babot 2003; Barton 2009; Crowther 2012; Henry et al. 2009; Mickleburgh and Pagán-Jiménez 2012).

The primary aims of this dissertation have been designed to collect all the necessary information for answering the research questions. The aims are also relevant for the broader context of using a foodways approach to archaeobotanical investigation. Through this multi-layered research design, this dissertation will contribute novelty to the discipline.

1.7.1 Primary aims:

1.) Infer starchy botanical culinary practices.
2.) Provide a view of cultural niche constructions and related human-plant adaptation strategies.
3.) Demonstrate the appropriateness of starch analysis for providing novel insights in regions with limited organic preservation.
4.) Contribute evidence to the growing database of human-plant interactions.

That which is eaten sustains communities and links societal formation because meals are representative of belief systems, social identities, and existence (Crouch and O'Neill 2000; Twiss 2007). Food is a social lubricant and deeply engages with identity. As such, understanding food choices used to create meals can contribute towards interpreting elements of group identities. More than food choices a foodways approach for investigations helps expose social lives and may enable discussions of economies, politics, and symbolic features of meals (Dietler 1996; Dietler 2007; Hastorf 2016; Pagán-Jiménez 2013). Indeed, culinary practices and their products are a large part of the foundation for quotidian life. As such, investigating culinary practices may enable richer understandings and deeper discussions regarding demographic pressures, increase in social stratification, overexploitation, the arrival of new people, mobility and exchange, shifting preferences and values, and/or climate change, which can all be causes of variation in culinary practices (Cooper and Peros 2010; Pagán-Jiménez et al. 2019; Twiss 2012). This is because foodways contains a range of daily and unique practices such as food acquisition, production, preparation, presentation, and consumption of foods. Starch analysis is an exemplary method for reconstructing these human-plant dependencies, particularly culinary practices. The aims of this dissertation are achieved through answering the research questions.

1.7.2 Primary research question:

How did starchy culinary practices vary in the case study areas?

The research involved to answer this simple yet profound question will also answer a host of corollary sub-questions: Which plants were processed? Which human-plant adaptation strategies were likely employed? Which cultural niches were constructed? How does this new data contribute to previous archaeological understandings of botanical foodways? These questions will be explored through four case studies investigated by sampling artifacts from five archaeological sites and analyzing them for starch content.

1.8 Case studies and dissertation outline

Four case studies will be investigated, each contending and adding information upon previous archaeological understandings of botanical foodways. Investigating foodways has been integral for the study of cultures, which creates a richer understanding of phytocultural complexes, transported landscapes, cultural niche constructions, and elements of culinary identities. Paleoethnobotanical analyses have just started to be applied on the archaeological sites of Long Island, The Bahamas and central Nicaragua. Starch analysis is an exemplary method for reconstructing human-plant dependencies, particularly culinary practices. In addition, there has never been a comparison of botanical foodways between the Greater Antilles (the presumed origin of transported foodways) and the Bahama archipelago. Thus, this dissertation is organized in six chapters including the introduction and a final synthesis. Chapters 2 and 5 are pioneering starch analyses to initiate archaeobotanical research at the LN-101 and Barillas sites respectively. Chapters 3 and 4 initiate archaeobotanical research at the Palmetto Junction site but include comparative analyses with El Flaco and La Luperona to create a richer understanding of plant use on multiscalar levels. Chapter 6 is a synthesis of the previous chapters to provide concluding remarks and situate the case studies in their space of Greater Caribbean archaeobotany.

Starting at the site most furtherly North from this dissertation is an investigation of the LN-101 site on Long Island, The Bahamas. Chapter 2, titled 'Determining precolonial botanical foodways: starch recovery and analysis, Long Island, The Bahamas' is a case study focused on the sampling and analysis of eight artifacts. The sampled artifacts consist of four limestone microliths, presumably used as grater chips set in a wooden board for grating dietary plants, two bivalve shells, presumably used to deskin geophytes, and two limestone handstones, thought to have ground or scraped plants. These artifacts were recovered from the LN-101 archaeological site (cal. 1088 ± 68 CE) on Long Island, Bahamas (Keegan and Pateman n.d.). Multiple earth ovens were discovered at this site, but also there were practically no clay vessel remains recovered. Thus, we wanted more information regarding which and how plants were being processed, prepared, and possibly cooked at this site. In addition, it was not considered that grater board teeth were created from limestone resources but these sampled microliths were morphologically similar to chert microliths recovered from other sites in The Bahamas so we wanted to investigate if they were used to process plants (Berman and Pearsall 2008). Overall, this case study will provide integral data regarding regional-specific plant processing and new information about human-plant interactions that involved limestone artifacts. The study of limestone microliths is unique and expands upon previous archaeological considerations of grater board functions and manioc use in the Greater Caribbean (Debert and Sherriff 2007; Pagán-Jiménez 2013; Perry 2002a; Perry 2004; Perry 2005; Rodríguez Ramos and Pagán-Jiménez 2006). This case study may be viewed as a supporting flank for the midline or “meat” of this dissertation’s next two case studies. The decision to use this case study as a supporting pillar was partially opportunistic. After learning that the archaeological site was in The Bahamas, and the materials included shell artifacts, this case study aligned with the core of the research design. The results are not directly comparable with the other case studies because of dissimilar sample sizes, but they certainly create a more nuanced understanding of precolonial foodways.

Because the sample size of shell artifacts sampled in the previous case study was relatively small, there was a need for a larger sample size to investigate if the use of shells was similar or if there were patterned variations. Chapter 3, titled ‘Starchy Shells: Residue analysis of precolonial northern Caribbean culinary practices’ is a case study focused on samples and analysis of starch content from 60 shell artifacts, presumably used to scrape geophytes and modify other dietary plants. These shell artifacts were recovered from archaeological contexts further south than the previous study to expand the regional perspective of shells used to process plants in the northern Caribbean. The residues were recovered from shells thought to have been associated with plant processing from the archaeological sites of El Flaco (cal. 1309 ± 81 CE), La Luperona (cal. 1352 ± 60 CE) both located in northwestern Dominican Republic, and Palmetto Junction (cal. 1391 ± 41 CE) located in the Turks & Caicos Islands (Hofman and Hoogland 2015a; Hofman and Hoogland 2015b; Hofman et al. 2018; Sinelli 2015). Ethnohistorical narratives have characterized shell tools exclusively as manioc peelers (Fernández de Oviedo 1851 [1535]:270; Fernández de Oviedo 1959 [1526]; Las Casas 1876 [1561]:147). Yet archaeologists have envisioned a broader set of functions and more diverse suite of processed plants were involved with bivalve shell tools (Antczak 1998; Antczak and Antczak 2008; Boomert 2000:324; Carlson 1993; Keegan et al. 2018; Lammers-Keijsers

2007:52; O'Day and Keegan 2001; Petitjean-Roget 1963; Ruiter 2009; Van Gijn et al. 2008). With a large sample size, this case study contributes a robust interpretation of human-plant-artifact interrelationships by elucidating which plants were processed and clarifying possible shell artifact functions. The roles of shell artifacts in starchy botanical foodways contributes to ongoing discussions regarding culinary practices in the northern Caribbean and related precolonial foodways in the Greater Caribbean (Berman and Pearsall 2008; Pagán-Jiménez 2013; Pagán-Jiménez et al. 2019; Rodríguez Ramos 2016).

If the culinary practices were entangled in cultural niche constructions, there must be a patterned use of plants at multiple stages in the food production process. Thus, another phase in plant preparation process is investigated, the use of clay griddles. Chapter 4, titled 'Late precolonial culinary practices: Starch analysis on griddles from the northern Caribbean' was carried out to create a more holistic view of starchy foodways in the northern Caribbean, this case study compares 45 samples analyzed for starch content that were recovered from clay griddles, presumably used to cook or prepare dietary plants and animals. These clay griddles were recovered from the same three sites- El Flaco, La Luperona, and Palmetto Junction. This case study compared foodways amongst sites with a focus on clay griddles, because they were one of the common artifacts presumed associated with preparing plants and archaeologically recovered from all three sites in this study. Earlier preconceptions envisioned clay griddles exclusively connected with the production of manioc flatbread in the Caribbean (see DeBoer 1975; Rouse 1992 12, 84, 133; Wilson 2007 83, 109). Other starch analyses of insular Caribbean griddles indicated their use with a broad suite of dietary plants but not manioc (Table 1.1). This case study investigated clay griddles from these three archaeological sites to clarify if the pattern of a broad spectrum of plants were prepared with these griddles as well.

Regarding unifunctional griddles, archaeologists who work in Central America have similar preconceptions to archaeologists who work with insular Caribbean artifacts. The standard Central American archaeological discourse presumed only maize was prepared on griddles (McCafferty 2011). This bias was also connected with alleged migrations from Mesoamerica around 800 CE, led by groups whose staple foodways consisted of maize *tortillas*[3] cooked on griddles (Gorin 1990). Chapter 5, titled 'Uses of pre-Hispanic kitchenware from central Nicaragua: Implications for understanding botanical foodways' is a case study that provides the

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[3] Flat-bread.

second supporting flank for this dissertation by investigating culinary practices in central Nicaragua at the Barillas site (cal. 1261 ± 37 CE) which revealed unique finds of ceramic griddle fragments (Donner and Geurds 2018).

This chapter was created to help answer questions about how clay griddles were used in Central America and expand the scope of this dissertation to the continental mainland. This part of the dissertation will demonstrate my adaptability to work outside of the insular Caribbean and simultaneously help investigate patterns of human-plant interactions in another area of the Greater Caribbean. Geographically, the Greater Caribbean region includes Nicaragua (Rodríguez Ramos 2010). Culturally, the Greater Caribbean has been argued to include coastal Nicaragua (Hofman et al. 2010). While no shell or limestone artifacts were recovered from the Barillas site, a high density of clay artifacts were recovered from stratigraphic contexts. After these finds were discussed, it was clear how this case study would be relevant to the overarching project. This case study in Nicaragua was carried out from six samples recovered from clay vessels (four flat vessels and one bowl shaped vessel). These samples were analyzed for starch content to help reconstruct pre-Hispanic culinary practices and evaluate the presumptions of unifunctional griddles in the Greater Caribbean. Furthermore, this case study constitutes innovative and novel research as the first archaeobotanical research in central Nicaragua.

Chapter 6, titled 'Final Thoughts' is a synthetic chapter of the major paleoethnobotanical findings of this dissertation and offers concluding remarks. This chapter also explores the theoretical implications in archaeobotanical interpretations of variations of culinary practices. In addition, limitations of this type of research are clearly explained coupled with recommendations for future research.

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CHAPTER 2

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Determining precolonial botanical foodways: Starch recovery and analysis, Long Island, The Bahamas

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Journal of Archaeological Science: Reports (2018, Volume 21)

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Abstract

Descriptions of precolonial foodways in the Caribbean Islands have relied primarily on contact-period European descriptions, which have been used to inform archaeological research. The use of ethnohistoric and indirect archaeological evidence is debated, and competing reconstructions of potential botanical foods and their cooking processes have resulted. To address this issue, starch analysis, which is suitable to provide information on human-plant interactions in tropical regions with poor botanical preservation, was carried out on samples from shell and limestone potential plant-processing tools from the Rolling Heads site, Long Island, The Bahamas. Results of this study revealed that some of these shell and lithic tools were used to process several different starchy food sources: maize (*Zea mays* L.), manioc (*Manihot esculenta* Crantz), and coontie (*Zamia* sp.). The presence of more than one plant species on both the microlith and shell tools, demonstrates their multi-purpose use. These novel data have also generated interpretations of plant processing with limestone grater chips. Overall, our research provides integral data regarding regional-specific processing of manioc, maize, and coontie. This report provides new information regarding human-plant interactions in the Caribbean. Finally, this study provides data on the use of shell tools and lithic graters for processing plants it contributes to ongoing discussions of reconstructing ancient Bahamian and related Caribbean foodways.

Keywords: starch analysis; foodways; Caribbean archaeology; microlith; shell tools; manioc

2.1 Introduction

Descriptions of precolonial foodways in the Caribbean Islands have relied primarily on contact-period European descriptions. The use of European accounts in conjunction with ethnographic data has been used to determine foodways predating these sources of information (Rouse 1992). We adamantly believe this method of informing archaeological research should be heavily debated, and competing reconstructions of precolonial foodways have resulted. Interpretations of botanical foodways reported in the Spanish chronicles suggest that manioc (*Manihot esculenta* Crantz) and sweet potato (*Ipomoea batatas* (L.) Lam.) were the most important cultigens, while maize (*Zea mays* L.) was of limited importance (see Newsom and Wing 2004; Pagán-Jiménez 2013; Sauer 1966). Despite numerous other botanical studies (Berman and Pearsall 2008; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez et al. 2015) microbotanical remains representing manioc's ubiquity has been statistically insignificant (less than 13%) in the Caribbean archaeological record (Pagán-Jiménez 2013; Pagán-Jiménez et al. 2017). In contrast, maize, sweet potato, bean (*Phaseolus* spp.), and coontie (*Zamia* spp.)[4] have been found in numerous studies in the broader Caribbean region (Pagán-Jiménez 2007; Pagán-Jiménez 2009; Pagán-Jiménez and Oliver 2008; Pagán-Jiménez et al. 2015; Rodríguez Suárez and Pagán-Jiménez 2008). Figueredo (2015) argues that maize was of greater dietary importance than manioc, whereas Newsom and Wing (2004:183) suggest coontie to be the primary consumed carbohydrate in The Bahamas. Veloz Maggiolo (1992), following Las Casas (1909), has also argued for the primacy of coontie, especially in the eastern Dominican Republic (Higüey Province). This study reports the first conclusive archaeological evidence for manioc and identified coontie in The Bahama Islands. Maize was identified in a previous study from The Bahamas (Berman and Pearsall 2008), and is also recorded here.

Efforts to understand the diversity and use of botanical foods in the Caribbean has gained substantial attention in the last forty years (Fortuna 1978; Keegan and DeNiro 1988; Newsom 1993; Newsom and Wing 2004; Pagán-Jiménez 2007), most recently through the extensive application of novel methods (Laffoon et al. 2016; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez et al. 2015; Pestle and Laffoon 2018). Starch grain analyses have consistently revealed the identification of cultivated, managed, and processed plants that were once believed not to preserve for archaeological recovery. These microbotanical remains have proven to be resistant to the dry, wet, and hot conditions that are typical in the tropics and may affect preservation.

In the tropics, because of copious amounts of rainfall and consistent high temperatures, organic remains decompose quickly in the humid soils (Babot 1996). Thus, archaeobotanical research

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[4] Plants of the genus *Zamia* are known locally in The Bahamas as coontie and thus, the term coontie is used to denote plants of this genus in the rest of this article.

is difficult and can be problematic primarily due to poor preservation. In addition, the majority of tubers do not produce, or are purposely suppressed from producing pollen and produce few diagnostic phytoliths in the plant organs that are utilized for food (Torrence 2006). Starch analysis also has the potential for recovering the most complete archaeobotanical record of many prominent economic plants in the precolonial Caribbean (Pagán-Jiménez 2011). Starch analysis has the unique ability to show human interactions for creating and modifying plant-based foods and this microbotanical remain preserves exceptionally well in tropical conditions.

The new information gained from this study exposes some of the phytocultural (human-plant interactions) dynamics of the precolonial Bahamas.[5] In 1492, the Indigenous Peoples of The Bahamas were the first people encountered during the Spanish intrusions and were called Los Lucayos ("people of the small islands"), which has been anglicized as Lucayan. The earliest evidence for a human presence the Bahama archipelago is dated to around 700-800 CE (Berman et al. 2013). It remains an open question of whether colonists arrived from Cuba, Hispaniola, or both (Keegan and Hofman 2017). It is thought that the first migrants into The Bahamas belonged to the Ceramic Age ("Arawak") colonization of the Antilles, which originated in northeastern South America around 500 BCE. There is, however, new evidence that their roots should be traced to the pre-Saladoid ("Ciboney") colonization of Cuba and that they practiced a horticultural economy (what Cuban archaeologists have called *modo de vida protoagrícola*) (Tabío and Rey 1985; Veloz Maggiolo and Zanin 1999). These differing conclusions have important implications concerning how botanical foodways in The Bahamas should be interpreted.

We begin with a discussion of the site from which the analyzed artifacts were recovered. Next, review the methods used, the taxonomic assessment of recovered starch grains, and the starch grains associated with the specific artifacts. We conclude with a discussion of the implications of botanical identifications for reconstructing socially learned practices of botanical food processing.

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[5] The Bahama archipelago designates a geographical area with two independent nations: The Commonwealth of the Bahamas and the Turks & Caicos Islands. There are notable differences in the archaeology of these islands (Keegan 1997). Therefore, the current study focuses solely on The Bahamas.

2.2 Archaeological background site LN-101

Long Island was devastated by Hurricane Joaquin in late September 2015. In The Bahamas, eight hurricanes were reported between 1888 and 1960 causing the loss of life, houses, and crops (Mills 2009:145-146). One hurricane every ten years was the average for The Bahamas (Doran Jr. 1955). Since 1960, an additional eight hurricanes have affected parts of The Bahamas, meaning hurricanes have increased to devastate this region at least once every seven years (Doran Jr. 1955; LeVin 2017). Climate change and the ensuing increase of storms are a direct and immediate threat to the Caribbean islands, the people, and their archaeological sites. One impact of Hurricane Joaquin was the substantial scouring of the 6-meter-high sand dune that rises above north-facing Lowe's beach north of Clarence Town (Fig. 2.1). Local residents Nick Constantakis along with Nick and Anthony Maillus found two frontal-occipital modified Lucayan skulls on the beach, and identified two places where human bones were exposed in the dune face (designated site LN-101). In October 2016, Pateman and Keegan excavated three skeletons from this unusual dune burial, but no cultural materials were found in association with the burials. They returned to the burial site with a team of volunteers in December 2016 and 2017 to establish the cultural context of the burials. Ground-penetrating radar was used to remotely sense the burial area, and a systematic shovel test survey was conducted along the top of the dune within five meters of the dune edge. No additional burials were encountered, but seven small activity areas were identified between Turtle Cove and Clarence Town (see Keegan and Mitchell 1984 for a previous survey in this area). Artifact Kr1 came from a different site (LN-103; ST-16, 0-50 cmbs), which was found during shovel testing. LN-103 is east of LN-101, and about 800 m west of the main beach road in Clarence Town (Fig. 2.1).

One of these activity areas is located 60 m east of burial #1 (LN-101). It is possible that some of the site has eroded into the sea, but there were neither artifacts on the beach nor anthropogenic evidence on the dune face. One shovel test revealed a fairly dense cultural deposit, buried under 60 cm of sand. An L-shaped section of a 2x2 m^2 was excavated to obtain a broader exposure (Unit 2). The artifacts (Kr2, Kr3, Kr4, Kr5, Kr6, Kr7 and Kr8, Table 2.1) in this analysis are from Unit 2 (FS 17, 60-90 cmbs; and adjacent FS 43, 70-90 cmbs). In one corner of Unit 2, there was the outline of a pit with a concentration of fire-cracked rock, ash, and black soil that has been identified as the remains of an earth oven (Fig. 2.2).

Earth ovens are ethnographically known to be comprised of seven parts: prepared basin, fire, layer of hot rocks, lower packing layer, food, upper packing layer, and an earthen cap (Black and Thoms 2014). Archaeological remains do not typically preserve all seven layers. Instead, the primary components that preserve would be the prepared basin, the fire leaves an ashy layer, followed by darker carbon-stained sediments. The earth oven reported here has all of the expected archaeological remains in addition to an absence of pottery but a close association with lithic plant processing tools that would assist with food preparation for an earth oven (Bel et al. 2018).

The one AMS date from Unit 2 returned cal 1020-1060 CE (32.4%) and 1075-1155 CE (63%) from charcoal recovered at 70-90 cmbs in Unit 2.[6] Continued testing in the area revealed four similar activity areas separated by about 200 m. All are of small size, and in addition to LN-101, two other activity areas also had earth ovens (including EO#3 at site LN-102, located on a low dune 500 m east of LN-101). A common characteristic of these activity areas was evidence for the manufacture of shell beads. A complete description of the excavation is being prepared (Keegan and Pateman n.d.).

Table 2.1
Artifact provenance and contextual information of the analyzed samples.

Provenance	Artifact raw material and type	Lab ID
LN-103 FS53	Limestone artifact	Kr1
LN-101 FS17	Shell (*Codakia orbicularis)*	Kr2
LN-101 FS17	Shell (*Codakia orbicularis)*	Kr3
LN-101 FS17	Limestone artifact	Kr4
LN-101 FS43	Limestone micro flake	Kr5
LN-101 FS43	Limestone micro flake	Kr6
LN-101 FS43	Limestone micro flake	Kr7
LN-101 FS43	Limestone micro flake	Kr8

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[6] Lab # PSUAMS-1568, 960 +/- 20 BP, cal AD 2-sig (OxCal), percentages reflect probabilities (P).

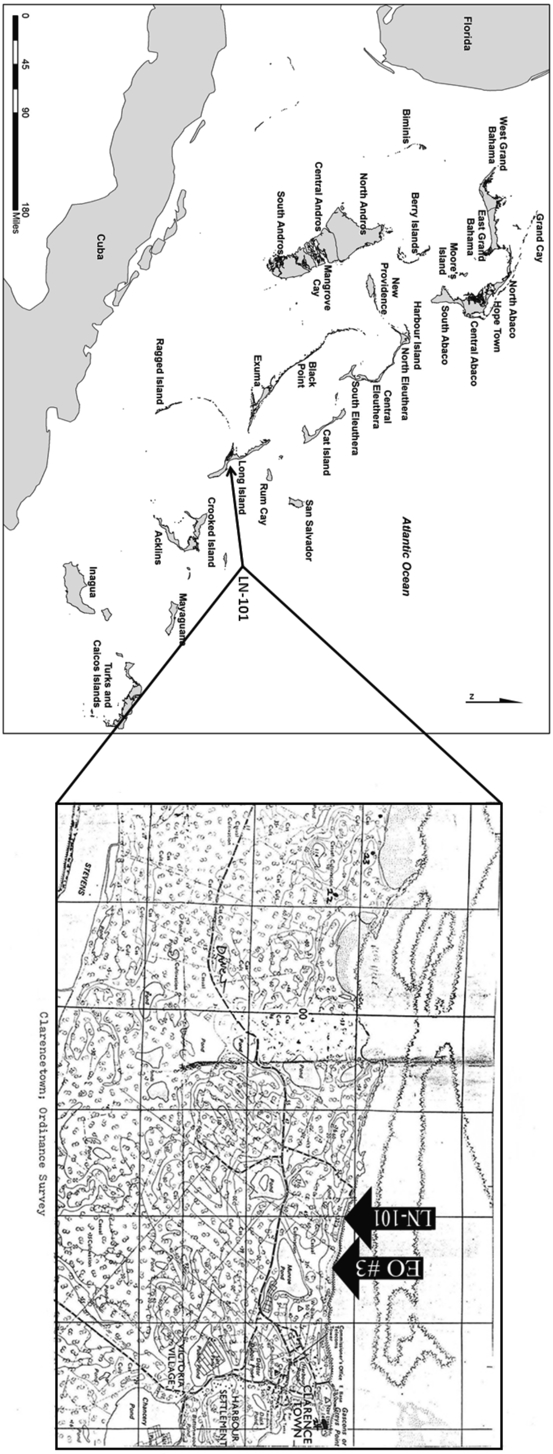

Figure 2.1
Map of The Bahamas and Clarence Town marking archaeological site LN-101 and earth oven #3 (EO#3)

Figure 2.2
Archaeological remains of the earth oven #3 (EO#3).

2.3 Methods

The artifacts were selected based on Keegan's archaeological experience for inferring what could have possibly been plant-processing tools. The artifacts were hand bagged in the field and air dried on newspaper. None of the artifacts were washed or brushed. They were brought to the Caribbean Archaeology Laboratory at the Florida Museum of Natural History where they were again handled when measured, weighed, described, and photographed. The objects were then wrapped in aluminum foil, rebagged, and sent for analysis. Keegan sent these artifacts to the Faculty of Archaeology, Leiden University via Ciofalo. When the artifacts arrived at Leiden University, they were relabeled with the starch lab identifications of Kr1, Kr2, Kr3, Kr4, Kr5, Kr6, Kr7, and Kr8 (Table 2.1).

For this study, no peripheral sediment samples were investigated for starch content. The rationale regarding sampling soil surrounding an artifact would be that if residues found on artifacts are not apparent in the soil, then the starch grains found on artifacts are more likely a result from use of the artifact. However, it seems that starches found in soil surrounding an artifact are more related to transference from the artifact (Pagán-Jiménez et al. 2015; Pearsall et al. 2004). Consistently throughout experimental and archaeological studies, starch grain frequencies in sediment samples are considerably less than those recovered from artifact surfaces (Atchison and Fullagar 1998; Barton et al. 1998; Haslam 2004; Loy et al. 1992; Piperno et al. 2009; Therin 1998).

Admittedly, there is still a possibility for human caused airborne starch to contaminate artifacts both during excavation and laboratory procedures (Barton et al. 1998; Crowther et al. 2014; Dozier 2016; García-Granero et al. 2016; Hart 2011; Laurence et al. 2011; Loy and Barton 2006; Mercader et al. 2017; Mercader et al. 2018). However, as the labs at the Faculty of Archaeology, Leiden University are being used for multiple studies of ancient microbotanical remains, they have been adequately fitted to prevent contamination. In addition, the negative results from this study seen in (Table 2.2) are a testament to the cleanliness of the laboratories and the security of the protocols followed to prevent post-excavation contamination. Regardless, the labs and consumables are consistently tested by different researchers working separately on starch research in the same facilities, with only one test with evidence of starch contamination. That test occurred more than a year prior to this analysis. During this routine contamination test on nitrile gloves from an unopened box a highly modified but unidentifiable starch grain was discovered. While the gloves claim to be ‘powder-free’, they are only made with less starch powder than other gloves that are not labeled as powder-free (Laurence et al. 2011; Loy and Barton 2006; Messner 2011:60). Because of this discovery, the choice to not to wear gloves, instead washing hands thoroughly before any laboratory procedures has been made.

After photographing each artifact they were lightly washed with purified water, which helped remove possible modern contamination and other matrix or lightly adhering residues that were never a part of the artifacts ancient use history (Barton and Torrence 2015). The entire surface of each artifact was sampled separately using an ultrasonic bath (procedure adapted from Pagán-Jiménez 2007; Pearsall et al. 2004; Perry 2004). For this extraction, the artifacts sat in ultra-purified water in new plastic cups undisturbed for a period of 20 min to “soak”. The sonicator was then run for a period of 5 min. As the artifacts were removed from the containers, they were rinsed with ultra-purified water drained into the containers with the contents successively poured into new 50 ml sterile plastic tubes. The tubes were centrifuged at 4000 rpm for 6 min. The supernatant (liquid lying above solid residue) was decanted and samples were left to dry in a controlled environment. All of the residue-sediment samples were processed for the separation of starch grains with Cesium Chloride (CsCl), as discussed subsequently.

The objective for this part of the protocol was to separate the starch grains through flotation and isolate them from other particles. The following protocol was applied to this study after Pagán-Jiménez (2007), (modified from Atchison and Fullagar 1998; Barton et al. 1998; Pagán-Jiménez et al. 2015; Pearsall et al. 2004). Once the samples were completely dried a heavy-liquid solution of CsCl and ultra-purified water, prepared to 1.80 g/cm^3 density was added. The solution and samples were agitated and mixed using an ultrasonic bath for at least 1 min then vortexed for 30 s. Next, samples were centrifuged at 2500 rpm for 5 min. The supernatant was decanted into new sterile micro-centrifuge 1.5 ml plastic tubes. Density separation isolates starch grains from other particles due to starches having an average specific gravity of 1.5 g/cm^3 (Pagán-Jiménez 2011).

In an effort to obtain a clean microscope slide, so microscopic observation was easier and starches were not obscured by other birefringent matter, all 1.5 ml plastic tubes with the remaining supernatant from the previous steps had CsCl added until the tubes were filled. These tubes were centrifuged at 2500 rpm for 5 min, and the supernatant was decanted into new micro-centrifuge 1.5 ml tubes. Following, ultra-purified water was added to fill the tubes, and the tubes were manually agitated to initiate a rinsing procedure. Next, the tubes were centrifuged for 8 m at 9000 rpm in a microcentrifuge. To reduce the CsCl solution's specific gravity, the supernatant was decanted and replaced with ultra-purified water, which dilutes the mixture. The next two rinses are the same, except for the time run in the microcentrifuge was decreased from 8 to 5 min. The remaining residues were slide-mounted in a small drop of glycerin. The microscope slides were covered with coverslips but not sealed. All slides were stored horizontally in new cardboard microscope slide holders for the subsequent microscopic observations.

2.3.1 Taxonomic ascription of the recovered starch grains

Studied microbotanical remains such as phytoliths, spores, and pollen are naturally dispersed in large quantities throughout the environment without human intervention; in contrast, starches are typically released from plant organs through human caused processes or in limited cases by decomposition (Beck and Torrence 2006; Ma et al. 2017; Pagán-Jiménez 2007). Thus, the relation between artifacts, human behaviors, and plant use appear to have a strong correlation seen best through starch analysis (Holst et al. 2007; Pagán-Jiménez 2009; Pearsall et al. 2004; Perry 2004).

At present, we have assembled a comparative reference collection of starch grains obtained from recent economically useful and edible plants with the majority collected and processed by Pagán-Jiménez with some samples obtained from CIMMYT's Maize Genetic Resources (Pagán-Jiménez 2007; Pagán-Jiménez 2015a). Other samples were obtained from the Economic Botany collection of Naturalis Biodiversity Center Leiden, the Netherlands, the Montgomery Botanical Center Coral Gables, Florida, and from specimens that are endemic to or locally grown in the Bahamas collected and processed by Ciofalo. In sum, the reference collection contains modern starches from more than 140 specimens representing 70 genera and 63 wild, domesticated, and cultivated species from the Antilles, continental tropical Americas (mainly the continental circum-Caribbean area), The Bahamas, and parts of the Old World, in order to assist in identifying taxa. Descriptive analysis of modern samples with detailed explanations of morphometric features allows for the identifications of ancient starches through comparison (e.g., Pearsall et al. 2004; Perry et al. 2007; Piperno and Holst 1998). For this study, if the majority of these observed diagnostic characteristics of the ancient starches are not seen in the modern reference collection, then the taxonomic identification is tentative at best. In these cases, the use of categories "cf." (in reference to the closest tentative classification) and "not identified" was employed. A reliable or secure identification was not established if archaeological starch grains exhibit traits that are not documented in our reference collection or in consulted published sources (Berman and Pearsall 2008; Dickau 2005; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Perry 2004; Piperno and Holst 1998; Reichert 1913). In this research there was also a focus during the identification process regarding plant processing techniques based upon published starch grain experimental studies (Babot 2003; Babot 2006; Henry et al. 2009; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2015b; Pagán-Jiménez et al. 2017), which were aimed to document different damaging factors and their visual effects on starch grains. Human caused manipulation of starchy plants and the associated damages and morphometric changes observed in both ancient starches and modern experimental samples can be correlated with these specific processes. Thus, secure and tentative identifications of starches in this study are based on diagnostic and/or distinctive features described elsewhere. Specific morphometric features used were shape, size, presence, and location of the hilum within the starches; as well as presence and appearance of fissures, presence and types of pressure facets, presence and appearance of lamellae, and in some cases the appearance and projection of extinction crosses (Pagán-Jiménez et al. 2016).

For measurements and observations, starches were photographed using a Leica DM2700 P polarizing light microscope. The primary indicative element, but not an exclusive component to discern starch gains from other residues, is the presence of the distinctive extinction cross which is observable under polarized light. All the starch grains recovered were photographed in multiple positions (when possible) by rotation and with different focal lengths. After the initial analysis, the slides were stored horizontally in new cardboard microscope slide holders for future observation and preservation. Additionally, the original sample collection tubes with remaining residues were filled with ultra-purified water, capped, and set aside in case further starch extraction was considered useful or a future phytolith study.

2.4 Results

Four artifacts Kr2, Kr3, Kr4, and Kr7 were processed with recovered starches. In addition, another four artifacts Kr1, Kr5, Kr6, and Kr8 were also sampled but there was no evidence of starch recovered from these four artifacts. Table 2.2 synthesizes the results attained from studying the starches recovered from these artifacts. This synthesis of associated results allows for further meaningful interpretations that will be integrated into a broader site analysis.

Table 2.2
Distribution of recovered starches by sample and their plant sources. [a] Ubiquity refers to the occurrence of identified taxa amongst the entire artifact sample spectra. It was calculated by dividing the presence of securely identified taxa by the total number of analyzed artifacts. [b] Minimum species richness combines both tentative ("*cf.*") and secure identifications. This excludes starches that were not identified because they could have been produced by some of the already identified taxa.

LN-101

Provenance	**LN-103 FS53**	**FS17**	**FS17**	**FS17**	**FS43**	**FS43**	**FS43**	**FS43**		
Lab ID	**Kr1**	**Kr2**	**Kr3**	**Kr4**	**Kr5**	**Kr6**	**Kr7**	**Kr8**		
Artifact material	**Limestone**	**Shell**	**Shell**	**Limestone**	**Limestone**	**Limestone**	**Limestone**	**Limestone**	**Total**	**[a]Ubiquity**
***Manihot esculenta* Crantz**			32				11		43	25
cf. *Manihot esculenta* Crantz			6				2		8	25
***Zamia* sp.**			1						1	12.5
***Zea mays* L.**		2					6		8	25
***cf. Zea mays* L.**		3					6		9	25
Not identified		0	9	1			4		14	--
Starch count	0	5	48	1	0	0	29	0	--	
[b] Minimum species richness		1	2				2		--	

2.4.1 Artifact Kr2

Figure 2.3
Codakia orbicularis plant processing tool (artifact Kr2).

This artifact is a shell (*Codakia orbicularis)* scraper that has macroscopically observed use-wear along the lip manifested in a broken and beveled edge (Fig. 2.3). This shell is approximately eight cm wide. Of the five starch grains recovered from this tool, two have been securely identified as maize (*Zea mays* L.) (Fig. 2.4 a, a1, d), on the basis of diagnostic continuous double borders, maximum size measurements of 21.96 µm and 19.4 µm respectively , and polygonal shapes according to our reference collection and other published sources (Holst et al. 2007; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Pagán-Jiménez et al. 2015; Pearsall et al. 2004). Two of the three starch grains tentatively identified as maize (Fig. 2.4 b, c) have evidence of pressure (scraping/cutting) probably generated by use of this shell. Of special note for interpretations is the starch grain in (Fig. 2.4 a, a1), because there is evidence for the beginning of a fold. This fold could have been caused from heating a maize cob/peduncle with low heat in a humid, but not boiling cooking environment, maybe to ease manipulation with this tool. Codakia shells are obtained easily along Caribbean coasts, and there is no indication they contributed to a significant part of the indigenous diet, instead they were likely considered useful for multifunctional tools (Van Gijn et al. 2008).

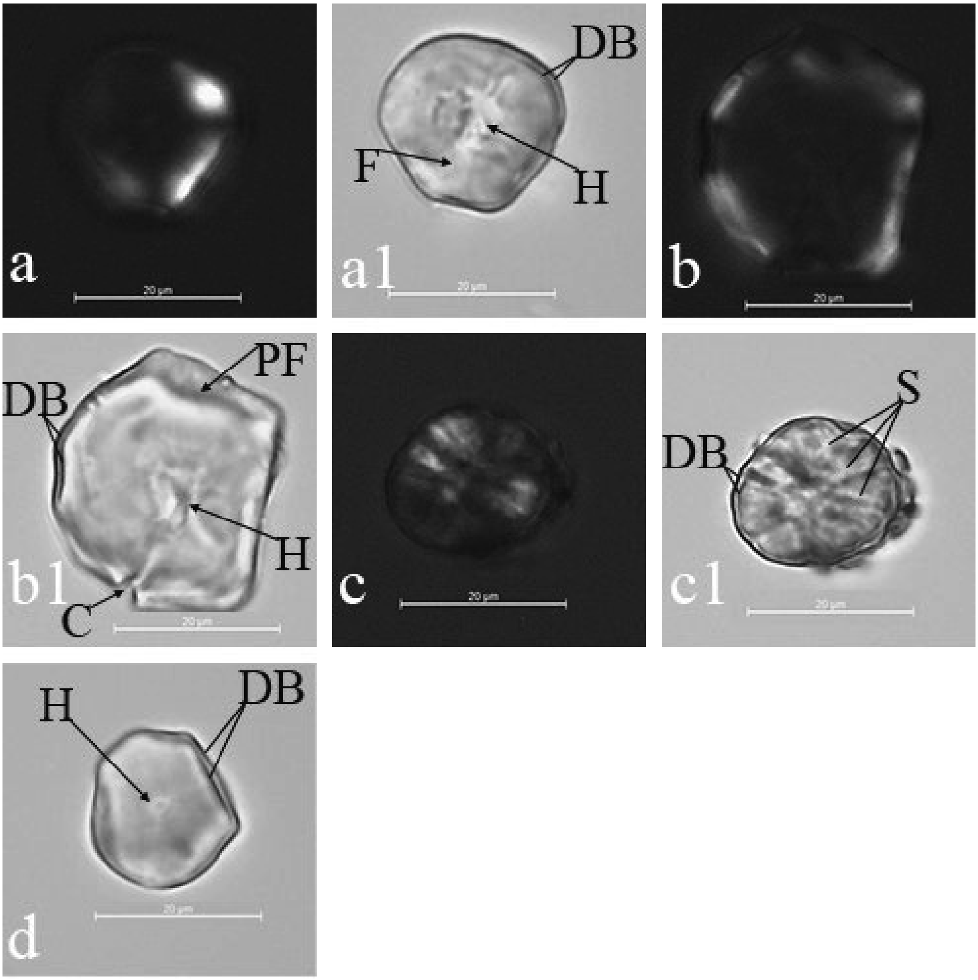

Figure 2.4
Starches recovered from artifact Kr2.
a Maize starch with polarizing filter and dark field view, notice partial optical loss of birefringence. **a1** The same maize starch with bright field view. **b** cf. maize starch with polarizing filter and dark field view, notice partial optical loss of birefringence. **b1** The same cf. maize starch with bright field view. **c** cf. maize starch with polarizing filter and dark field view, notice partial optical loss of birefringence. **c1** The same cf. maize starch with bright field view. **d** Maize starch with bright field view. Figure legend: “C” crack; “DB” double border; “F” fold; “H” hilum; “PF” pressure facet; “S” striation.

2.4.2 Artifact Kr3

Figure 2.5
Codakia orbicularis plant processing “tool” (artifact Kr3).

This artifact is a shell scraper (*Codakia orbicularis)* that has macroscopically observed signs of use-wear along the lip manifested in a beveled and broken edge. This artifact is notably smaller than artifact Kr2, with a longest measurement of approximately three and a half centimeters. At least two potentially poisonous taxa are represented in the 48 recovered starches from this tool, which evidently processed multiple starchy-food sources. Of the 48 starches, 32 have been securely identified as manioc, one as coontie, six tentatively ascribed as manioc, and nine with no identifications (many were too regular, meaning common in many species, or with not enough diagnostic features to identify) (Table 2.2). The majority of identified manioc starch grains are bell shaped, with lineal or stellate fissures, have two to five pressure facets, and all range in measurements between 7.91-21.39 µm, all of these characteristics match our reference collection and previously published sources (Pagán-Jiménez 2015a; Perry 2002b; Piperno 2006). It would have been beneficial to carry out a use-wear analysis, especially on the bivalve tools because based upon experimental studies manioc is known to create a unique polish topography when microscopically observed (Lammers-Keijsers 2007:56).

Of the nine starches with no identification, the starch shown in Fig. 2.6 a is worthy of note because there is evidence of the beginning of fermentation, with the starch grain being partially affected by enzyme degradation. Another starch grain shown in Fig. 2.6 b has been securely identified as manioc, which also has surface damage from enzymatic activity (Pagán-Jiménez 2015b). With only two of 48 starch grains with signs of enzymatic activity it is unlikely soil bacteria (postdepositional activity) led to these alterations. Alternatively, the 46 starches without signs of enzyme degradation may just have been more naturally resistant to bacterial digestion (Hutschenreuther et al. 2017). The starches in (Fig. 2.6 b-l) are some of the exemplified manioc starch grains recovered from this shell tool.

The starch grain in Fig. 2.6 m has been securely identified as coontie because it was consistent with our reference collection with the size (30.13 µm), shape (truncated and lenticular, when rotated), lamellae (faint undulating), and extinction cross arm shape (curved x shape). For comparison, our reference collection contains a few different species of coontie and a particularly relevant sample of *Zamia lucayana* B. (see more on this species in section 2.5 Discussion). Because we are unsure, which species of coontie has been identified in this study, we wish to report the size ranges for multiple species of coontie from our reference collection (Table 2.3). In addition, since Berman and Pearsall (2000) state that size is one of the defining differences between coontie and *yautia* (cocoyam) (*Xanthosoma* sp.); thus, it is useful to report size measurements for our sample of cocoyam (*Xanthosoma sagittifolium* L. Schott) (Table 2.3). Therefore, the identified coontie starch in this study is almost double the length of the largest cocoyam sample measurement from our collection, and in conjunction with the other previously described characteristics; it has been securely identified to the level of coontie's genus- *Zamia.*

Table 2.3
Our reference collection of coontie and cocoyam starch grain measurements, medians, and standard deviations

Species	Provenance	Sample size	Size range (µm)	Median (µm)	SD. (µm)
***Zamia lucayana* B.**	Montgomery Botanical Center Coral Gables, Miami, Florida	104	9.4-61.7	33.9	±13.28
***Zamia pumila* L.**	San Juan, Puerto Rico	138	5.72-49.4	15.29	±7.03
***Xanthosoma sagittifolium* L. Schott.**	San Juan, Puerto Rico	83	3.1-15.61	10.24	±2.95

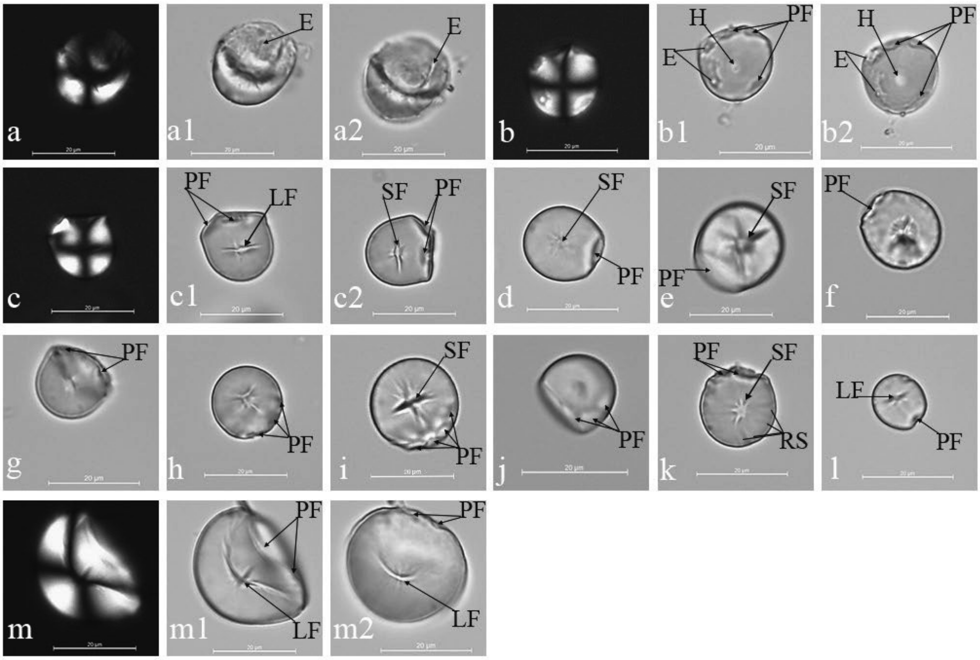

Figure 2.6
Starches recovered from artifact Kr3.
a Unidentified starch with polarizing filter and dark field view, notice partial optical loss of birefringence. **a1** The same unidentified starch with bright field view. **a2** The same unidentified starch at a different focal length with bright field view. **b** Manioc starch with polarizing filter and dark field view. **b1** The same manioc starch with bright field view. **b2** The same manioc starch at a different focal length with bright field view exposing the enzymatic damage. **c** A different manioc starch with polarizing filter and dark field view. **c1** The same manioc starch with bright field view. **c2** The same manioc starch with bright field view rotated exposing diagnostic features. **d-l** Other securely identified manioc starch grains with bright field view. **m** Coontie starch with polarizing filter and dark field view. **m1** The same coontie starch with bright field view. **m2** The same coontie starch rotated exposing a diagnostic shape. Figure legend: “E” enzyme degradation; “H” hilum; “LF” lineal fissure; “PF” pressure facet; “RS” radial striation; “SF” stellate fissure.

It is less probable that all of the manioc starches recovered from this artifact originated from the same tuber. However, it is likely that they represent manioc grown during the use-history of the artifact, which is a circumscribed snapshot of manioc cultivation. It is not often this many ancient manioc starches have been securely identified on one artifact. We hope that reporting the size measurements for ancient manioc starches will help future researchers identify manioc starches in their own samples. This also adds to the mounting evidence that smaller starches do not survive taphonomic processes as often as resistant starches. Thus, of the 32 starch grains securely identified as manioc from our study in comparison with measurements from other research summarized in (Table 2.4) the following conclusions can be made. All the reported measurement ranges of modern manioc have recorded smallest length measurements of less than 1.21 µm compared to the ancient starch measurements from this study. In addition, four out of five of the modern manioc reference collections have median, mean, or common size measurements smaller than the median measurements for the ancient starch grains, both in this study and the average reported by Ugent et al. (1986). The combined information provides evidence suggesting that ancient immature and thus smaller starches do not survive taphonomic processes as often as mature and larger (resistant) starches. This idea is similar to how some species are naturally more resistant to enzyme digestion (Hutschenreuther et al. 2017), and may be similar to how some resistant starches survive the human digestive process better than others (Pereira and Leonel 2014). As Piperno (2006:58) states, "size alone does not universally separate wild from domesticated *Manihot"*. In addition, the evidence from our findings could also refute the idea that starch grains from cultivated plants became larger over time compared to the species ancestors (e.g., Perry 2002b; Perry et al. 2007). However, many factors can influence the size of manioc starches including cultivation practices, tuber size, and soil fertility (Perry 2002b).

Table 2.4
Collection of manioc starch grain measurements, medians, and standard deviations

Source	Provenance	Variety (bitter or sweet)	Sample size	Size range (µm)	Median (µm)	SD. (µm)
This study	LN-101, archaeological	n/a	32	7.91-21.39	16.42	± 3.4
Ugent et al. (1986)	Casma Valley, Peru archaeological	n/a	n/a	5-35	20 (average)	n/a
Ciofalo's reference collection	Providenciales, TCI street market grown on North Caicos	Sweet	108	3.1-20.7	10.55	±3.362
Pagán-Jiménez (2007)	Aibonito, Puerto Rico, farm, locally produced	Sweet	126	5-20	13.05	± 3.784
Pagán-Jiménez (2015a)	Quito, Ecuador, street market	Sweet	20	6.7-37.3	17.16	± 7.96
Piperno (2006)	n/a	n/a	n/a	6-28	13-16 (mean)	n/a
Reichert (1913)	n/a	Sweet	n/a	5-20	15 (common size)	n/a

2.4.3 Artifact Kr4

This artifact (Fig. 2.7) is a limestone tool that could be classified as a "blade" based on morphology. The macro use-wear patterns seem to indicate the sharp edges were used. However, as the entire artifact was sampled all at once it is impossible to determine the exact micro-context of the recovered starch grain.

Figure 2.7
Limestone “tool” (Artifact Kr4).

The one starch grain recovered from this artifact was severely altered by processing (Fig. 2.8). The extinction cross experienced an optical loss of birefringence, the surface of the starch grain is bumpy, which indicate pressure (grinding/grating/cutting) probably from use of this tool (Babot 2003; Mickleburgh and Pagán-Jiménez 2012). In addition, there is a bright ring around the hilum, which is a damage pattern only observed on maize starch grains after the plant has been intensely ground (Mickleburgh and Pagán-Jiménez 2012). However, because there were not enough diagnostic characteristics observable on the starch and only one starch was recovered this starch cannot be identified nor can the “tool” be determined to be a plant-processing implement.

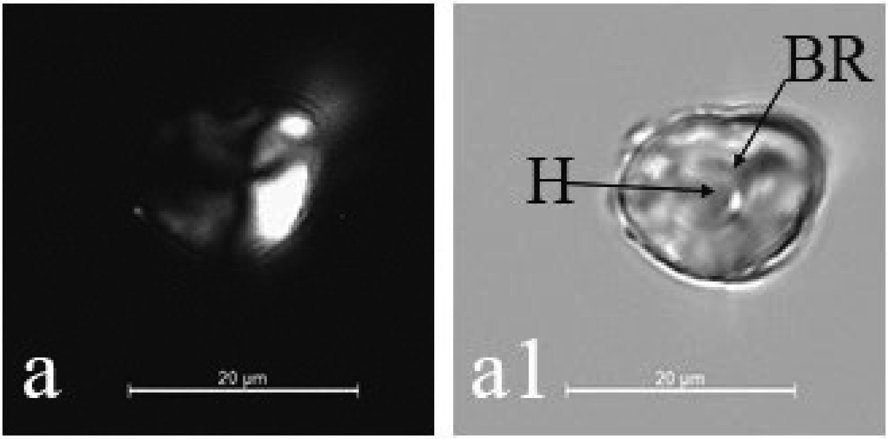

Figure 2.8
Starch recovered from artifact Kr4.
a Unidentified starch with polarizing filter and dark field view, notice the partial loss of extinction cross.
a1 The same unidentified starch with bright field view, notice the bumpy surface.
Figure legend: "BR" bright ring; "H" hilum.

2.4.4 Artifact Kr7

Figure 2.9
Limestone grater chip (artifact Kr7).

This artifact (Fig. 2.9) is a limestone microlith. It is plausible that the microlith examined in this study is a grater chip that was entrenched in a wooden board. This artifact is larger but morphologically similar to some of the chert microliths analyzed by Berman and Pearsall (2008), and to the ethnographic grater flakes examined by Walker et al. (1989). There were 29 starches recovered from this tool. Eleven of the starch grains have been securely identified as originating from manioc (Table 2.2**).** Three of those 11 manioc starch grains have some particles on and near the surfaces of the grains (example Fig. 2.10 g) indicating that the plant organ was heated in a dry cooking environment (sensu Henry et al. 2009). Of particular interest for further interpretations is one of the unidentified starch grains (shown in Fig. 2.10 a, a1, a2), which has evidence of pits in the surface of the grain likely caused by enzymatic degradation. There are also six confirmed maize starch grains and six tentatively identified maize starch grains (Fig. 2.10 b-f). Seven of these 12 maize starch grains have evidence of pressure (grating/grinding/cutting) damage. In sum, 17 of the 29 starches have damage patterns due to pressure. We infer that the damage patterns were manifested from a degree of pressure being applied to the plant organs because of the use of this tool or the larger grater board.

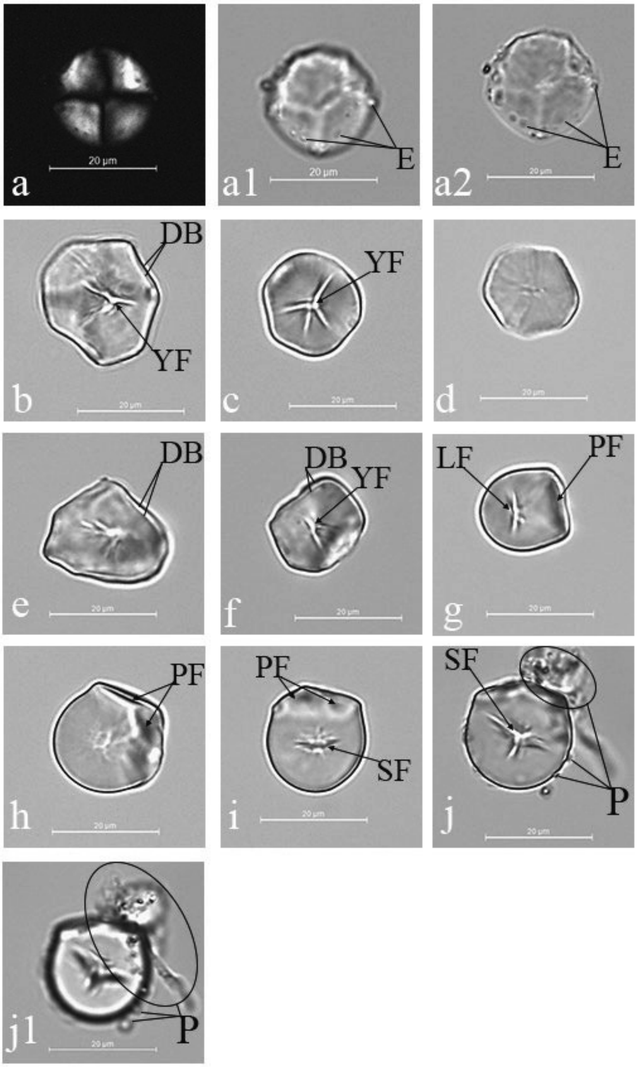

Figure 2.10
Starches recovered from artifact Kr7.
a An unidentified starch with polarizing filter and dark field view. **a1** The same unidentified starch with bright field view. **a2** The same unidentified starch grain with bright field view at a different focal length highlighting the enzymatic damage. **b-f** Five securely identified maize starches with bright field view. **g-i** Three securely identified manioc starches with bright field view. **j** Manioc starch with bright field view. **j1** The same manioc starch with bright field view at a different focal length highlighting the particles on and near the surface.
Figure legend: “DB” double border; “E” enzyme degradation; “LF” lineal fissure; “P” particles; “PF” pressure facet; “SF” stellate fissure; “YF” Y-shaped fissure.

2.4.5 Artifacts Kr1, Kr5, Kr6, and Kr8

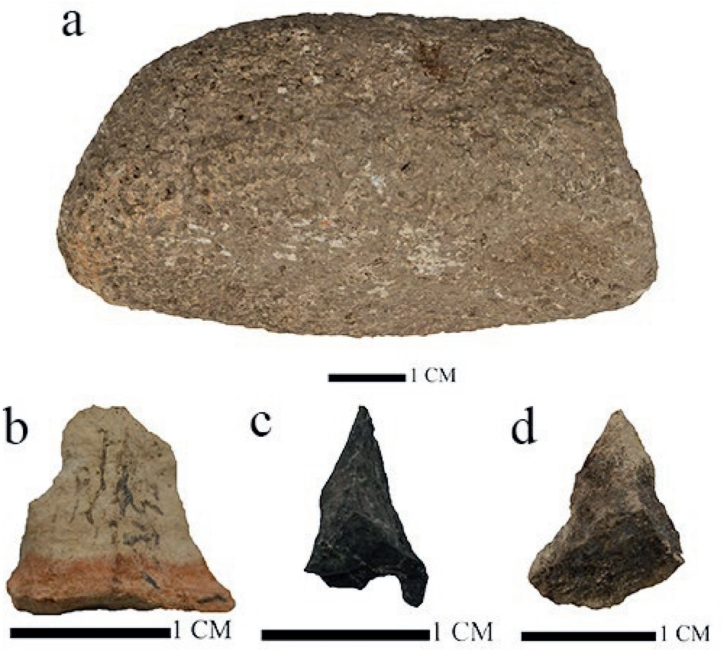

Figure 2.11
Lithic artifacts sampled without recovered starches.
a Artifact Kr1, **b** Artifact Kr5, **c** Artifact Kr6, **d** Artifact Kr8.

We believe these four artifacts without recovered starches to suffice for control samples mitigating concerns for post-depositional, post-excavation, pre-processing, and sample mounting contamination. Artifact Kr1 (Fig. 2.11 a) has macroscopic evidence of smoothing on what could be presumed to have been the bottom (contact area) of a sandstone mano. Kr5 (Fig. 2.11 b) appears to have been bifacially flaked and worked by percussion. Kr6 (Fig. 2.11 c) does not have a flat bottom as the other micro-flaked objects do in this assemblage, maybe it was manufactured but then discarded because of this flaw. KR8 (Fig. 2.11 d) is a pyramidal shaped, small fragment of limestone. These artifacts were all processed and sampled with the exact same procedure as the previously described artifacts. However, no ancient starches were recovered, which could be from multiple reasons such as micro-taphonomic issues of preservation (Haslam 2004; Langejans 2010) or processing plants which produce little or no starches (Hart 2011). Alternatively, these tools could have been used to process fish (Debert and Sherriff 2007). Lastly, maybe these pieces of limestone were not modified by humans and thus unused.

2.5 Discussion

The identification of cultigens is only one step in the investigation of botanical foodways, including the associated plant procurement and subsequent food processing techniques (Keegan 2010). Foodways in the precolonial Caribbean are often described in accordance with ethnohistoric accounts (Las Casas 1909; Sauer 1966; Sears and Sullivan 1978; Sturtevant 1969). Manioc and sweet potato were considered to be the most important crops, and these were cultivated in mounded fields associated with large villages positioned to take advantage of superior soils some distance from the coast (Keegan and Hofman 2017). In contrast, archaeological sites in The Bahamas are usually discovered to have been located on sandy soils directly on the beach (personal observations). Deposits are typically ephemeral and of small size, which suggests frequent movements.

Although coontie is listed as native to The Bahamas (Britton and Millspaugh 1962), it currently has a restricted distribution. Today there are only six Bahama Islands with native populations of coontie: Abaco, Andros, Eleuthera, Grand Bahama, New Providence, and Long Island (Calonje et al. 2013). The three coontie populations on Long Island have been a single panmictic population during the course of their history, but currently are considered a [critically] endangered species known as *Zamia lucayana* B. (common name: Long Island Coontie or Bay Rush) (Calonje et al. 2013). Currently, *Zamia lucayana* B. is only found in our study area in pockets along a 6.5 km by 100 m wide strip along the dune between Turtle Cove (Hamiltons) and Clarence Town (Calonje et al. 2013). Coontie prefers an open habitat, with wind and salt stunted vegetation (less than 50 cm tall) dominated by coppiced sea grape (*Coccoloba uvifera* (L.) (Meerow et al. 2012). The endangered status and restricted range of *Zamia Lucayana* B. may be due to the absence of human disturbance and the regrowth of Palmetto woodlands along the Atlantic coastal dune on Long Island.

Berman and Pearsall (2000) reported starch grain evidence of "cf. *Xanthosoma* sp. (yautia) or cf. *Zamia* sp. on two microliths from the Three Dog site on San Salvador." Given its current distribution, if the plant producing the observed starch from that study was grown locally it is either not coontie, or the range for coontie was greater in the past, as it has been suggested by a previous study that found modern coontie populations growing wild in unexpected areas of distribution in Puerto Rico (Pagán-Jiménez and Lazcano-Lara 2013). The recovery of possible coontie from San Salvador and the restricted range of modern coontie in The Bahamas, raise the possibility that the Lucayans transported coontie seeds or male and female plants between islands, and that coontie was cultivated or encouraged to grow by maintaining cleared areas (i.e., gardens).

In the same way that farming practices have been defined by European accounts, food processing suffers a similar bias. It is commonly assumed that meals were prepared in pottery vessels, with pepper pot used as the prime example (Berman and Pearsall 2008; Newsom and Wing 2004:202). Most archaeologists now recognize that griddles (flat cooking plates) were used to cook a variety of foods, but now it must be considered that a similar variety of foods were processed and cooked with tools analogous to the ones from this study (Pagán-Jiménez 2013; Rodríguez Suárez and Pagán-Jiménez 2008). The usual complement to pepper pot is cassava bread made from bitter (poisonous) manioc tubers processed through a sequence of procedures and then baked on a flat clay griddle (Rouse 1992:12). Yet, potsherds are so uncommon at LN-101 it would be difficult to reconstruct even one large vessel, and there is no evidence of griddles. The tools from this study were found in association with an earth oven, which is evidence for a previously unreported cooking technique in The Bahamas. Three such ovens have now been identified in the study area. Given the effort required to construct and use earth ovens, it is likely that a large quantity of various foodstuffs were baked at the same time (Thoms 2008; Wandsnider 1997).

Ethnographic accounts attest to maize being baked in its husk in earth ovens (Stevenson 1915:76). Baking maize before further processing with a shell tool would explain the evidence for heating observed on some starch grains recovered from artifact Kr2. We believe the starches recovered from artifact Kr2 were deposited on its surface while it was being used as a food preparation tool. Two of the three starch grains tentatively identified as maize have evidence of pressure (scraping/cutting), probably generated by use of this shell tool to remove maize kernels from a cob for further processing into other foods. The evidence from artifact Kr2 displays starches damaged by both heat and/or pressure. Certain foods require maize kernels to be removed before further processing (Pagán-Jiménez et al. 2016). The collated information helps us suggest that mature, but not dry, maize cobs were baked in an earth oven and then scraped with this shell tool to release the kernels to ease further processing, consumption, or storage (Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez et al. 2016; Wandsnider 1997).

The recovered starches from artifact Kr3 likely accumulated on its surface while it was used as a food preparation tool. With respect to the evidence of enzymatic degraded starches, some recipes require manioc to be fermented before being turned into a final product such as the

Makushi of Guyana, South America who mix fresh manioc tubers with tubers that have fermented as part of their process to make farine (Elias et al. 2000). In addition, many techniques to preserve foods require help from enzymatic activity (Green 2010). Thus, the starches with enzymatic degradation damage on this tool lead us to a few plausible interpretations. Including that, at least one of the food sources was in storage, in which time it began to naturally ferment before being processed with this shell tool. This fermentation may have been intentional as in the case of the previously mentioned recipe or as a method of preservation, or alternatively, the plant organs were in storage for too long and it was time to eat them before they completely spoiled.

This research presents a limestone microlith that we interpret to have been embedded in a wooden grater board functioning as a plant-processing tool. Moving past older archaeological literature and ideas, that thought plant-processing tools were used to prepare only one type of plant (see DeBoer 1975), this study adds to the mounting evidence providing the understanding that grater boards were not used to process only one type of plant (Berman and Pearsall 2008; Oliver 2001; Perry 2002a; Perry 2004). It is worth noting that the samples analyzed here are all limestone, whereas in the other study from The Bahamas that recovered starch grains from grater chips, they were bipolar-flaked, white chert microliths imported from the Greater Antilles (Berman and Pearsall 2000; Perry et al. 2007). Over 550 bipolar-flaked chert microliths were recovered at the Governor Beach site on Grand Turk in the context of beadmaking. In this case, they were identified as drill bits (Carlson 1993) thus, not all microliths are grater chips. Because The Bahamas are devoid of igneous and metamorphic lithic sources (Keegan 1997:45), we believe the limestone microliths are localized adaptations to the Bahamian geological environments.

2.6 Conclusions

Reconstructions of precolonial dietary subsistence strategies have been excessively dependent on zooarchaeological and ethnohistorical data with their admitted limitations. However, paleoethnobotanical studies also have inherent taphonomic biases and other limitations such as the spectra of plants that can be preserved, represented, and recovered. Overall, the results of this study offer a partial insight into the phytocultural dynamics of the research area. While the limited number of studied samples can be used to place the identified plants and food behaviors in chronological and geographical contexts, this data should not be used for inferring the economic or cultural significance of one plant over others at the intra- or inter-site levels. For inferring economic and cultural importance of botanical foods at different chronological and geographical scales, the study of many other artifacts or at least a larger number of samples at the site level must be analyzed and we encourage more interdisciplinary research incorporating use-wear, isotopic, and macrobotanical analyses when possible (e.g., Hofman et al. 2008).

Based on indirect inferences, manioc was believed to have been the staple root crop of Indigenous Caribbean peoples, and maize wrongly considered as a minor or even high-status food source (Newsom and Wing 2004:210; Rouse 1992:12). Direct archaeological evidence has demonstrated that manioc use was less ubiquitous and maize use was more common that the indirect evidence led earlier scholars to believe (Berman and Pearsall 2008; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez et al. 2015). In light of these understandings, the results from this study are a significant addition to the knowledge database of precolonial botanical foodways by adding to the mounting evidence for the ubiquitous use of maize, demonstrating the use of coontie in The Bahamas, and establishing that limestone and shell tools were used to process manioc. In addition, we have highlighted potentially different processing and cooking techniques inferred from the findings of maize, previously heated before scraping the kernels, and manioc, some of them fermented before being peeled.

This research has provided novel insights, in a region with poor botanical preservation. We have demonstrated a strong case for the further study of microlithic tools from poor quality lithic sources. This research should also encourage others working on foodways in tropical regions to consider a greater diversity of plant resources, and to identify and report earth ovens. The plant remains recovered from these artifacts and the associated earth oven contexts reveal a more complex set of functions than was previously considered for precolonial Bahamian foodways, involving the processing of several starchy plants. The presence of starch grains on the surface of a microlithic tool is the first such archaeological evidence for manioc food processing with a limestone grater chip in the Caribbean. Through this research, we want to stress that paleoethnobotany and archaeometrics can contest or improve our archaeological inferences, which have been erroneously based on indirect evidence and 16th century European descriptions.

2.7 Acknowledgements

The results of this study are part of the PhD project of Andy Ciofalo carried out at the Faculty of Archaeology, Leiden University in the context of the ERC-Synergy NEXUS1492 project that received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 319209. We thank both

Leiden University and the Florida Museum of Natural History for providing support and lab spaces for our work. We wish to thank Nick Constantakis along with Nick and Anthony Maillus and the team of archaeological volunteers who made this work possible on Long Island, The Bahamas. We also wish to thank Sylvia from North Caicos who grows some of the best manioc. We are grateful to the Antiquities, Monuments, and Museum Corporation in The Bahamas as the agency that granted us the permission to conduct the fieldwork and the laboratory analysis. We also are grateful to Leiden Universities Caribbean Research Group for their insightful comments and suggestions. Finally, we would like to thank the two anonymous reviewers for their feedback that improved this paper.

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CHAPTER 3

3

Starchy Shells: Residue analysis of precolonial northern Caribbean culinary practices

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Archaeometry (2020)

Chapter 3 Starchy Shells: Residue analysis of precolonial northern Caribbean culinary practices

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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.

El Flaco

Lab ID	Shell taxa	Sample volume (ml)	Sample weight (g)
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

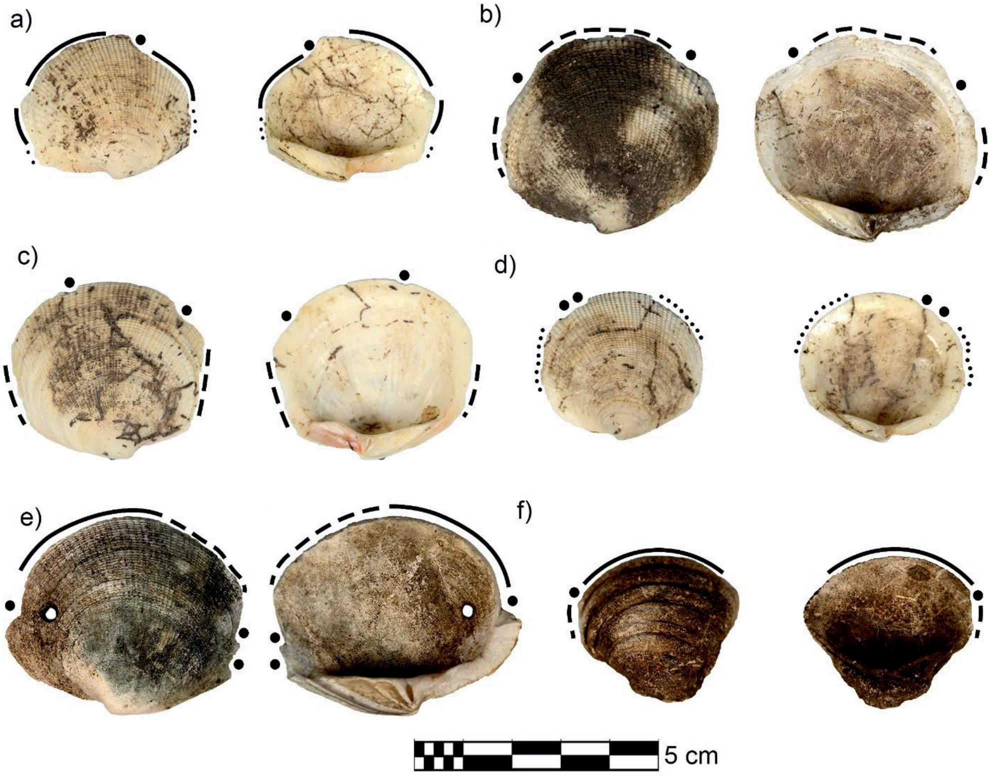

Figure 3.2
Selected shell artefacts from this study. Macroscopically visible wear produced relief of radial ribs and grooves at the ventral margins, which produced polishing (solid line), micro detachments (dots), and combinations of polishing, and micro-detachments (dashed lines). **a** FL66; **b**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

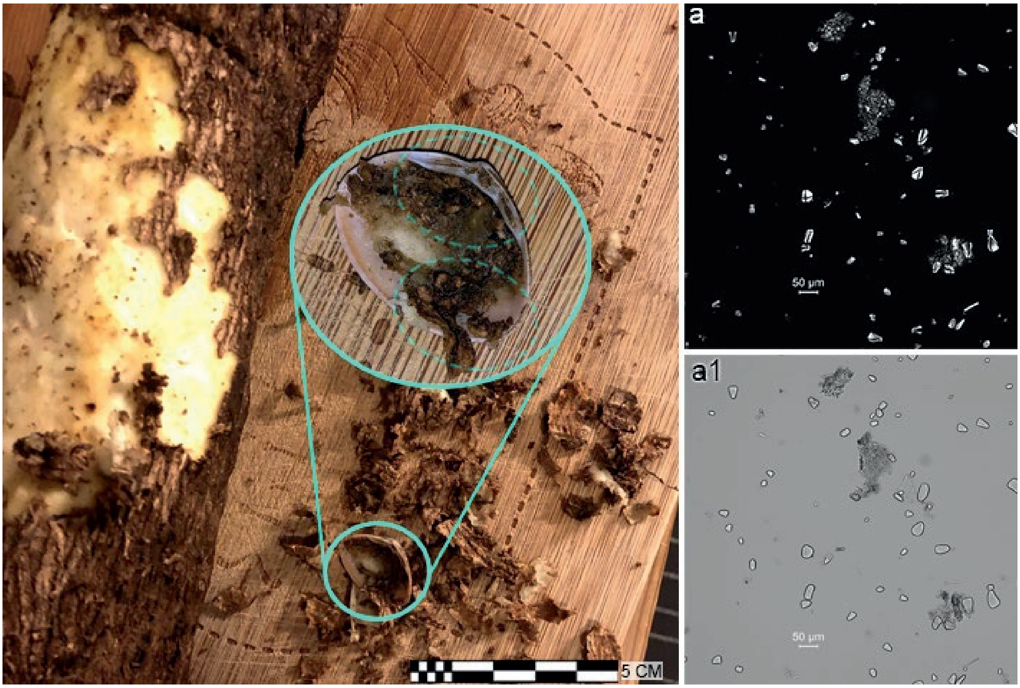

Figure 3.3
Bivalve shell used to peel modern yam (*Dioscorea cayennensis* subsp. *rotundata* (Poir.) J.Miège). Dashed ellipses highlight visible areas of concentrated starch collection in magnified image of used shell. **a** Sample of starch grains recovered from experimental bivalve shell tool under 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]CL5			1					1					[a]CL3		9 + [a]CL8
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]CL7					2										2+ [a]CL7
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).

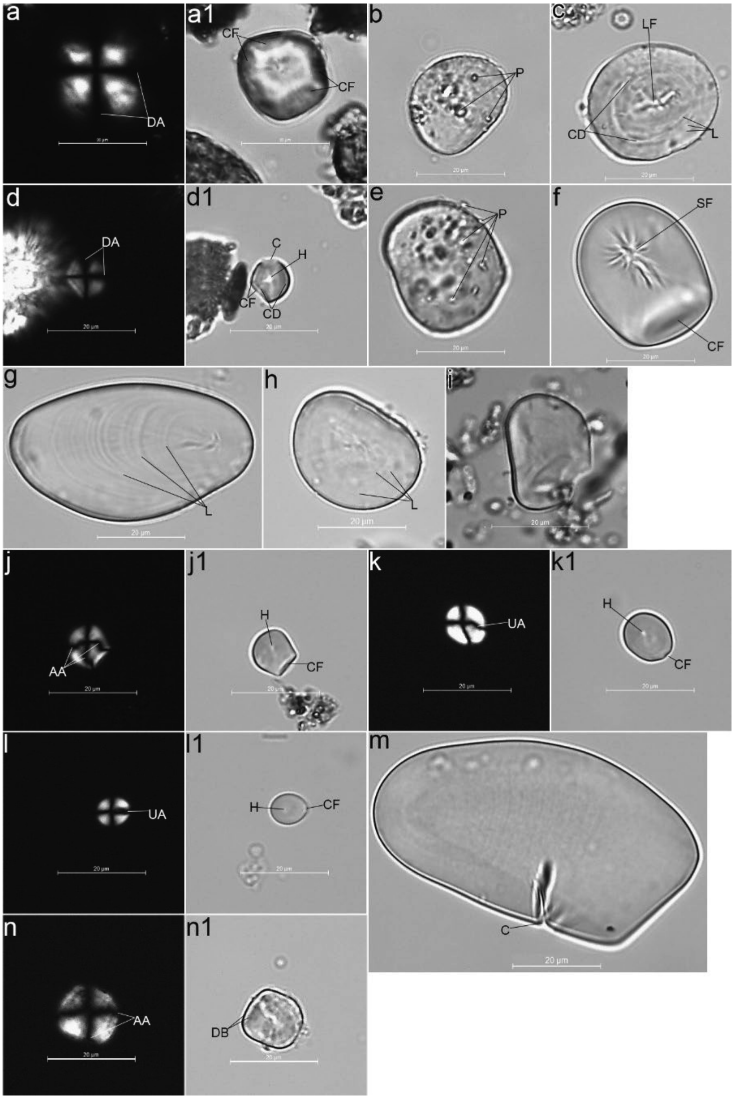

Figure 3.4
Examples of starch residues recovered from the 60 sampled shells. Grey background pictures are starches under bright field view and black background images are starches under polarized light and dark field view. **a** FL69, sweet potato starch. **a1** FL69, sweet potato starch. **b** FL99, 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.

3.7 Acknowledgements

The authors would like to acknowledge the research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 319209. Research was also made possible from a study trip to the TCI (Turks & Caicos Islands) through the Leiden University Fund/ Byvanck Fonds 76Ol/M/l 9.01.2O17/Bck. The authors thank both Leiden University and University of Central Florida for providing support for the work. The authors are also grateful to DEMA (Department of Environment and Maritime Affairs) in the TCI that granted permission to carry out this study. Thanks to Zara Ali for assistance in identifying archaeological shells. The work carried out with the shells of El Flaco, has been achieved within the structure of paleoethnobotanical research designed and carried out by Dr. Jaime Pagán-Jiménez for NEXUS1492. Without his guidance, the present work would have been next to impossible. The authors are also grateful to the anonymous reviewers for their insightful feedback. The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CHAPTER 4

Late precolonial culinary practices: Starch analysis on griddles from the northern Caribbean

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Journal of Archaeological Method and Theory (2019, Volume 26, Issue 4)

Chapter 4 Late precolonial culinary practices: Starch analysis on griddles from the northern Caribbean

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Abstract

Late precolonial (c. 800-1500 CE) culinary practices in the northern Caribbean have received limited investigations. Determining foodways has been integral for the study of cultures, yet there has never been a comparison of foodway dynamics in the Caribbean between the Greater Antilles (the presumed origin of people who migrated into The Bahamas) and the Bahama archipelago. The objective of our study was to analyze microbotanical residues (starches) extracted from 45 clay griddles (food preparation platters) to illuminate a partial view of the phytocultural repertoire of this region and explicate variations of the identified culinary practices. The griddles were excavated from three archaeological sites: El Flaco and La Luperona in northwestern Dominican Republic, and Palmetto Junction on the western coast of Providenciales, Turks & Caicos Islands. Regarding the creation of plant-based food on griddles, our data suggests that the people who lived at El Flaco produced maize (*Zea mays* L.) products, La Luperona residents prepared guáyiga/coontie/zamia (*Zamia* sp.) foodstuffs, and Palmetto Junction ostensibly had a focus on the production of manioc (*Manihot esculenta* Crantz) based foods. This survey of foodways has exposed particular cultural niches, different adaptation strategies, and associated culinary practices.

Resumen

Las prácticas culinarias precoloniales (c. 800-1500 CE) en el norte del Caribe han sido investigadas de manera limitida. Determinar las dimensiones de la alimentación ha sido fundamental en el estudio de las culturas; no obstante, en el Caribe nunca se ha realizado una comparación de estas dinámicas entre las Antillas Mayores (el atribuido origen migratorio de humanos a las Bahamas) y el archipiélago de las Bahamas. El objetivo de este estudio fue analizar los residuos microbotánicos (almidones) extraídos de 45 burenes (platos de preparación de alimentos) para proporcionar una visión parcial del repertorio fitocultural de esta región y explicar las variaciones de las practicas culinarias identificadas. Los burenes fueron excavados en tres sitios arqueológicos: El Flaco y La Luperona en el noroeste de la República Dominicana, y Palmetto Junction en la costa occidental de Providenciales, Islas Turcas y Caicos. En lo referente a la producción de alimentos basados en las plantas, nuestros datos obtenidos en los burenes sugieren que las personas que vivieron en El Flaco se concentraron en la producción de derivados del maíz (*Zea mays* L.); los residentes de La Luperona prepararon productos alimenticios de guáyiga/zamia (*Zamia* sp.); y en Palmetto Junction presumiblemente sus habitantes se enfocaron en la producción de alimentos derivados de yuca (*Manihot esculenta* Crantz). Este estudio de las dimensiones de la alimentación ha puesto de manifiesto la existencia de nichos culturales particulares, diferentes estrategias de adaptación, así como divergentes prácticas culinarias asociadas a ellas.

Keywords*:* **s**tarch analysis, foodways, Caribbean archaeology, griddles, manioc, cultural niche construction, culinary practices

4.1 Introduction

The subject of foodways has been integral for reconstructing past lifeways. That which is eaten sustains communities both ideologically and corporally, because food is symbolically and factually representative of belief systems, social identity, and existence (Crouch and O'Neill 2000; Twiss 2007). Throughout the world, people have made the act of eating into a theater where a multitude of social relations can be symbolized, created, and strengthened or destroyed (Welch and Scarry 1995). Moreover, the social need for belonging has been assuaged through consumed food that was accepted at the community level (Dweba and Mearns 2011). Food has provided comfort and cemented or expressed group identity; therefore, the study of foodways can effectively illuminate socio-cultural structures that perpetuated learned behaviors. As such, understanding foods and their associated culinary practices can contribute towards interpreting identities. Through our study, a partial view of Caribbean Indigenous People's culinary practices became more evident.

Diet and subsistence patterns contribute a substantial amount of information for understanding people's lifeways. However, anthropologists have moved past attempts to determine which foods were featured in social organizations in favor of investigating the function of food as a part of the semiotic system within particular socio-cultural frameworks (Appadurai 1981; Morehart and Morell-Hart 2015; Morell-Hart 2012). Worldwide, more consistent applications and advances in archaeobotany have enabled archaeologists to address research problems regarding plant domestication, economies, subsistence strategies, human introductions of new plants, and the role of foods during social events (Barton and Torrence 2015; Henry et al. 2014; Liu et al. 2018; Pagán-Jiménez et al. 2015; Pearsall 2018; Piperno 2011; Zarrillo et al. 2018).

This improved methodology facilitates a more comprehensive conceptualized view of foodways, to include not only dietary elements but also the profusion of related behaviors including production, preparation, storage, and presentation of foods. To disentangle human-plant interrelationships, archaeobotanical interpretations need well-grounded data generated from systematic investigations, and we postulate that determining past phytocultural[7] scenarios through empirical evidence should be at the forefront of research on archaeological foodways.

In the Caribbean, plants were an agroeconomic foundation; connected with ceremonial, civic, and daily activities by providing foods, medicine, and materials for craft production (Newsom and Wing 2004). Deborah Pearsall (1983; 1985) researched macroremains and initiated full-fledged, systematic, paleoethnobotanical analyses in the Caribbean. Subsequently, Lee Newsom (1988; 1991; 1992; Newsom 1993) began to identify archaeological plant macro remains from Haiti, followed by Puerto Rico, Bonaire, and the Lesser Antilles. Macrobotanical research in the Neotropics provided useful information but did not recover empirical evidence for many of the presumed key agroeconomic plants (Dickau 1999; Newsom 1988; Newsom 1991; Newsom 1992; Newsom and Wing 2004; Piperno and Pearsall 1998). Moreover, tropical regions are notorious for poor organic preservation (Pearsall 2003), and suitable macrobotanical data can be unrecoverable in these contexts. During this time, Pearsall (1989) expanded her research area into The Bahamas combining macroremains and phytolith analyses.

More recently, other plant microfossils have been studied in the Caribbean (Castilla-Beltrán et al. 2018) and particularly starch analyses of these plant remains have been profitably utilized to reconstruct the archaeobotanical record and culinary practices (Bel et al. 2018; Ciofalo et al. 2018; Pagán-Jiménez 2016; Pagán-Jiménez et al. 2015). For the first time, we are now systematically applying microbotanical analyses in the northern Caribbean with comparisons amongst sites and between islands. This approach produces empirical evidence for making well-grounded interpretations regarding functions of plant-based foods in cultural frameworks of tropical regions.

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[7] For the purpose of our research, phytocultural has been defined as human-plant interrelationships which is a broad category including a plethora of related botanical foodways.

We provided direct archaeological evidence of human-plant interactions determined from microbotanical residues (starches) extracted from 45 clay griddles (flat 'cooking'[8] plates). We excavated griddles from three archaeological sites: El Flaco and La Luperona in the Dominican Republic, and Palmetto Junction in the Turks & Caicos Islands. Our collated data and interpretations add to ongoing discussions regarding the roles of plants in transported landscapes, niche constructions, and culinary practices (Berman and Pearsall 2008; Laffoon et al. 2016; Mickleburgh et al. 2019; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2013; Rodríguez Ramos 2011; Smith 2015; Smith 2016; Smith and Chinique de Armas 2018; Zeder 2016).

4.2 Regional Background

The deep history of the northern Caribbean is brimming with rich culinary practices (Newsom and Wing 2004,114-188; Pagán-Jiménez 2013; Smith and Chinique de Armas 2018). The excitement has been exponential as researchers expand upon and contrast with European written sources, demonstrating the immense diversity of culinary practices that were present in Neotropical regions (Berman and Pearsall 2008; Morehart and Morell-Hart 2015; Newsom 2008; Pagán-Jiménez 2007; Piperno et al. 2009; Rodríguez Ramos 2016; Sheets et al. 2012; Staller et al. 2006). For the Caribbean, Ramón Pané et al. (1999) and Bartolomé de Las Casas (1909) wrote descriptions of the use of manioc (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L.), maize (*Zea mays* L.), and coontie/guáyiga/zamia (*Zamia* sp.)[9]. These writings portrayed what Europeans believed were the dietary and symbolic significances of plants for the Caribbean Indigenous Peoples. However, it is errant to project ethnohistoric sources onto the past in an attempt to elucidate the archaeological record (Wobst 1978; Wylie 1985). Extrapolations of contact period written sources applied to the archaeological record from centuries before are problematic due to cultural changes (i.e. which plants were used and how they were processed) due to the magnitude of disruption from European invasions, systematic colonization, and enslavements (Denevan 1992; Jennings 1975; Keegan 1996; Montenegro and Stephens 2006; Pagán-Jiménez 2009; Wilson 1993). For these reasons, we

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[8] Prior to deposition into the archaeological record, some griddles may have been used as surfaces to process plants without cooking similar to modern kitchen countertops (Rodríguez Suarez and Pagán-Jiménez, 2008), thus, some griddles may have been used as flat food preparation plates that did not involve cooking.

[9] A plant of the genus Zamia is known locally in The Dominican Republic as guáyiga and in The Bahamas as coontie and thus, the term zamia is used to denote plants of this genus in the rest of this article.

turned to archaeological data to illuminate phytocultural scenarios of a region in the northern Caribbean during the advent of European invasions.

Traditionally archaeologists have believed that as indigenous “horticultural” schemes were being maximized during the Late Ceramic Age (c. CE 800-1500), they evolved into “agricultural” systems and created surpluses of crops, such as manioc (Keegan 1996; Keegan 2000; Newsom and Wing 2004:189). Manioc use by precolonial Caribbean people has been primarily assumed from ethnohistoric written sources, as well as the presence of microlithic grater chips, shell tools, and clay griddles (Crock and Bartone 1998; Fernández de Oviedo 1851 [1535]; Las Casas 1909:32; Loven 1935:359-366; Newsom and Wing 2004; Rouse 1992:12). These plant-processing tools, supposedly related with manioc, have often been regarded as carrying out a single function and processing one type of plant (see DeBoer 1975; Rouse 1992; Wilson 2007). Due to the abundance of these types of artifacts, it was assumed that manioc was an integral part of precolonial subsistence patterns in the Caribbean (Allaire 1999; Wilson 2007:86). However, regarding archaeological manioc starches from the Greater Caribbean region[10], they have been recovered from the artifacts listed in Table 4.1.

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[10] The Greater Caribbean (pan-Caribbean) region has been envisioned geographically as the sea-scape and continental areas proximally surrounding the insular Caribbean islands (Rodríguez Ramos 2010).

Table 4.1
Manioc starch recoveries from Greater Caribbean archaeological contexts.

Location	Type of artifact	No. of recovered manioc starches	Reference
Panama	Lithic grinding base	5 (S)	(Piperno and Holst 1998)
Panama	Lithic chopper Lithic grinding base	5 (S)	(Dickau et al. 2007)
French Guiana	3 clay griddles	7 (S)	(McKey et al. 2010)
French Guiana	Clay bowl	2 (S)	(Pagán-Jiménez 2012)
French Guiana	Clay griddle	1 (S)	(Bel et al. 2013)
Venezuela	Clay griddle, 2 clay pots	NA	(Pagán-Jiménez in Oliver 2014)
Colombia	Handstone	NA	(Piperno and Pearsall 1998:200)
Colombia	Lithic grinding base Lithic chopper 3 Handstones	13 (S)	(Aceituno and Loaiza 2014)
Belize	Lithic biface	2 (T)	(Rosenswig et al. 2014)
Guatemala	Lithic handstones Metates Clay jar	19 (S), 5 (T) 27 (S) 1 (S), 1 (T)	(Cagnato and Ponce 2017)
Panama	Lithic grinding base	1 (S)	(Aceituno and Martín 2017)
Puerto Rico	2 Handstones	4 (T)	(Pagán-Jiménez et al. 2005)
Puerto Rico	Coral milling base	Several (T)	(Pagán-Jiménez 2007:127)
Puerto Rico	Handstone 2 Lithic grinding bases	3 (S) 1 (S), 4 (T)	(Pagán-Jiménez and Oliver 2008)
Puerto Rico	Clay pot	1 (S)	(Pagán-Jiménez 2011a)
Aruba	Dental calculus	1 (S)	(Mickleburgh and Pagán-Jiménez 2012)
Dominican Republic	Clay vessel	1 (S) 1 (T)	(Pagán-Jiménez in Ulloa Hung 2014:138)
Martinique	Clay pot	1 (S)	(Pagán-Jiménez 2016)
Long Island, The Bahamas	Shell artifact Microlith	32 (S), 6 (T) 11 (S), 2 (T)	(Ciofalo et al. 2018)

(S)-secure identification (T)-tentative identification

Prior to our current study, out of 31 clay griddles from the Caribbean, Venezuela, and French Guiana that have been analyzed for starch content and five have demonstrated evidence for manioc remains (Bel et al. 2013; McKey et al. 2010; Pagán-Jiménez in Oliver 2014; Pagán-Jiménez in Ulloa Hung 2014:115,138; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Pagán-Jiménez 2011b; Pagán-Jiménez 2012; Rodríguez Suárez and Pagán-Jiménez 2008). Rodríguez Suárez and Pagán-Jiménez (2008) analyzed five clay griddles and recovered starches from a variety of species but no manioc starch, their study also proved that starches preserved and could be recovered from charred remains on griddles (see also Zarrillo et al. 2008). In sum, although long assumed to have been a staple cultigen, manioc has been sporadic or virtually invisible in the data generated from microbotanical investigations in the northern Caribbean and absent from griddles that have been analyzed for starch content

(Berman and Pearsall 2000; Berman and Pearsall 2008; Chinique de Armas et al. 2015; González Herrera 2016; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez in Ulloa Hung 2014:115,138; Pagán-Jiménez 2007; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Rodríguez Suárez and Pagán-Jiménez 2008). Starch analyses that have been carried out within the Greater Caribbean region also do not support the traditionally assumed view that manioc was a dietary staple (see discussions on this in Pagán-Jiménez 2013; Pagán-Jiménez et al. 2017; Perry 2002; Perry 2005).

Preconceptions regarding the dietary role of maize, envisioned it as a restricted crop, or of less value than manioc for the Caribbean Indigenous Peoples (Loven 1935:370; Newsom and Wing 2004:155; Rouse 1992:12). However, maize has consistently been one of the most ubiquitous plants represented by recovered starch residues from various studies throughout the Caribbean (Berman and Pearsall 2008; Ciofalo et al. 2018; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2013). The labels of ubiquitous, staple, and major dietary components should not obscure the nature of diverse vegetal subsistence for the precolonial Caribbean (Pagán-Jiménez 2007; Pagán-Jiménez 2013; Rodríguez Ramos et al. 2013b). The broad spectrum of plants prepared in the Caribbean has become apparent particularly from archaeobotanical investigations of griddles (McKey et al. 2010; Pagán-Jiménez 2008; Pagán-Jiménez 2012; Pagán-Jiménez 2013; Rodríguez Suárez and Pagán-Jiménez 2008).

The multifunctional use of griddles was first determined from the use of gas chromatography that exposed the presence of both plant and animal lipids (Rodríguez Suárez 2001; Rodríguez Suárez 2004). However, it was several years until the diversity of plants prepared on griddles was ascertained (Pagán-Jiménez 2007; Rodríguez Suárez and Pagán-Jiménez 2008). Rodríguez Suárez and Pagán-Jiménez (2008), documented that griddles were used to prepare sweet potato, arrowroot *(Maranta arundinacea* L.*),* bean (*Phaseolus vulgaris* L.), cocoyam (*Xanthosoma* sp.), zamia, and maize. The discovery of maize prepared on griddles in the Caribbean contradicted the presumptions of a few archaeologists (e.g., Newsom 2006; Newsom 2008; Newsom and Deagan 1994; Newsom and Pearsall 2003; Rouse 1992). It is now evident that an attributed function of an artifact based on morphology alone or artifact assemblages are not reliable indicators of precolonial culinary practices. To summarize, the current understanding of phytocultural scenarios within the northern Caribbean during the late precolonial period included humans who cultivated, processed, and consumed crop species such as maize, sweet potato, leren (*Calathea allouia* (Aubl.) Lindl.)*,* yam (Dioscoreaceae), cocoyam, and arrowroot (Marantaceae) in addition to collecting and possibly managing wild (or semi-wild) plants such as zamia and wild bean (*Phaseolus vulgaris* L.) (Berman and Pearsall 2000; Berman and Pearsall 2008; Chinique de Armas et al. 2015; González Herrera 2016; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2009).

Our case study of griddle use in the northern Caribbean was designed to expose how indigenous socio-cultural behaviors associated with this specialized food-processing tool were employed and which plants were parts of the culinary repertoire in the northern Caribbean. Culinary practices are another line of evidence revealing the immense diversity of Indigenous Caribbean Peoples' culture. If the culinary practices that involved griddles were successfully shared in the region of interest, then similar starchy plants and associated potential foodways ranking positions should be identified. On the contrary, if these culinary practices were unsuccessful amongst these communities then we would expect to find limited use of griddles and/or evidence of dissimilar types of starchy plants recovered. If any of these assumptions are supported, then plausible interpretations may be developed, further informing us about culinary practices.

To better comprehend foodways at different geographical scales, we compared botanical foodways of intra- and inter islands/sites in the northern Caribbean with overlapping occupation dates. Since 2013, Leiden University within the NEXUS1492 synergy project, under the direction of Prof. dr. Corinne Hofman, has carried out archaeological research in northwestern Dominican Republic. Prior to and more recently within the NEXUS1492 synergy project, Dr. Jaime Pagán-Jiménez has developed archaeobotanical criteria for foodways research in Dominican Republic and the Greater Caribbean region. Our present study incorporated those developed criteria for a comparison of foodways between, and selection of artifacts to we sampled from, the archaeological sites of El Flaco, La Luperona, and Palmetto Junction. The aim of this comparison of botanical foodways was to reconstruct cultural niches, adaptation strategies, culinary practices, and likely transported landscapes.

4.3 Archaeological Settings

4.3.1 Northern Dominican Republic

The archaeological sites of El Flaco and La Luperona are located in northwestern Dominican Republic, and have been interpreted as hamlets of permanent households occupied during the 13th to 15th centuries (Hofman and Hoogland 2015; Hofman et al. 2018). Situated between the Cibao valley and the Cordillera Septentrional, El Flaco is located 300 m above mean sea level and 20 km from the current coast (Hofman and Hoogland 2015). The ecotone of the southern side of the Cordillera Septentrional, where El Flaco is situated, is primarily a subtropical dry forest, but transitional with subtropical moist forest (Moya Pons 2004:32-33). El Flaco's material culture remains are characterized by pottery from both the Chican and Meillacan subseries and other pottery with interpreted mixed features of these two subseries (Hofman and Hoogland 2015; Jacobson nd). Beyond dietary plants, archaeological evidence from a predominance of endemic rodent, avian, and reptile remains in the faunal assemblage compared to that of marine-sourced remains suggests that the inhabitants of El Flaco focused on consumption of terrestrial animals (Shev 2018:177).

La Luperona is located 8 km North of El Flaco across the Cordillera Septentrional and is within view of and approximately 18 km from the coastal zone. The ecotone of the northern side of the Cordillera Septentrional, where La Luperona is situated, is primarily a subtropical moist forest, but transitional with subtropical very moist forest (Moya Pons 2004:32-33). The material culture remains are characterized primarily by pottery from the Meillacan subseries (Hofman and Hoogland 2015). However, evidence from pottery paste recipes implied there was an exchange of products and/or knowledge between La Luperona and El Flaco (Ting et al. 2016). This web of practitioners who shared clay recipes could have also shared foodways incorporating prepared meals on the pottery available in their social network. Although, having similar cultural materials does not always suggest similar foodways and the selection or rejection of food takes place at the level of self on a quotidian basis, these decisions may be reinforced at the community level during practices of eating together (Bourdieu 1979; Mintz 1985:4). Local environmental conditions are varied between these archaeological sites, so it would not be surprising if some plants were more successfully grown than others at the different locations (Fuente García 1976; Moya Pons 2004; Reyna Alcántara and Polonia Martínez 2012).

4.3.2 The Bahamas and Turks & Caicos Islands

It is widely believed that the Turks & Caicos islands functioned as an interaction hub for the proximal region of influence for Hispaniola (comprised of modern day Haiti and Dominican Republic) (Berman et al. 2013; Keegan 2007; Keegan and Hofman 2017:172; Keegan et al. 1998; Morsink 2012; Sinelli 2010; Sinelli 2013). Since 2014, the University of Central Florida, under the direction of Pete Sinelli and Andy Ciofalo, has carried out archaeological research at the Palmetto Junction site. A series of radiocarbon dates c. CE 1280-1455[11] indicate that Palmetto Junction was regularly occupied for almost 200 years (Sinelli 2015) and was contemporaneous with the Dominican Republic sites in the current study. The site of Palmetto Junction is located on a narrow isthmus on the western end of Providenciales, Turks & Caicos Islands (Fig. 4.1). This site is characterized by a high frequency and robust density of Palmetto Ware style pottery sherds covering its surface and throughout the investigated archaeological contexts. Among the largest sites in the Bahama archipelago[12], Palmetto Junction encompasses nearly 2 ha of confirmed activity areas and likely households. There are more than 20 middens of dense deposits containing abundant faunal remains, pottery sherds, and other material culture remains. Reef fish from the faunal assemblage have been interpreted to have contributed a significant portion to the indigenous diet at Palmetto Junction (DuChemin 2005). However, there is also significant evidence of hutia (*Geocapromys ingrahami*) being exploited for food and possibly management by humans; indeed more hutia remains have been recovered from Palmetto Junction than at any other site excavated so far in the Bahama archipelago (LeFebvre et al. 2018). Currently, the Turks and Caicos Islands are located within the Bahamas Zone III and considered dry tropical forest ecotone (Sears and Sullivan 1978). However, it is problematic to extend modern environmental records to the past; it is still a necessity to help understand a range of possibilities for precolonial environments and plausible ethnobotanical settings.

More than 90% of the thousands of pottery sherds recovered at Palmetto Junction were of the Palmetto Ware style (Sinelli 2015). Chican and Meillacan pottery account for the remainder of the assemblage. Wild cotton (*Gossypium* sp.), manioc, and chili pepper (*Capsicum* sp.) presently grow across the site without human intervention, and likely have descended from plants originally cultivated by Indigenous Peoples who lived there centuries ago. The size of Palmetto Junction and the density of both hutia and pottery remains make it unique among Bahamian archaeological sites. The location of Palmetto Junction is ideally positioned to maximize access to local clay, both botanical and animal resources, as well as to facilitate contact with people further North in The Bahamas or further South in the Greater Antilles.

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[11] Lab # Beta-384425, 660 +/- 30 BP, cal CE 2-sig (IntCal 13) and Lab # Beta-384427, 460 +/- 30 BP, cal CE 2-sig (IntCal 13).

[12] The Bahama archipelago designates a geographical area with two independent nations: The Commonwealth of the Bahamas and the Turks & Caicos Islands. Therefore, Providenciales is geographically the southern Bahamas.

Figure 4.1
Map of northern Caribbean showing the location of El Flaco, La Luperona, and Palmetto Junction. Prepared by Dr. Eduardo Herrera Malatesta.

4.4 Scope of Study

Niche construction is a theory used to clarify how and why an organism transformed, shaped trajectories, and adapted within their own local environments (Odling-Smee et al. 2003; Smith 2016; Zeder 2016). The effectiveness of human niche construction is founded on the capacity for culture, which includes high-levels of cooperation (Laland and O'Brien 2010). Previously, the human niche has been defined as culture (Downs and Bleibtreu 1972), and a “cultural niche” may be considered as the way an organism made a living (Lambert 2018). The epitome or perhaps primary building blocks for constructing how humans make a living are food products.

Regarding plant-based food products, several human-environmental interrelationships need to be fulfilled to solidify foundations of a constructed, preferred diet. Firstly, landscapes must be transformed to create appropriate socio-environmental conditions for different types of foods. Secondly, multidimensional human-environmental relationships at different geographical scales help the niche constructors adapt, incorporate, and reinforce successful foodways. This context of food creation, specifically the ways of preparing food products with a widely used culinary tool (griddle), may reveal one of the most crucial stages ever produced by a cultural niche -the humanization and devouring of the landscape.

For our study, the examined cultural niche was the way humans created starchy foods using griddles. Even if the creators did not consume the prepared foods, the finished products could have been traded with local or regional communities, and thus a part of their constructed niche, to make a living. If the culinary practices were successful, cultural transmissions could positively reinforce these practices in local or regional communities. Alternatively, if they were unsuccessful, new culinary practices should emerge (Eerkens and Lipo 2005; Zeder 2016). To investigate this idea, we carried out multiscalar analyses of botanical foodways with a focus on clay griddles because griddles were one of the common food preparation implements archaeologically recovered from most Ceramic Age Caribbean sites and all three sites in our study.

4.5 Materials and Methods

4.5.1 Artifact management and sample extraction

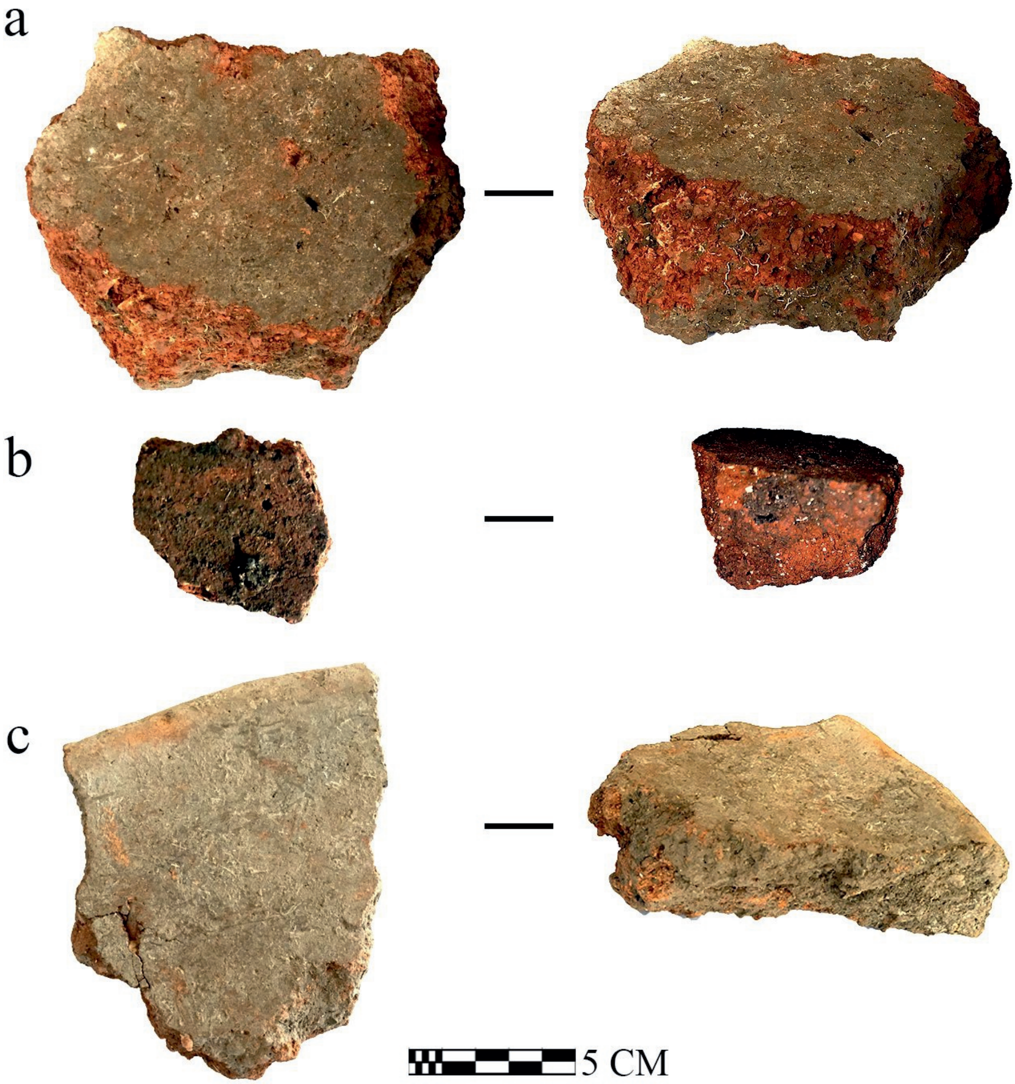

Figure 4.2
Three separate clay griddle fragments, one from each site in this study. **a** El Flaco Sample 585. **b** Palmetto Junction Sample 102. **c** La Luperona Sample 4.

Table 4.2
Samples by site, lab identification, and provenance (ZSSQ is zone, sector, and square locations).

El Flaco

Lab ID	Find No.	Feature Type	Unit No.	Field Provenance and Layer
27	2596	None	77	ZSSQ 63-54-37
550	1461	None	34	ZSSQ 63-47-81, L. 1
558	2456	None	73	ZSSQ 63-73-38, L. 2
576	2229	None	60	ZSSQ 63-38-9, L. 1
585	2374	None	68	ZSSQ 63-45-52, L. 2
601	1577	None	32	ZSSQ 63-82-57, L. 6
612	1562	None	33	ZSSQ 63-83-62, L. 5
631	N/A	None	70	ZSSQ 63-73-9, L. 4
632	2709	None	70	ZSSQ 63-73-18, L. 4
782	1265	None	19	ZSSQ 63-67-24 L. 6
788	1219	None	30	ZSSQ 63-66-28 L. Comb Layers
792	806	None	13	U. 13 ZSSQ 63-56-78 L. 2
795	1181	None	30	U. 30 ZSSQ 63-56-84 L. Comb Layers
796	27	None	1	U. 1 ZSSQ 63-64-94 L. 6
797	8115	None	13	U. 13 ZSSQ 63-56-87 L. 4

La Luperona

Lab ID	Find No.	Feature Type	Unit No.	Field Provenance and Layer
1	49	Fill	3	30-40 cmbs
2	25	No record	1	ZSSQ 54-47-75, L. 4
3	25	No record	1	ZSSQ 54-47-75, L. 4
4	25	No record	1	ZSSQ 54-47-75, L. 4
5	93	Fill	3	40-50 cmbs, Fill 3
6	14	None	1	ZSSQ 54-47-75, L.3
8	12	Fill	1	ZSSQ 50-47-76, L. 3
10	29	None	1	ZSSQ 54-47-75, L. 5
11	54	Fill	3	40-50 cmbs
13	10	None	1	ZSSQ 54-47-66, L. 2
14	16	None	1	ZSSQ 54-47-66, L. 3
15	21	None	1	ZSSQ 54-47-66, L. 4
17	N/A	None	1	ZSSQ 54-47-65, L. 4
18	4	None	1	ZSSQ 54-47-75, L. 1
19	6	NA	1	ZSSQ 54-47-76, L. 2

Palmetto Junction

Lab ID	Field Specimen No.	Feature Type	Unit	Field Provenance and Layer
102	118	Midden	U	20 cmbs L. 3
103	119	Midden	U	30 cmbs L. 4
104	119	Midden	U	30 cmbs L. 4
105	125	Midden	V	40 cmbs L. 5
106	125	Midden	V	40 cmbs L. 5
107	126	Midden	V	50 cmbs L. 6
108	126	Midden	V	50 cmbs L. 6
127	118	Midden	U	20 cmbs L. 3
128	127	Midden	V	60 cmbs L. 7
129	134	Midden	X	2 cmbs L. 1
130	132	Midden	W	40 cmbs L. 5
132	131	Midden	W	30 cmbs L. 4
133	136	Inside combustion feature	X	20 cmbs L. 3

136	142	Midden	Z	31 cmbs L. 2
138	143	Midden	Z	41 cmbs L. 3

We chose 15 griddle finds that consisted of a clay fragment or multiple fragments from each archaeological sites because La Luperona had this amount recovered which was the fewest griddle finds recovered from any of the three sites, but it means one hundred percent of griddle finds from La Luperona were sampled Table 4.2. Because the sampled griddles were recovered from three separate archaeological sites and were likely produced by different communities of potters they did not have the same color clay or surface treatments (e.g., did not have visible slip or paint and 20% of sampled griddles from Palmetto Junction had weaving impressions on the presumed bases). However, all sampled griddles were flat, thick (average thickness was greater than 2 cm), and macroscopically porous. In addition the sampled griddles were similar to ethnographic descriptions of some clay griddles; large (2-4 cm thick), flat, and made of coarse clay (Bel 2009; Loven 1935:367; Pennington 1963:217). Because we had tight control over the excavations and observed the recovery of all clay sherds, this reduced the possibility fragments of the same griddle were sampled twice. When we recovered griddle sherds from the same unit and stratigraphic layer, if they fit together and were possibly fragments of the same griddle, we sampled and treated them as the same griddle find. The majority of the sampled griddles were large, thick, and flat enough that it was impossible they came from flat-bottomed bowl-shaped vessels. As it has been extensively demonstrated in Caribbean archaeology (Hoogland and Hofman 1993; Keegan and Hofman 2017:91; Rouse 1941:92; Winter 1978), precolonial clay griddles are the only tools in the region having such morphometric characteristics. These characteristics are also in accordance with ethnohistoric descriptions of griddles (Fernández de Oviedo 1959 [1526]; Las Casas 1909).

Of the three sites, El Flaco had the most fieldwork seasons carried out and more than 150 separate griddle finds were isolated and sampled for microbotanical residues. Of all the sampled griddle finds at El Flaco, the 50 recovered outside of features were targeted for this study. Palmetto Junction had 30 griddle finds isolated and sampled for microbotanical residues. For each site, during archaeological recovery, we isolated the griddle finds and stored them in new plastic bags. We then assigned each griddle find a starch-lab identification number. Also, we entered the selected griddle sample identification numbers into a random number generator on random.org (Haahr and Haahr 2018). Finally, we randomly generated 15 integers, applied them to the samples from El Flaco and Palmetto Junction, and subsequently processed and used them along with all the La Luperona samples for our research Table 4.2.

The samples from this analysis (~0.214 g each) come from sediment obtained from dry-scraping the used surfaces of the griddle fragments. The procedures we followed were primarily after Pagán-Jiménez (2007), and we included slight modifications based on (Atchison and Fullagar 1998; Pagán-Jiménez et al. 2015; Pearsall et al. 2004; Zarrillo 2012; Zarrillo et al. 2008). The starch extraction protocol first called for us to lightly wash each artifact with distilled water. This washing procedure removed much of the sediment that adhered to the griddle fragments postdepositionally and was likely not a part of the artifact's use-history (Barton and Torrence 2015). Then we used a wash bottle with distilled water with significant water pressure for a final rinse, which likely removed the majority of any possible post-depositional, excavation, post-excavation, contamination (Hart 2011). This washing procedure was also necessary to improve the reliability of accessing the griddles regular (original surface) and negative surfaces (cracks, crevices, fissures, holes, and pores).

We dry-scraped the sampled surfaces of each griddle with a sterilized dental pick in its entirety to the depth of approximately 1 mm, unless the fragment was larger than 5 cm^2. In the cases of larger fragments, we scraped a systematic grid-like pattern in approximated areas of 1x1 cm and roughly, to the depth of 1 mm, which helped obtain a representative sample of each large griddle fragment. We collected the scraped residues on new printing paper and funneled them into new 1.5 ml vials. Between the times we sampled each artifact, we washed all lab surfaces, hands, and instruments used with distilled water to prevent cross-contamination between samples. We payed particular attention to cleaning the used dental pick by applying high-pressured distilled water from a wash bottle and heat from a lighter until red hot, which removed and/or destroyed starches that possibly remained on the dental pick (Pagán-Jiménez et al. 2015; Zarrillo et al. 2008).

For our study, we did not investigate any sediment samples from the artifact contexts for starch content. The rationale regarding sampling soil near an artifact was that if residues found on artifacts are not apparent in the soil, then the starches extracted from the artifact's surfaces were more likely to have resulted from use of the artifact. Other studies determined starches recovered from sediments that were near an artifact related to transference from the artifact to the surrounding soils (Ma et al. 2017; Pearsall et al. 2004; Piperno et al. 2000). However, we excavated the artifacts from Palmetto Junction from classic middens, which concerned us because of the possibility for ancient depositional contamination. Therefore, we sampled and analyzed a few non-culturally modified objects (hand-sized lithics without macroscopic use-wear traces) from the middens at Palmetto Junction for starch content. We detected no starches from these control samples.

4.5.2 Heavy density liquid separation for the recovery of ancient starches

We transferred sediment samples from the griddles to the labs at Leiden University and subjected them to a flotation procedure to separate starches from the rest of the material. We applied this part of the procedure primarily after Pagán-Jiménez (2007), and (modified from Atchison and Fullagar 1998; Barton et al. 1998; Dickau 2005; Henry et al. 2016; Pearsall et al. 2004; Perry 2010; Therin et al. 1999; Zarrillo 2012; Zarrillo et al. 2008). We prepared a solution of heavy-liquid cesium chloride (CsCl) to 1.79 g/cm^3 and subsequently added it to each vial. We then placed each vial into an ultrasonic bath for 1 min. We deemed this ultrasonic step necessary for two reasons. First, it assisted in breaking apart any carbonized and conglomerated residues. Second, the ultrasonic bath aided mixing the CsCl solution and residues.

Next, we centrifuged the samples at 2500 rpm for 8 min during the first phase of the flotation. This phase isolates starches with an average specific gravity of 1.5 g/cm^3 or more (Banks and Greenwood 1975). We then decanted the supernatant into new vials that each had ultra-purified water added and initiated the CsCl solution being diluted. The second phase of the flotation procedure consisted of us centrifuging the vials at 9000 rpm for 8 min. During this phase, any possible starches began to move down in the vials. We repeated this second phase two more times but operated the centrifuge for 5 min each dilution cycle. Between each cycle, we decanted the supernatant and added ultra-purified water, which reduced the specific gravity of the CsCl solution and forced any starches to the bottoms of the vials. After the last cycle, we added no water; instead, we added a small drop of glycerol (~0.1 ml). Next, we slide mounted and microscopically observed the remaining residue and glycerol solution with a cross-polarized Leica DM2700 P at 400 X. Finally, we counted starches, described, photographed them, and then compared them to the reverence collection established by Dr. Pagán-Jiménez.

4.5.3 Taxonomic identification of the recovered starch grains

To aid in taxonomic ascription, our reference collection contains modern starches from 140 individual specimens representing 70 genera and 63 wild, domesticated, and cultivated species from the Antilles, continental tropical Americas primarily the insular Caribbean, and parts of the Old World. Ciofalo added specimens purchased at local Caribbean markets and collected from the wild in The Bahamas, as well as from the Economic Botany collection of Naturalis Biodiversity Center Leiden, The Netherlands. We first located starches under polarized and color filtered view. The color filter reduced background ‘noise’ (other birefringent particles) and made most starches appear with light purple and yellow hues (even if they were damaged) alternating amongst the triangles of the starch that were manifested by the extinction cross. A starch extinction cross is an indicative element, but not exclusive, which differentiated starches from many other particles. When we detected a starch, we photographed it multiple times with both polarized filters and bright field view (normal transmitted light). Importantly for taxonomic identification, we photographed each starch with different focal lengths and rotated them when possible.

After we observed, photographed, and described the recovered starches, we compared them to our modern reference collection and published sources (Cagnato and Ponce 2017; Dickau 2005; Dickau et al. 2012; Holst et al. 2007; Horrocks and Rechtman 2009; Mickleburgh and Pagán-Jiménez 2012; Musaubach et al. 2013; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Pagán-Jiménez et al. 2016; Pagán-Jiménez et al. 2015; Pearsall et al. 2004; Perry et al. 2007; Piperno and Dillehay 2008; Piperno and Holst 1998; Piperno et al. 2000; Piperno et al. 2009; Reichert 1913; Zarrillo 2012; Zarrillo et al. 2008). We identified starch grains to the lowest taxonomic level when possible. The morphometric features employed for identification were size, shape, border, facets, lamellae, fissure, hilum type, and extinction cross arms morphology. When a starch’s diagnostic characteristics were obscured or absent, either category ‘not identified’ or ‘cf.’ was used, the latter in reference to the closest tentative identification. Thus, we based both secure and tentatively identified starches on diagnostic features.

In addition to taxonomic diagnostic characteristics, we observed and recorded damage to the starches likely caused by culinary practices. We compared these described damage characteristics to experimental studies, which aided with interpretations of the likely causes of damage to the recovered starches (Babot 2003; Babot 2006; Barton 2007; Beck and Torrence 2006; Delwen 2006; Gomez et al. 1992; Gomez et al. 1991; Henry et al. 2009; Lamb and Loy 2005; Logan et al. 2012; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2015b; Pagán-Jiménez et al. 2017; Piperno et al. 2004; Vinton et al. 2009; Wang et al. 2017). The damage caused to the starches was another line of evidence for us, demonstrating how culinary practices emerged in this data set.

4.6 Results

Table 4.3 provides the summary of results obtained from the samples investigated for starch content. The highest success rate we obtained (73%) for the extraction of starches from El Flaco griddle samples Table 4.3. While both La Luperona and Palmetto Junction had significant success rates of starch recovery (60%), Palmetto Junction had, a larger average number of individual starches per sample (3) compared with El Flaco (1.5) or La Luperona (1). Fewer starches recovered per sample could be due to many factors including the frequency that griddles were used, anthropogenic mechanical damage due to food processing and cooking, or taphonomic reasons (organic or chemical degradation) (Barton 2009; Hutschenreuther et al. 2017; Pagán-Jiménez 2008; Rodríguez Suárez and Pagán-Jiménez 2008). However, there was a negligible difference of porosity or other negative surfaces between the samples in this study from the Dominican Republic compared with The Bahamas, which would not influence the greater number of starches, recovered from the Palmetto Junction samples. In addition, another reason we recovered few individual starches from some of the griddles in this study, may be due to which foods were processed with the griddles, i.e. terrestrial animals, marine food sources, or non-starchy dietary plants.

Both tuberous and seed plants dominated our assemblage of identified starch grains, which included zamia, manioc, maize, and chili pepper. We securely identified chili pepper from only one sample from La Luperona. We did not identify any remains of either maize or manioc from La Luperona. Whereas Palmetto Junction's most ubiquitous plant remains securely identified by us were from manioc (27%). The most commonly recovered evidence (ubiquity) of cultivars from the entire artifact assemblage were from manioc and maize plant remains. Ubiquity refers to the occurrence of identified plant taxa amongst the entire artifact sample spectra (Hubbard 1980). It is important to remember that interpretations based on ubiquity analyses are limited by both the sample size and preservation (Kadane 1988); with 45 artifacts from three archaeological sites these limitations have been likely marginalized. However, we do not believe these ubiquity measures suggest or indicate the identified plant's contributions to overall diet.

Table 4.3
Identified taxa per sample and the number of individual starches observed. Sample type abbreviations are as follows: CGF= Clay griddle fragment; CGRF= Clay griddle rim fragment. Other abbreviation is CL= starch cluster. [a] Clusters are not included in the individual starch totals, because the precise number of starches in the clusters could not be determined. [b] Ubiquity was calculated by dividing the presence of identified taxa and [b1] also by combining both, secure and tentative identified taxa by the total number of analyzed artifacts per site. [c] 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.

El Flaco

Lab ID	27	550	558	576	585	601	612	613	631	632	782	788	795	796	797			
Sample type	CGF	CGRF	CGF	CGRF	CGF	CGF	CGF	CGF	CGRF	CGF	CGRF	CGF	CGF	CGRF	CGF	Total	[b]Ubiquity	[bI] Ubiquity
Zamia sp.				1												1	7	7
Manihot esculenta															2	2	7	7
cf. Zingiberaceae		1														1	7	7
Zea mays								2								2	7	33
cf. Zea mays							1					1	1		1	4	27	--
Unidentified			1	1	1	1	2				4		1		3	14	--	--
Individual Starches	0	1	1	2	1	1	3	1	0	0	4	1	2	0	6	23	--	--
[c] Minimum species richness	0	1	1	1	1	1	1	1	0	0	1	1	1	0	2	--	--	--

La Luperona

Lab ID	1	2	3	4	5	6	8	10	11	13	14	15	17	18	19			
Sample type	CGF	CGRF	CGF	CGF	CGF	CGF	CGRF	CGRF	CGF	CGF	CGF	CGF	CGF	CGF	CGRF	Total	^{b}Ubiquity	^{b1}Ubiquity
Zamia sp.												1			1	2	13	27
cf. Zamia sp.								2			1	2				5	20	--
cf. Xanthosoma sagittifolium								2								2	7	7
Capsicum sp.												1				1	7	7
Unidentified			2		2	1	1	3 + ^{a}CL ~26	1							10	--	--
Individual Starches	0	0	2	0	2	1	1	7	1	0	1	3	0	0	1	19	--	--
^{c}Minimum species richness	0	0	0	0	0	1	1	2	0	0	1	2	0	0	1	--	--	--

Palmetto Junction

Lab ID	102	103	104	105	106	107	108	127	128	129	130	132	133	136	138			
Sample type	CGF	CGF	CGF	CGF	CGF	CGF	CGF	CGF	CGF	CGF	CGRF	CGF	CGF	CGF	CGF	Total	^{b}Ubiquity	^{b1}Ubiquity
Zamia sp.											1					1	7	13
cf. *Zamia* sp.										1						1	7	--
Manihot esculenta	21	1	1							1						24	27	40
cf. Manihot esculenta	2 + ^{a}CL ~300		2		1			1								6	27	--
Zea mays															1	1	7	20
cf. Zea mays			1								1					2	13	--
Unidentified	7	1	2										1			11	--	--
Individual Starches	30	2	6	0	1	0	0	1	0	2	2	0	1	0	1	46	--	--
^{c}Minimum species richness	1	1	2	0	1	0	0	1	0	2	2	0	1	0	1		--	--

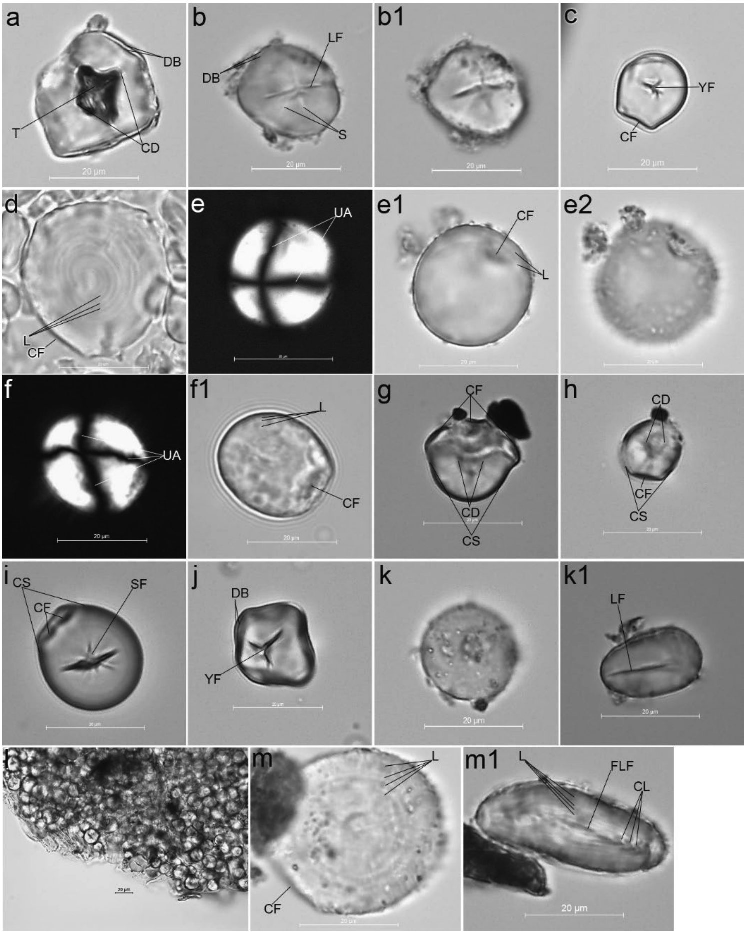

Figure 4.3
Examples of starch residues recovered from the 45 sampled griddles. **a** From Sample 613, maize starch under bright field view. **b** From Sample 788, cf. maize starch under bright field view. **b1** From Sample 788, the same cf. maize starch under bright field view at a different focal length. **c** From Sample 797, manioc starch under bright field view. **d** From Sample 10, cf. zamia starch under bright field view. **e** From Sample 15, cf. zamia starch under polarized light and dark field view. **E1** From sample 15, the same cf. zamia starch under bright field view. **e2** From sample 15, the same cf. zamia starch under bright field view at a different focal length. **f** From Sample 19, zamia starch under polarized light and dark field view. **f1** From Sample 19, the same zamia starch under bright field view. **g** From Sample 102, manioc starch under bright field view. **h** From Sample 102, manioc starch under bright field view. **i** From Sample 102, manioc starch under bright field view. **j** From Sample 138, maize starch under bright field view. **k** From Sample 15, chili pepper starch under bright field view. **k1** From Sample 15, the same chili pepper starch under bright field view but rotated. **l** From Sample 102, cluster of cf. manioc starches under bright field view. **m** From Sample 15, Zamia sp. starch under bright field view. **m1** From Sample 15, the same Zamia sp. starch under bright field view but rotated. Scale bar= 20 µm. Figure legend: "CD" central depression; "CF" compression facet; "CL" compressed lamellae; "CS" constricted area; "DB" double border; "FLF" false lineal fissure; "L" lamellae; "LF" lineal fissure; "S" striation; "SF" stellate fissure; "T" toasting damage; "UA" undulating extinction cross arm; "YF" Y-shaped fissure.

From the Dominican Republic archaeological sites, the samples allowed us to identify other domestic and possibly wild taxa that included maize, chili pepper, and zamia. Due to the identification of maize starch grains amongst the sample spectra, El Flaco griddle use incorporated the production of maize into food derivatives Table 4.3. El Flaco griddle samples also demonstrated evidence for manioc, zamia, and cf. Zingiberaceae. The latter of which was represented by one starch that measured 53 µm x 19.1 µm, and was oblong in shape, convex on both the distal and proximal ends. When we compared the cf. Zingiberaceae starch to our modern reference collection and published sources, this starch appeared significantly damaged, encrusted in particles, and would not rotate which left its taxonomic identification at the family level (Pagán-Jiménez et al. 2015). Sample 613 from El Flaco had evidence of maize (Fig. 4.3 a), which measured 17.8 µm x 15.1 µm, and was pentagonal in shape with a prominent double border. In addition, this maize starch had a dark central depression that is not found in our reference collection of unmodified starches. Sample 788 from El Flaco had evidence of a cf. maize starch (Fig. 4.3 b), which measured 22.4 µm x 19.4 µm, and had a faint but noticeable double border. This cf. maize starch had asymmetrical striations near the lineal fissure and most of the starch was encrusted in particles. Sample 797 from El Flaco had both manioc and cf. maize recovered suggesting this griddle helped process multiple types of edible plants.

La Luperona griddles had zamia recovered as the most ubiquitous type of starchy plant remains identified Table 4.3. La Luperona griddle use reflected patterns of other griddles studied from Caribbean archaeological contexts; which included being used to process multiple species of plants and the absence of manioc (Pagán-Jiménez 2008; Pagán-Jiménez 2010; Rodríguez Suárez and Pagán-Jiménez 2008). In our comparison of griddle use, La Luperona was the exception for an absence of both manioc and maize identified from the analyzed griddle assemblage. Sample 15 from La Luperona had evidence of a chili pepper starch (Fig. 4.3 k), which measured 22.6 µm x 21.6 µm, and was circular in shape, but oval when rotated with a prominent lineal fissure (Fig. 4.3 k1). Sample 15 also had evidence of a zamia starch (Fig. 4.3 m), which measured 41.83 µm x 34.66 µm, with pronounced concentric lamellae, and was circular in shape, but oval in shape with an apparent false lineal fissure when rotated (Fig. 4.3 m1). This zamia starch's false lineal fissure is noticeably different from the chili pepper lineal fissure. The false lineal fissure is likely a visual artifact from the compression of the lamellae. The size of the starch, shape of the lamellae, and compression facet helped us to confirm the identification of this zamia starch grain (Fig. 4.3 m, m1). Sample 10 had evidence of two cf. cocoyam starches, which had longest measurements of 10.15 µm and 8.14 µm respectively, both were bell shaped with at least two basal facets. Because they were unable to be rotated, their taxonomic identification was left tentative. Both Sample 15 and Sample 10 provided us with evidence for multiple species of plants being prepared.

The Palmetto Junction griddle assemblage provided us evidence for the use of manioc, maize, and zamia. Sample 102 from Palmetto Junction had the most starches recovered of all samples. We recovered 30 individual starches and securely identified 21 manioc starch grains. Seven starches were unable to be identified. From sample 102, there are examples displayed (Fig. 4.3 g, h, and i) of securely identified manioc starches determined based on their size (g-17.9 µm x 16.9 µm, h-12.4 µm x 11.9 µm, i-22.5 µm x 20.3 µm, shape (truncated bell shaped), amount of compression facets (2-4), and constricted areas (look pinched). In one example, from these three manioc starches (Fig. 4.3 i) a diagnostic stellate fissure was visible. All of the previously listed descriptions fit diagnostic characteristics of bell-shaped manioc starches of our reference collection and published sources (Cagnato and Ponce 2017; Ciofalo et al. 2018; Pagán-Jiménez 2015a:68,69; Piperno 2006:68). In addition, from Sample 102, there was a cluster of approximately 300 starches, with some exposed starches with visible diagnostic characteristics of manioc (Fig. 4.3 l). This cluster of starches was also partially covered with organic material, possibly plant tissue such as cellulose or proteins. Because these starches were partially obscured, part of a cluster, and not able to be rotated, we identified them as cf. manioc, but we left them out of the total individual starch count Table 4. 3.

Table 4.4
Percentages of recovered individual starches with damage patterns from cooking processes. Humid heat and dry heat are in reference to what the cooking environments most likely were to create the starch damage patterns observed.

	Humid Heat	Dry Heat	Heat	Pressure	Enzymatic	Undamaged
El Flaco	17	35	52	26	13	26
La Luperona	5	16	21	42	5	37
Palmetto Junction	11	11	21	24	9	52

Of the griddles that had recovered starches, El Flaco had 64% with evidence containing at least one starch that had damage due to heat Table 4.4. La Luperona had 88% of the griddles with evidence of at least one starch damaged by pressure Table 4.4. Palmetto Junction had 67% of the griddles with evidence of at least one starch damaged by pressure Table 4.4. From the entire assemblage of recovered individual starches 34% displayed alterations of their characteristics consistent with patterns of damage due to heat, 28% had damage signs attributed to pressure, and 9% had damage patterns indicating enzymatic degradation occurred (Henry et al. 2009; Pagán-Jiménez et al. 2017; Vinton et al. 2009; Wang et al. 2017). Of the individual starches we recovered from El Flaco, 52% were damaged by heat, 26% by pressure, and 13% by enzymatic activity. Of the individual starches we recovered from La Luperona 21% were damaged by heat, 42% by pressure, and 5% by enzymatic activity. Of the individual starches we recovered from Palmetto Junction 21% were damaged by heat, 24% by pressure, and 9% by enzymatic activity.

4.7 Discussion

Some of the griddle fragments presented evidence of having been exposed to heat. For example, the charred remains area visible in Fig. 4.2 b near the bottom of the left image. From this griddle (Palmetto Junction Sample 102), we recovered 30 individual starches and a cluster of more than 300 starches. While we dry-scraped the entire used surface of the sherd, it is plausible that some of these starches came from that small cluster of charred remains. The starches were in various states of preservation with evidence of food preparation damage. From Sample 102, two of the 21 confirmed manioc starches (Fig. 4.3 g, h), each had evidence of a central depression, which are considered folds created from hot and partially humid cooking environments during the production of manioc-based foods on a griddle (Pagán-Jiménez et al. 2017). The partially humid cooking environments were possibly generated from slightly moist manioc flour.

Many starches we recovered displayed evidence of pressure without noticeable damage from heat Table 4.4; a few reasons may explain these differences in starch damage signs and preservation. Clay is a poor thermal conductor; this means griddles heated up slowly and not all starches received intense heat or were completely cooked. Thus, not all starches gelatinized and some are well preserved. For illustration, we microscopically examined pieces of cooked cassava bread (a flatbread made of manioc flour) created by Ciofalo from a modern Haitian recipe (Fig. 4.4). The recipe included the following steps: 1) manioc tubers were peeled and grated with a metal kitchen knife followed by a metal grater (which was made from a flattened tin can with a tip of a nail driven through it repeatedly and approximately 0.5 cm apart to create a rough surface for grating); 2) the mass of grated manioc was squeezed in a standard dishtowel to remove the majority of liquid; and 3) the remaining mass was placed spread out on a table and left to dry for six hours. The resulting product was the consistency of moist flour that was formed into circular and flat (1-3 cm thick) layers on a metal skillet. We cooked this flat bread at approximately 125 °C for 3-5 min then flipped it over to cook the other side for the same amount of time.

Once viewed by us under the microscope, a single drop of the sampled cassava bread contained thousands of starches representing different stages of damage, some significantly gelatinized and hundreds undamaged (Fig. 4.4). Another possibility is that after the griddle was used to cook some food and without being thoroughly washed, its use life was extended by being used as a table for cutting or pounding food or other preparation techniques where heat was not involved (Rodríguez Suárez and Pagán-Jiménez 2008). It is also possible that both the causes of heat and damage were not directly related to use of the griddle and instead occurred earlier in the cooking process, such as roasting manioc and then scraping the skin off with a tool (Ciofalo et al. 2018). Thus, some starches damaged by heat and others damaged only by pressure were preserved on some griddles.

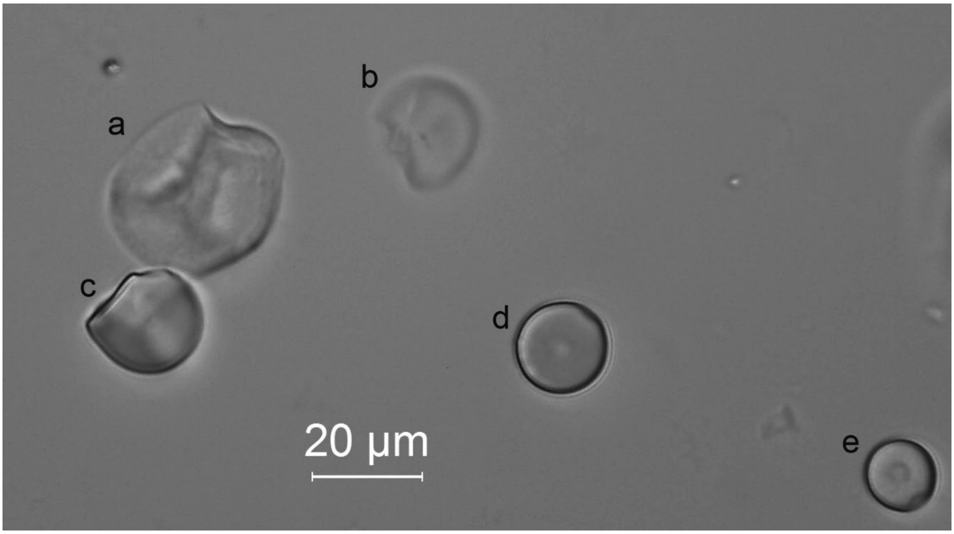

Figure 4.4
Modern starches under bright field view, obtained from cassava flatbread prepared by Ciofalo **a** Significantly gelatinized manioc starch. **b** Significantly gelatinized manioc starch. **c** Undamaged manioc starch. **d** Undamaged manioc starch. **e** Partially damaged manioc starch from a hot and slightly humid cooking environment.

Varieties (cultivars) of manioc are split into two categories of bitter or sweet based on the amount of cyanogenic glucosides (toxins) in the plant (Carneiro 2000). Methods of processing bitter manioc to avoid cyanide poisoning can include boiling, fermenting, or roasting, but more typically tubers are grated and the poisonous juice is squeezed out of the manioc mass (Elias et al. 2000; Flibert et al. 2016; Pagán-Jiménez 2011a). Currently, in Dominican Republic and Turks & Caicos, both bitter and sweet varieties are grated and squeezed because that is part of the process to make flour. Once manioc is made into flour and dried, it can be stored longer than unprocessed tubers, which makes manioc flour both an easily preserved food source and a mobile trade good (Lathrap 1973; Sheets et al. 2012). Because neither the sequence of procedures to remove poison from manioc nor the steps needed to create flour are necessarily intuitive, preparation techniques may have traveled with the plant as transferred knowledge

(Eerkens and Lipo 2007) to avoid producing poisoned manioc foods and/or creating manioc flour (Blench 2014). Alternatively, other poisonous plants (such as zamia) endemic to both Dominican Republic and the Bahama archipelago may have been processed using similar methods to manioc. Therefore, the procedures to remove poison from manioc may have been locally developed for zamia and then applied to manioc when it was introduced, which would have been the addition of another tuberous plant to a pre-existing cultural repertoire needing similar food processing technologies (Leach 1999).

Supposed "manioc-only artifacts" consistently have had a broad suite of plant species identified from their microbotanical remains (Berman and Pearsall 2008; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2013; Perry 2002; Perry 2005; Rodríguez Suárez and Pagán-Jiménez 2008). From our analysis, the majority of griddles (60%) that had manioc recovered from their surfaces also had residues of other plants species recovered and identified; this is empirical evidence that invalidates earlier preconceptions of definitive tool types associated with manioc use (see other disscusions on this in DeBoer 1975; Perry 2002; Perry 2005). The ancient starch data we recovered during this study indicate archaeobotanical data are (again) a more reliable source for assessing the plants processed with these tools than are early European written documents. Including tentatively identified starches, our study recovered identified manioc starch from seven out of 45 sampled griddles Table 4.3. Adding the data from our study, to griddles from the Greater Caribbean region analyzed for starch content that demonstrated evidence of manioc, the new total is now 12 out of 76 griddles (Bel et al. 2013; McKey et al. 2010; Pagán-Jiménez in Oliver 2014; Pagán-Jiménez in Ulloa Hung 2014:115,138; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Pagán-Jiménez 2011b; Pagán-Jiménez 2012; Rodríguez Suárez and Pagán-Jiménez 2008).

Sample 613 from El Flaco had evidence of a maize starch grain (Fig. 4.3 a), that was likely toasted in a similar fashion for the creation of *tostado* (toasted maize kernels with a little water) (Babot 2006). Sample 788 from El Flaco had evidence of cf. maize that was altered by light pressure (such as scraping or grating) determined from the asymmetrical central striations. The maize kernel that produced this starch was also cooked in a dry cooking environment, but likely completely dry, evinced from the encrustation of particles on the surface of the starch. Likewise, Sample 15 from La Luperona provided us evidence of cf. zamia (Fig. 4.3 e2) and chili pepper (Fig. 4.3 k) starches encrusted with particles, suggesting they were prepared in dry cooking environments as well. We are not sure what the particles are made from that cover the surface of starches that were cooked in dry cooking environments, but it is possible they were parts of other less-resistant starches that were broken apart during the cooking process (Henry et al. 2009). Regarding the ubiquity of maize starch remains recovered from El Flaco and Palmetto Junction griddles, La Luperona appears as an outlier. It is possible that maize was prepared in different ways at La Luperona instead of on griddles. Studies involving other food preparation tools from all three sites are ongoing by Ciofalo and at El Flaco, macrobotanical and other microbotanical studies (phytoliths and starches) are currently being carried out by Dr. Jaime Pagán-Jiménez, so this picture may change in the light of new evidence.

Table 4.5
Potential foodways rank based on ubiquity measures of sampled artifacts, where 1 is the most likely to have contributed to plant-based foods prepared on griddles.

Archaeological site	El Flaco	La Luperona	Palmetto Junction
***Zamia* sp.**	2	1	3
Manihot esculenta	2		1
Zea mays	1		2
Capsicum sp.		2	

The potential foodways ranks based on the data generated from our study do not intend to influence interpretations of contributions to overall diet, instead potential foodways ranks is a possible crescendo for discussions and interpretations of ubiquity measures, but only a hint of possible culinary preferences regarding starchy plants prepared on these griddles (Pearsall 2018:66). Maize, as the most ubiquitous plant remains we identified from the analyzed residues from El Flaco, suggests that many of their households had access to maize, and perhaps maize was the preferred or most valued plant ingredient for their culinary practices with these griddles, contributing to its potential foodways rank Table 4.5. La Luperona inhabitants prepared zamia-based foods on griddles, and Palmetto Junction occupants prepared recipes incorporating manioc on griddles, which may suggest starchy foodways ranks or preferred culinary practices Table 4.5. Maize has been one of the most ubiquitous plant residues recovered from Greater Antilles archaeological contexts, and thus, most households likely had access to foods created from maize (Chinique de Armas et al. 2015; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2010; Pagán-Jiménez and Oliver 2008; Rodríguez Suárez and Pagán-Jiménez 2008). However, maize was not native to the Greater Antilles nor to the Bahama archipelago and required human assistance to be propagated (Doebley 2004; Liogier 1978; Newsom 2006; Tian et al. 2009). Therefore, we add additional evidence from our study and agree with the interpretation that maize was a part of the transported landscape brought to these islands (Berman and Pearsall 2008; Rodríguez Ramos 2011; Rodríguez Ramos et al. 2013b). The maize starch grains we recovered from these griddles supports the idea that kernels were removed from the cob (peduncle) and altered by grinding, pounding, or toasting which would be culinary practices absent from European written sources for the Greater Antilles (Fernández de Oviedo 1959 [1526]; Las Casas 1876 [1561]; Las Casas 1909; Pané et al. 1999).

These results provided us with some insights into the studied areas constructed cultural niches involving clay griddles and associated adaptation strategies, which likely involved the translocation of exogenous plants, and the culinary practices involved to manipulate those plants to produce edible food sources. The identified plants and interpreted foodways have been placed in the described geographical and chronological contexts. A combined phytocultural system can be suggested for this area of the northern Caribbean, which includes 1) the development of "conucos" house gardens (for the production of manioc, possibly together with maize and other fruit and spicy plants such as chili pepper), it was these gardens where experimentation and cultural acceptance of exotic plants conceivably occurred before being integrated as a significant culinary source (Boivin et al. 2012); 2) the use of open plots (for the production of maize and manioc which are efficient in sunny areas); 3) tropical dry forest management (for the procurement or production of zamia); and 4) the use of clay griddles for the production of a broad suite of plant-based foods. Similar phytocultural scenarios have been suggested for human groups from the Greater Antilles from the Early Ceramic Age (400 BCE – 800 CE) (Pagán-Jiménez 2007; Rodríguez Suárez and Pagán-Jiménez 2008). From our study, we have added a line of evidence for similar phytocultural systems during the Late Precolonial period in both the Dominican Republic and the southern Bahama archipelago. While for griddles the ubiquitous prepared plant complex at El Flaco (zamia, maize, manioc) varied from La Luperona (zamia, chili pepper), it does not appear to have major new additions at Palmetto Junction (zamia, maize, manioc), but the preferences, values, or supply of manioc appears to have been different at Palmetto Junction. For this investigation, we took an approach to foodways using cultural niche construction theory to interpret phytocultural dynamics in local (site level), micro-regional (northwestern Dominican Republic), and macro-regional contexts (northern Caribbean).

We have reconstructed culinary practices and cultural niches at different geographic scales. It is evident that at El Flaco zamia, maize, manioc, and a plant from Zingiberaceae were prepared on griddles. At La Luperona, the community perhaps did not use or favor manioc and maize but incorporated zamia, chili pepper perhaps as a condiment, and possibly cocoyam into their culinary repertoire. Palmetto Junction seemingly had culinary practices similar to El Flaco by preparing zamia, maize, and manioc on griddles. Through adding microbotanical evidence to a growing database of dietary plants processed in the northern Caribbean, archaeologists are illustrating a diverse spectrum of starchy foodways (Berman and Pearsall 2000; Berman and Pearsall 2008; Chinique de Armas et al. 2015; Pagán-Jiménez 2010; Rodríguez Suárez and Pagán-Jiménez 2008).

Reinforced culinary practices require cultural information to be transmitted as well as biological foundations of mental and physical facilities to harvest, process, cook, and consume the food (O'Brien et al. 2010). Once transmitted, dietary practices serve as units of replication that can be inherited and modified as part of a cultural repertoire (Eerkens and Lipo 2005; Smith 2013). Through different forms of management, plant procurement, and food preparation humans create their desired niches (Zeder 2015). Interpretations from our data offer explanations regarding how cultural niches were constructed i.e. how and which plants were prepared on griddles. Cultural niche construction theory offers a perspective on why these niches were constructed i.e. to reproduce successful foodways that were preferred and offered modes of stability in dynamic environments.

It should be stressed that precolonial human impacts on zamia, maize, and manioc have never been suitably assessed in this case study area. However, the idea that Caribbean Indigenous Peoples might have served as dispersal agents for zamia, maize, and manioc into the northern Caribbean cannot be excluded. The translocation of objects, ideas, and plants previously integrated into a system of preferences and values could have aided in overcoming unfamiliar encounters with new places by making new areas more humanized and creating consistent supplies of food vis-à-vis transported landscapes (Anderson 1967; Berman and Pearsall 2008; Pagán-Jiménez 2013; Rodríguez Ramos et al. 2013a). Routinized daily practices can minimize feelings of uncertainty by increasing predictability and familiarity (Berman and Pearsall 2008; Bourdieu 1977:8; Pagán-Jiménez et al. 2019). Communities that used culinary practices involving particular plants could have occurred for more reasons than personal preferences or familiarity; they could also have prepared these products for purposes of exchange for strengthening and maintaining relationships with other communities (Dietler 2007; Hofman and van Duijvenbode 2011). These exchanges could have provided supplementary resources needed for other niches such as access to marine food sources.

4.8 Final Remarks

Our main points are exemplified by the similarities between El Flaco and Palmetto Junction phytocultural strategies, where manioc and maize were most preferred, valued, or used for production of foods with griddles. We expected these similarities of plant-based foods prepared on griddles between El Flaco and La Luperona, because there is evidence of trade or communication between these sites. However, from our study, the culturally constructed niches appear more contrasting between neighboring habitations (El Flaco compared with La Luperona) than between sites from neighboring islands (El Flaco and La Luperona combined and compared with Palmetto Junction).

In our study, we used the concept of cultural niche construction to interpret the ancient starch remains, illuminate a partial view of phytocultural repertoires, and explicate variations of identified culinary practices at three precolonial habitations in the northern Caribbean. The evidence suggests that each site had a different use or preference of plant-based food production on griddles. The plant ingredient that all three sites had in common was zamia, which may be reflective of wild abundance of this plant in the past, or mobility and exchange with other areas where zamia was available. In addition, all three sites prepared dietary plants on clay griddles. We suspect this routinized daily practice created a sense of familiarity even with different foods being prepared on the griddles. The particular plants and the ways they were processed on the griddles were successful culinary practices, which were imbedded within the lifeways of these Indigenous Caribbean Peoples.

Earlier pre-conceptions viewed the griddle as exclusively entangled with the production of cassava flatbread in the Caribbean (see DeBoer 1975; Rouse 1992; Wilson 2007). Other starch analyses of Caribbean griddles indicated their use in preparing a broad suite of dietary plants but not manioc (Pagán-Jiménez in Ulloa Hung 2014:115,138; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Rodríguez Suárez and Pagán-Jiménez 2008). The results from our study also demonstrated that a broad suite of vegetal-based foods were prepared on griddles, but at two of the sites, evidently manioc as well. The plant remains we recovered from griddles at El Flaco were different from those at La Luperona where we believe pottery or knowledge of clay preparation were exchanged (Ting et al. 2016). Thus, for the Dominican Republic sites studied here, there ostensibly was a community of practice[13] for some of the pottery production but distinctive communities of plant preparation on these griddles. Finally, regarding insular Caribbean clay griddles analyzed for starch content, these are the first reported

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[13] See Lave and Wenger (1991:98) for the basis of how we understand the community of practice concept.

griddles with recovered manioc starch remains. The more artifacts we analyze, the greater the possibilities are for revealing evidence of dynamic culinary practices.

4.9 Acknowledgements

We thank both Leiden University and the University of Central Florida for providing support for our work. We are grateful to the Department of Environment and Maritime Affairs (DEMA) on Providenciales, Turks & Caicos Islands that granted permission to conduct the fieldwork and laboratory analyses. We would like to thank the many participants of excavations in Dominican Republic and Turks & Caicos Islands. Thanks to Simone Casale and Eduardo Herrera Malatesta for the creation of Fig. 4.1. Thank you to Joseph Sony Jean for the cassava bread recipe. We also are grateful to the team members of the Faculty of Archaeology, Leiden University, for their insightful comments and suggestions on an earlier draft of this manuscript. Our work carried out with the materials of El Flaco (Dominican Republic), have been performed within the framework of a paramount paleoethnobotanical research designed and carried out by Dr. Jaime Pagán-Jiménez for NEXUS1492. Without Dr. Pagán-Jiménez, our work would not be possible, special thanks to him for his guidance with the starch analysis. Finally, we would like to thank the three anonymous reviewers for their insightful feedback, which made critical changes to the final draft of this manuscript.

4.10 Funding Information

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 319209. Research was also made possible due to a study trip to The Bahamas through the Leiden University Fund/ Byvanck Fonds 76Ol/M/l 9.01.2O17/Bck.

4.11 Open Access

4.12 References

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CHAPTER 5

Uses of pre-Hispanic kitchenware from central Nicaragua: Implications for understanding botanical foodways

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Archaeological and Anthropological Sciences (2020, Volume 12, Issue 1)

Chapter 5 Uses of pre-Hispanic kitchenware from central Nicaragua: Implications for understanding botanical foodways

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Abstract

Archaeobotanical investigations in central Nicaragua are absent and preservation of organic remains are poor; therefore, we have applied starch analyses to samples from fragments of clay vessels excavated from layers dated to cal 1224 and 1391 CE at the Barillas site, Nicaragua. The approach to this dataset reveals the ways people interacted with edible plants in southern Central America. The scarcity of griddles recovered from ancient Nicaraguan archaeological contexts has previously co-determined narratives on human mobility or cultural influence from the Mesoamerican culture area, due to the debatable presumption that this type of artifact necessarily entangles production and consumption of maize *tortillas*. In this article, we present results demonstrating evidence for the use of several starchy plants. The reconstructed culinary practices are vital for disentangling human-plant interrelationships and challenge earlier conceptions of ancient foodways in Central America. This research constitutes the first starch analysis in Nicaragua and the recovered plant remains belonging to manioc (*Manihot esculenta* Crantz), chili pepper (*Capsicum* sp.), and maize (*Zea mays* L.) have provided empirical evidence of ancient foodways. Concomitantly, these results have invalidated the preconception that griddles were tools used exclusively for the production of maize *tortillas*.

Resumen

Debido a la escasez de investigaciones arqueobotánicas en el centro de Nicaragua y a la supuesta deficiente preservación de restos orgánicos, esta investigación propone el análisis de granos de almidones provenientes de vasijas excavadas en el sitio Barillas (1224 - 1391 años Cal E.C.). Los datos obtenidos en este trabajo echan luz acerca de las diferentes formas en que los antiguos habitantes del sur de Centroamérica preparaban y consumían alimentos. La ausencia de comales en contextos arqueológicos nicaragüenses ha determinado ciertas narrativas acerca de movimientos poblacionales y la influencia del área cultural mesoamericana, ya que se presume que este tipo de artefactos necesariamente implica la producción y consumo de tortillas de maíz. En este artículo presentamos los resultados de los análisis arqueobotánicos de granos de almidón extraídos de implementos de cocina que fueron recuperados en el contexto de excavaciones estratigráficas. Las prácticas alimentarias identificadas en este trabajo son fundamentales para elucidar las interrelaciones entre plantas y seres humanos, así como para desafiar las preconcepciones relacionadas con las tradiciones culinarias en la antigua América Central. Los datos presentados constituyen los primeros resultados de análisis de granos almidones en el país y los restos recuperados de mandioca (*Manihot esculenta* Crantz), chile (*Capsicum* sp.) y maíz (*Zea mays* L.) proporcionan evidencia empírica del antiguo uso de alimentos de origen vegetal en el centro de Nicaragua. De igual manera, los resultados invalidan la idea de que los comales consistían en implementos de cocina utilizados exclusivamente para la producción de tortillas de maíz.

Keywords: Nicaragua archaeology; archaeobotany; starch analysis; foodways; culinary practices

5.1 Introduction

Research on pre-Hispanic foodways in southern Central America has received differential attention. While extensive work has been conducted in Panama (Cooke and Jiménez 2008; Dickau 2005; Piperno 2009; Piperno and Holst 1998; Piperno and Pearsall 1998) and some research has taken place in Costa Rica (Blanco and G. Mora 1995; Cooke and Sánchez 2001; Hoopes 1994), paleoethnobotanical research in Nicaragua has been very scarce (exception Dickau 1999). There is an absence of published archaeobotanical investigations for central Nicaragua. Therefore, most descriptions of pre-Hispanic subsistence practices in Nicaragua rely primarily on a single sixteenth Century Spanish chronicle, which states that squash (*Cucurbita* sp.), beans (*Phaseolus* sp.), and maize (*Zea mays* L.) were the economic botanical foods for the Indigenous Peoples of southern Central America (Fernández de Oviedo 1851 [1535]). The scarce evidence of this “trinity” of staple crops has added decisive commentary to the debate surrounding Mesoamerican speakers of Otomanguean and Nahuatl languages migrating down from present-day Mexico into ancient Nicaragua (Constenla Umaña 1991; McCafferty 2015).

In addition, in 1522 CE Gil González Dávila, the first Spanish *conquistador* to arrive in what now is Pacific Nicaragua, reported cultural and linguistic similarities with parts of present-day Mexico (Somoza 1954). Beyond Pacific Nicaragua, archaeological interpretations on Nicaragua’s central region are also affected by this interpretive bias. The Barillas site, located in the study area (Fig. 5.1),was previously attributed to the Cuapa phase; initially understood to be a ceramic complex related to the arrival of a supposed foreign cultural group to the area (Gorin 1990; Rigat 1992) (for an initial critique of this see Geurds (2013)). The exogenous strangers supposedly brought new lithic tool types and pottery styles, which could have entangled new foodways (Gorin 1990). In contrast, we argue here that many of the practices detailed in this article are primarily the results of endogenous developments and not the sole consequence of unidirectional interactions with surrounding communities.

Relative to other regions of Nicaragua, the central region has a recent but by now considerable history of systematic archaeological research. Following on from initial systematic work by the Proyecto Arqueológico Chontales (Gorin 1990; Rigat 1992), the Proyecto Arqueológico Centro de Nicaragua (PACEN), under the direction of Alexander Geurds has carried out research in the valley of Juigalpa, 25 km northeast of Lake Cocibolca since 2007 (Fig. 5.1). In 2015, with the goal to increase knowledge of pre-Hispanic food practices in central Nicaragua a standardized protocol for macro and microbotanical sampling was included in all stratigraphic test pits excavated within the 52 square kilometer study area of PACEN. As a result, both macro and microbotanical sampling was successfully carried out in 50 different excavation units from 18 archaeological sites.

One of these sites, Barillas, has revealed unique finds of ceramic griddle fragments (flat 'cooking' plates, which could have also been used as surfaces to process plants without cooking) (Rodríguez Suárez and Pagán-Jiménez 2008), commonly known as *comales* in Spanish literature, recovered from cultural layers dated to cal 1261 CE (±37) ±2σ, Beta-457276 and cal 1333 CE (±58) ±2σ, Beta-443734 (Donner et al. 2018; Donner and Geurds 2018) using Oxcal 4.3.2.2 (Ramsey 2017) and the IntCal 13 atmospheric curve (Reimer et al. 2013). Despite a promising number of excavations in Nicaragua, no griddles have been reported from the Pacific coastal region of the country as of yet (Bovallius 1886; Bransford 1881; Lange 1996; McCafferty 2011; McCafferty 2015; Norweb 1964; Squier and Comparato 1990). The only exception consists of three unconfirmed griddle fragments, which may well be tripod plate fragments (Healy and Pohl 1980:255). In contrast, excavations in the Caribbean watershed have yielded some interpreted griddle fragments (Gassiot Ballbé and Palomar Puebla 2006; Martinez Somarriba 1977; Vázquez Moreno 2016), but published archaeobotanical analyses are unavailable.

For the Pacific coastal region of Nicaragua, the prevailing idea is that griddles were not used and maize was primarily cooked in other types of vessels or consumed raw (McCafferty 2011).

Even though there is macro and microbotanical evidence for maize cultivation in pre-Hispanic Pacific Nicaragua, it is currently not considered to have been a dominant dietary component (Dickau 1999). Instead, a variety of species including amaranth (*Amaranth* sp.), purslane (*Portulaca* sp.), beans, squash, as well as fruit trees have been identified, which indicate a diversity of botanical subsistence systems (Dickau 1999; López Sáez and Galeano 2007; McCafferty and Dennett 2013). The presence of grater chips has led to the idea that manioc (*Manihot esculenta* Crantz) may have been a significant dietary component (Debert 2005). However, with an inconclusive residue analysis on the thousands of *raspaditas* (microliths) recovered from the Santa Isabel site (Pacific Nicaragua), their function remains a mystery (Debert and Sherriff 2007).

Traditionally, maize *tortillas* have been regarded as central to Mesoamerican foodways, and cassava bread -a *tortilla* like flatbread made of manioc- was a prevalent food item in South America and the Caribbean (Lathrap 1973; Pagán-Jiménez 2013). However, recent studies show that both manioc and maize were used in all of these areas (Cagnato and Ponce 2017; Ciofalo et al. 2018; Ciofalo et al. 2019; Dickau et al. 2012; Pagán-Jiménez and Oliver 2008). The previously mentioned starch analyses also casted doubt upon the idea of maize only *tortillas* created on griddles from southern Central America, which complicates straightforward connections between plant species, artifact use, and cultural provenance.

In this article, suspected griddle fragments from the Barillas site in central Nicaragua were analyzed for starch content and their uses have been interpreted. Microbotanical analysis of the griddle fragments aimed to identify starchy plants and shed light on the socially learned practices entangled with local foodways. The results of this study challenge prevailing views on ancient foodways in this region, and contribute to discussions regarding reconstructions of Central American foodways more widely.

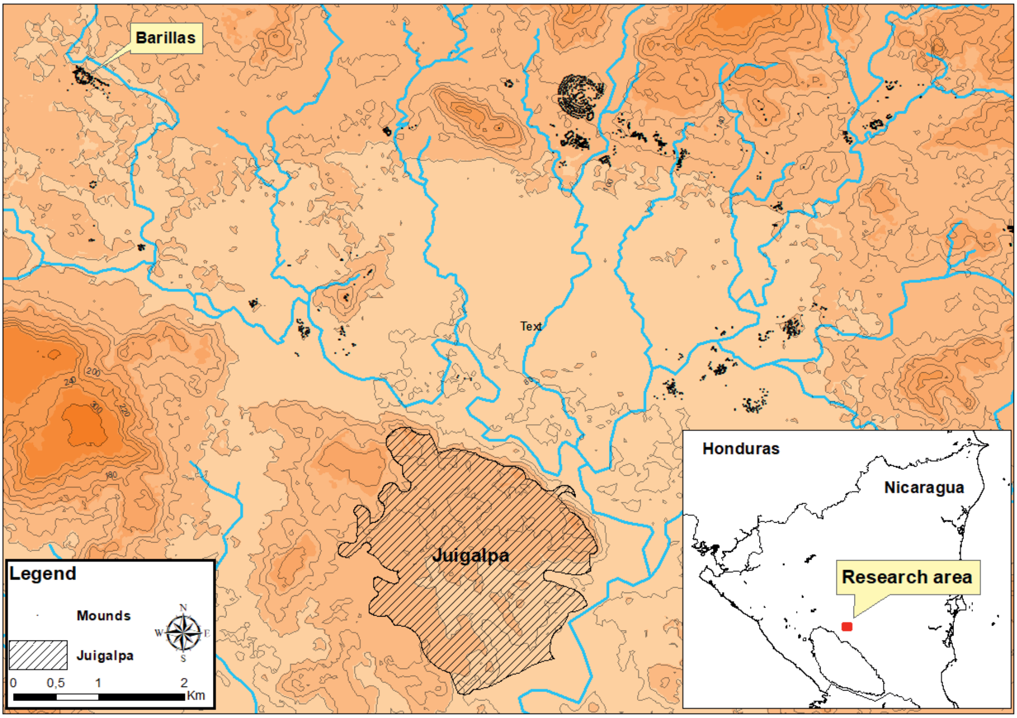

Figure 5.1
The archaeological site of Barillas in central Nicaragua. Prepared by Simone Casale.

5.2 Regional setting

The Barillas site is located 100 m west of the Mayales River, 5 km northwest of the city of Juigalpa. The site consists of 131 man-made mounds, built using a combination of bedrock fragments, sediment, pebbles, and debris (broken ceramic sherds and lithic artifacts). Three different excavation units were placed throughout the site, two in association with mounds (Units 1 and 3), and one in the middle of a flat area surrounded by mounds (Unit 2). The artifact assemblage used in this study was recovered from the first two pits, which might relate to practices associated with food preparation and consumption. Unit 1 was placed at the foot of a mound possibly related to shared practices performed near and/or in the site's central open space, while Unit 3 was located at the foot of a possible household mound (see Fig. 2 Donner et al. 2019). The off-mound communal area of Unit 2, in contrast, did not yield any griddle fragments. Even though the excavation units showed different stratigraphic characteristics, two types of archaeological evidence were remarkably absent. First, we found no evidence of macrobotanical remains, even though the flotation protocols were standardized for the entire study area, yielding very good results in all sites with no exceptions. Second, no zooarchaeological remains were recovered from any of the units excavated at Barillas (Donner et al. 2018). Because archaeobotanical investigations in central Nicaragua are absent and preservation of organic remains are limited, we have applied starch analyses to samples from fragments of clay vessels excavated from layers at the Barillas site, dated to cal 1224 and 1391 CE.

5.3 Material and methods

5.3.1 Artifact management

Five artifacts— four flat sherds and a shoulder/neck fragment of a pot were sampled and analyzed for starch content (Fig. 5.2). The five samples from the artifacts are referred to as Sample 1, 2, 3, 4, and 5 and were processed and analyzed for starch content at the Faculty of Archaeology, Leiden University (Table 5.1). These five artifacts were chosen for microbotanical sampling because of their morphological features, which suggested shapes like plates or griddles. The sample size was limited, partially because cooking and storage kitchenware only represents 7.3% of the ceramic sample at the Barillas site. Therefore, it is not surprising that griddles represented approximately 3% of the excavated assemblage. Subsequent studies on kitchenware will determine whether food consumption practices at the Barillas site tended towards communal and/or individual servings. Sample 4 consisted of a fragment of an *olla* (cooking pot), which was sampled for comparative purposes. Four of the five artifacts presented in this article were washed in the field following basic cataloguing procedures after archaeological recovery, which is not considered ideal for microbotanical analysis, although Barton (2007) achieved positive results from washed museum artifacts, and we hoped to do the same in this case. Once the artifacts were brought to Leiden University, they were photographed and sampled for microbotanical residues.

Figure 5.2
The five clay artifacts that were sampled for analysis of starch content **a** Sample 1 interpreted as a plate NR166. **b** Sample 2 interpreted as a plate NR165. **c** Sample 3 interpreted as a griddle NR168. **d** Sample 4 interpreted as an *olla* NR169. **e** Sample 5 interpreted as a griddle NR163.

5.3.2 Artifact sample extractions

The recovery of microbotanical samples was a challenge possibly due to the poor preservation of organic remains at the site. However, after testing two different methods we succeeded in the task. First, ultrasonic extraction (Sediment 1) was applied with no results. Then, minimal dry scraping in an attempt to recover plant residues while retaining technological macrotrace data for ceramic analysis (Sediment 2) was successful. Because Sediment 2 contained starch results and Sediment 1 did not, this suggests the starches from Sediment 2 were deposited (or absorbed) in the artifact's surface from persistent or prolonged use instead of brief contact with plant matter.

A wash bottle with ultra-purified water was used with significant water pressure to rinse the artifacts, which removed the majority of additional soil matrix that was loosely adhered and not a part of the artifacts use-history (Barton and Torrence 2015). This type of washing also assists in removing possible modern contamination (Chandler-Ezell and Pearsall 2003). Artifacts were set to dry in a dust and wind free area before proceeding with the following protocols.

A concern for all ancient starch analyses should be the potential for modern starch contamination and researchers should include protocols designed to check for and mitigate this type of contamination (Crowther et al. 2014). At the Leiden Faculty of Archaeology, the labs and consumables were consistently sampled separately during this study, and no modern starches were detected. The protocol was applied after Pagán-Jiménez (2007), and further modified based on (Atchison and Fullagar 1998; Barton et al. 1998; Pearsall et al. 2004; Zarrillo et al. 2008). In an attempt to retain macrotrace data, all artifacts except Sample 4 were left to "soak" in ultra-purified water in separate, new plastic bags for less than 5 min. The artifacts were then placed in an ultrasonic bath for 9 min. The aqueous sediment was extracted from the sample bags and transferred to new 50 ml plastic tubes (Table 5.1**,** Sediment 1).

After each sample in the Sediment 1 category was separated for starch content through a flotation using a heavy-liquid solution of cesium chloride (CsCl) (described below), and residues were analyzed under a microscope with negative results for starch content, the decision was made to use an alternative sampling method. The absence of starch content from Sediment 1 samples are a demonstration of the cleanliness of the laboratories and can be viewed as a contamination test of lab consumables. All five artifacts had their internal surfaces (ideal for cooking or serving) minimally dry scraped with sterilized dental picks. Negative artifact surfaces (i.e. pores, cracks, crevices) were targeted first, as such surfaces help preserve starches that were manipulated, processed, or cooked with the artifacts (Hart 2011). The preservation of starches in the artifact's negative surfaces is explained through a limited post-depositional exposure to destructive agents, such as enzymes, microorganisms, fluctuations of soil moisture, temperature, and pH levels (Haslam 2004). Because the average weight of residues and artifact material removed was 0.34 g, (Table 5.1), this scraping procedure was determined to have been minimally destructive and has retained macrotrace data in the areas that were not scraped. The scraped residue fell onto new printing paper for collection. The dry residues (Table 5.1**,** Sediment 2) were carefully funneled into new 1.5 ml plastic tubes, and then labeled.

Macroscopically, the sampling procedure for Sediment 2 (dry scraping) appeared to have been more intrusive and damaging to the artifacts than the sampling procedure for Sediment 1 (ultrasonic). However, both the weight and volume of all Sediment 1 samples were more than that of the Sediment 2 samples (Table 5.1). We can therefore suggest that the sampling procedure for Sediment 2 samples was the least destructive method that allowed the recovery of data for both archaeobotanical and macrotrace analyses.

5.3.3 Heavy density liquid separation for the recovery of starches

After each sample was completely dried, a heavy-liquid solution of CsCl and ultra-purified water was added, prepared to 1.79 g/cm^3 density. The sample with solution was agitated and mixed using an ultrasonic bath for at least 1 min. Next, ancient starches were separated from other particles using a centrifuge operated at 2500 rpm for 8 min (procedure modified from Atchison and Fullagar 1998; Barton et al. 1998; Pagán-Jiménez 2007; Pagán-Jiménez et al. 2015; Pearsall et al. 2004). The supernatant (liquid lying above the solid residue) was decanted into new centrifuge vials. Ultra-purified water was added to each vial and they were centrifuged for 8 min at 9000 rpm, which initiated the process to remove CsCl from the sample. As the starches began to sink during this part of the process, the supernatant was removed, more ultra-purified water was added, and the sample was centrifuged at 9000 rpm but for 5, rather than 8 min. Again, the supernatant was decanted and ultra-purified water was added, then the sample was centrifuged again at 9000 rpm for 5 min. Finally, after the CsCl was sufficiently diluted and removed from the samples they were slide-mounted in a small drop of glycerin for microscopic observation.

For the purpose of comparison for taxonomic ascription, we used an assembled reference collection of starches obtained from recent economically useful and edible plants with the majority collected and processed by Dr. Jaime Pagán-Jiménez in Puerto Rico, who also obtained some samples from CIMMYT's Maize Genetic Resources (Pagán-Jiménez 2007; Pagán-Jiménez 2015a). Other samples were obtained from the Economic Botany collection of Naturalis Biodiversity Center Leiden and from markets and wild growing plants in the Neotropics. In sum, the reference collection contains modern starches from more than 140 specimens representing 70 genera and 63 species from the Antilles, continental tropical Americas (mainly the continental Greater Caribbean area), and from the Old World.

Descriptive analysis of modern samples with detailed explanations of morphometric features allowed for the taxonomic identifications of ancient starches through comparison (e.g., Pearsall et al. 2004; Perry et al. 2007; Piperno and Holst 1998). For this study, the morphometric features used were the starch's size, shape, and border (edges). In addition, the ancient starch's shape and position of extinction cross, hilum appearance and location, presence and shape of both fissures and compression facets were documented. If the ancient starch characteristics were not observed in our modern reference collection or in published sources (Cagnato and Ponce 2017; Dickau 2005; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Perry 2002b; Perry et al. 2007; Piperno 2006; Piperno and Holst 1998; Reichert 1913), then taxonomic ascription was deemed uncertain. If a starch had an uncertain taxonomic identification, the prefix "cf." was used to indicate the closest possible taxonomic ascription; and when a starch was not successfully identified, we just used the term not identified. This research also had a focus on food processing damage signs on the ancient starch based upon comparisons with experimental studies in published literature (Babot 2003; Babot 2006; Henry et al. 2009; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2015a; Pagán-Jiménez et al. 2017).

For observations and descriptions, each starch was photographed using a Leica DM2700 P polarizing light microscope with different focal lengths and rotated, when possible, to record and describe its characteristics. After the initial analysis, slides were stored in new cardboard holders for further observation and preservation. Furthermore, every sample collection tube with remaining residue was filled with ultra-purified water, temporarily sealed, and set aside for preservation.

Table 5.1
Artifact provenance and contextual information of the analyzed samples.

Sample no.	Starch lab reference no.	Provenance	Sample type	Sediment 1 (ultrasonic) Sample volume(ml)/weight(g)	Sediment 2 (dry-scraping) Sample volume(ml)/weight(g)
Sample 1	NR166	UBI3CXV12	Clay rim fragment of a plate	1.0//0.230	0.2//0.060
Sample 2	NR165	UBI3BXV14	Clay rim fragment of a plate	0.7//.178	0.3//0.163
Sample 3	NR168	UBI1AIB5	Clay fragment of a griddle	2.0//.691	0.3//0.202
Sample 4	NR169	UBI1BIB5	Clay neck fragment of an *olla*	None	0.8//0.991
Sample 5	NR163	UBI1BIII5	Clay fragment of a griddle	1.2//0.209	0.4//0.296

5.4 Results

The starches from this study were recovered only from dry scraping layers of clay and thus releasing the starches from their protected microenvironment. We postulate the most likely cause for the entrapment of starches within the clay artifact's surfaces was through intense or prolonged use of the ceramics as food related implements. Table 5.2 synthesizes the results attained from studying these samples. Overall, the plant remains identified demonstrate the use of seed, fruit, and tuber crops, which has helped expose human processing of starchy plants through socially learned practices.

Table 5.2
Distribution of recovered starches per sample and their plant sources. [a] Ubiquity refers to the occurrence of identified taxa amongst the sampled artifact assemblage. It was calculated by dividing the presence of securely identified taxa by the total number of analyzed artifacts. [b] Minimum species richness combined both tentative ("cf.") and secure identifications. This excluded starches that were not identified because they could have been produced by some of the identified taxa.

	Sample id	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**		
	Sample type	**Clay rim fragment of a plate**	**Clay rim fragment of a plate**	**Clay fragment of a griddle**	**Clay neck fragment of an *olla***	**Clay fragment of a griddle**		
							Starch count	**[a]Ubiquity (%)**
Taxa	***Manihot esculenta***				2	1	3	40
	cf. *Manihot esculenta*				1		1	20
	***Capsicum* sp.**					1	1	20
	Zea mays	1		1		4	6	60
	Not identified			1			1	--
	Starch count	1	0	2	3	6	--	--
	[b]Minimum species richness	1	0	1	1	3	--	--
	Ceramic technology possibly related to cooking			Quartz tempering	Quartz tempering	Quartz tempering		

5.4.1 Artifact Sample-1

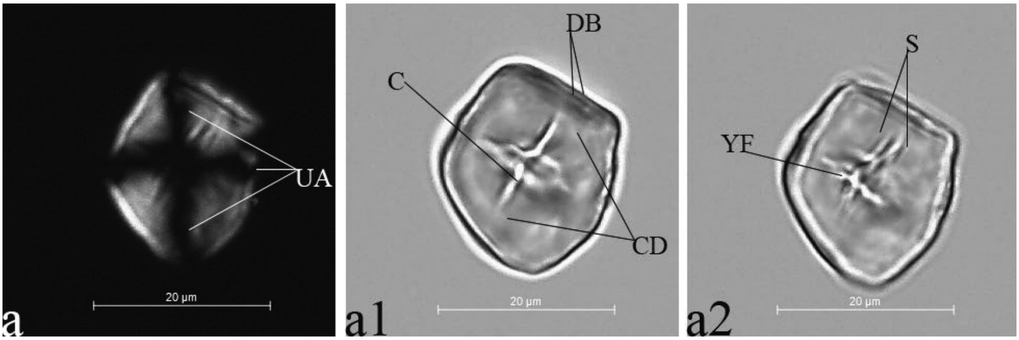

Figure 5.3
Starch recovered from Artifact Sample-1.
a Maize starch under polarized light and dark field view. **a1** The same maize starch under bright field view. **a2** The same maize starch under bright field view at a different focal length.
Figure legend: "C" crack "CD" central depression; "DB" double border; "S" striation; "UA" undulating extinction cross arm; "YF" Y-shaped fissure.

The ceramic analysis determined that this artifact (Fig. 5.2 a) was part of a medium-grained plate with feldspar tempering excavated on mound. Manufacturing practices, from clay procurement to firing and decoration, followed the local tradition of ceramic production (Donner et al. 2018). One starch grain (Fig. 5.3 a, a1, a2) identified as maize was recovered from the surface of this ceramic fragment measured 23.9 µm x 19.2 µm, and had a pentagonal shape with an undulating extinction cross. No lamellae were visible. The hilum was centric, a Y-shaped fissure was present, and a continuous double border was observed. This starch had a circular central depression (Fig. 5.3 a1), which was consistent with damage patterns from grinding maize (Mickleburgh and Pagán-Jiménez 2012; Vinton et al. 2009). In addition, this starch featured a crack and thin striations near its center, alterations due to pressure (grinding, cutting, scraping, or pounding) consistent with practices involving the preparation of flour-based foods (Mickleburgh and Pagán-Jiménez 2012).

5.4.2 Artifact Sample-2

This artifact (Fig. 5.2 b) consisted of a clay fragment from a coarse-medium-grained plate, with feldspar temper that measured 25 cm in diameter and was excavated on mound. The lip of the sherd was flat and beveled and the manufacturing practices determined from this sample were of local origins (Donner et al. 2018). This sherd had no evidence of starch recovered from its surface.

5.4.3 Artifact Sample-3

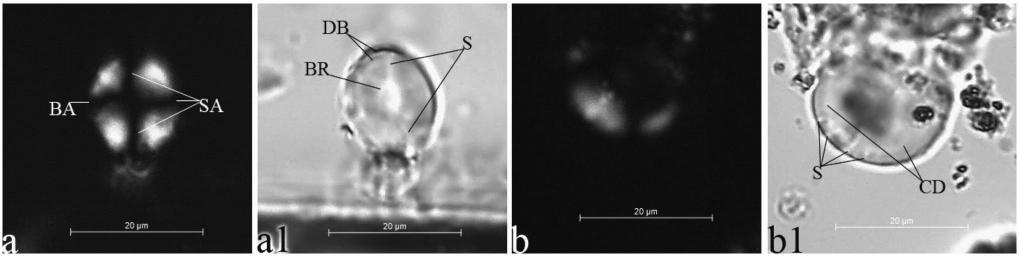

Figure 5.4
Starches recovered from Artifact Sample-3.
a Maize starch under polarized light and dark field view. **a1** The same maize starch under bright field view. **b** Unidentified starch under polarized light and dark field view; note the optical loss of birefringence. **b1** The same unidentified starch under bright field view.
Figure legend: "BR" bright ring; "BA" bent extinction cross arm; "CD" central depression; "DB" double border; "S" striation "SA" straight extinction cross arm.

The sample was taken from an artifact (Fig. 5.2 c) that was determined to have been a part of a coarse grained, quartz tempered griddle, with a 25 cm diameter, excavated off-mound. The recovered sherd had no visible surface treatment nor decorations. As in the samples described above, the steps for the manufacturing process followed the local tradition for pottery manufacture. There were two starches recovered from the used surface of this griddle. The first starch grain identified as maize (Fig. 5.4 a, a1) measured 16.9 µm x 13.9 µm. The extinction cross had three straight arms and one bent. The starch was oval shaped. No lamellae were visible. The hilum was open and centric with a bright ring around the hilum. There was no fissure present, but a double border was visible. There were a few striations from the hilum to the border. The striation and the bright ring indicated the plant organ that produced this starch was modified by pressure. The second starch (Fig. 5.4 b, b1) was unidentified because the starch would not rotate and it was partially covered by other organic material, thus the three-dimensional shape could not be determined. However, there were thin striations along the border indicating pressure was applied during culinary practice. The cooking environment was likely hot and slightly humid which was interpreted from this unidentified starch's large central depression and optical loss of birefringence (Henry et al. 2009; Pagán-Jiménez et al. 2017).

5.4.4 Artifact Sample-4

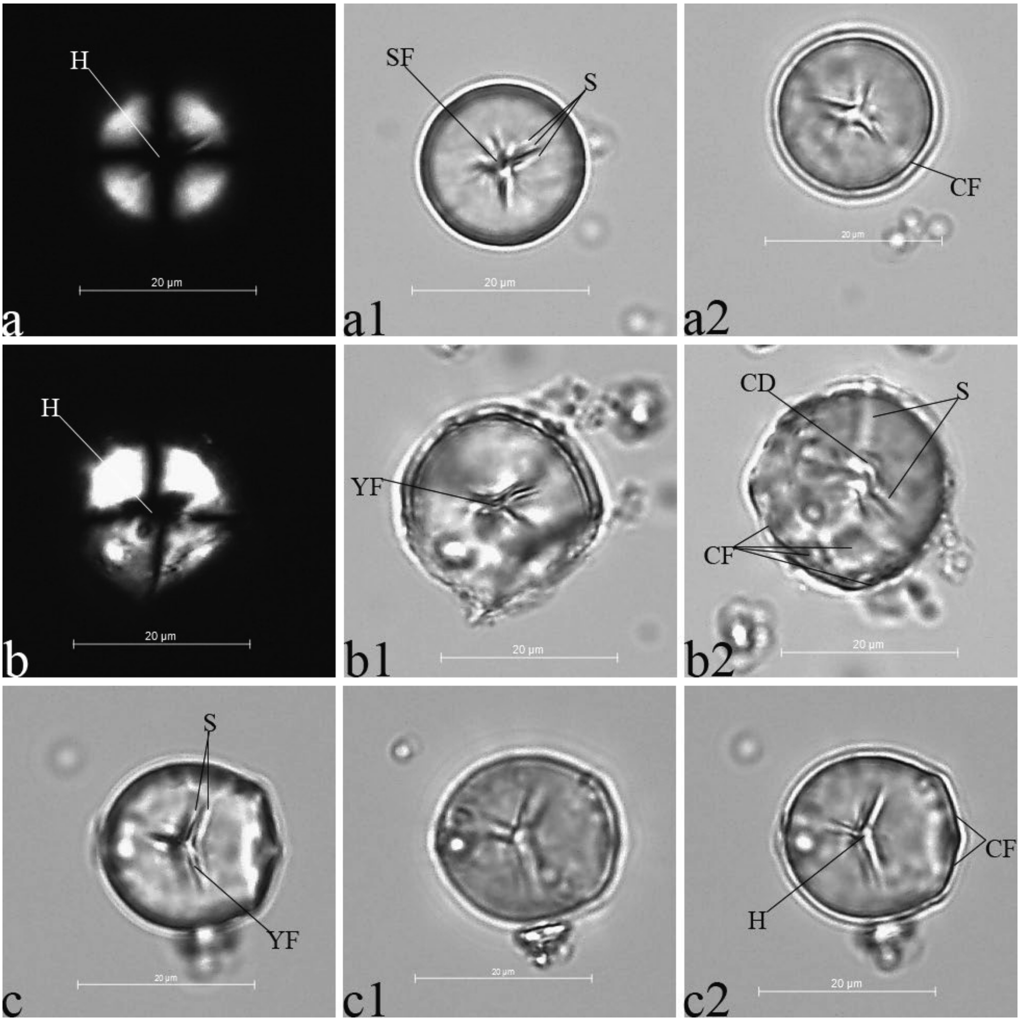

Figure 5.5
Starches recovered from Artifact Sample-4.
a cf. manioc starch under polarized light and dark field view. **a1** The same cf. manioc starch under bright field view. **a2** The same cf. manioc starch but rotated. **b** Manioc starch under polarized light and dark field view. **b1** The same manioc starch under bright field view. **b2** The same manioc starch but rotated. **c** Manioc starch under bright field view. **c1** The same manioc starch at a different focal length. **c2** The same manioc starch at a different focal length.
Figure legend: "CD" central depression; "CF" compression facet; "H" hilum; "S" striation; "SF" stellate fissure; "YF" Y-shaped fissure.

This sherd (Fig. 5.2 d) was determined to have been a part of an *olla*. The vessel was medium grained, quartz tempered, with a 7.5 cm throat diameter, and it was excavated off-mound. As in the previous samples, it was manufactured and followed the local technical tradition for ceramic production. Three starches were recovered from the interior area of the neck of this vessel. Two of the starches have been positively identified as manioc and one was identified as cf. manioc. The tentatively identified manioc starch (Fig. 5.5 a, a1, a2) measured 18.3 µm x 18.2 µm, was approximately spherical but had some basal flattening when rotated (Fig. 5.5 a2). There were no lamellae visible. A diagnostic stellate fissure was present. This starch exhibits enough characteristics to be identified as cf. manioc. There were thin asymmetrical striations near the fissure, suggesting that applying pressure was part of culinary practices.

The manioc starch grain (Fig. 5.5 b, b1, b2), which measured 19.9 µm x 19.8 µm, had a truncated bell-shape, with four flat basal compression facets, noticed when rotated (Fig. 5.5 b2). No lamellae were visible. A Y-shaped fissure was present, as well as a centric hilum. This starch exhibited white striations from the center of the fissure extending to the border and a small central depression, which suggest light pressure was applied to the plant organ as part of culinary practices (Mickleburgh and Pagán-Jiménez 2012; Vinton et al. 2009).

The next starch grain identified as manioc (Fig. 5.5 c, c1, c2), measured 19.7 µm x 18.2 µm, also had a truncated bell-shape but with two flat basal compression facets. No lamellae were visible, and a Y-shaped fissure was present. The hilum was closed and centric. For this truncated bell-shape of manioc starches, this starch has a longer than average (16 µm) length measurement, with an enlargement possibly due to culinary practices (Pagán-Jiménez 2007:221). This starch also has asymmetrical striations near the fissure, suggesting a degree of pressure occurred as part of culinary practices.

5.4.5 Artifact Sample-5

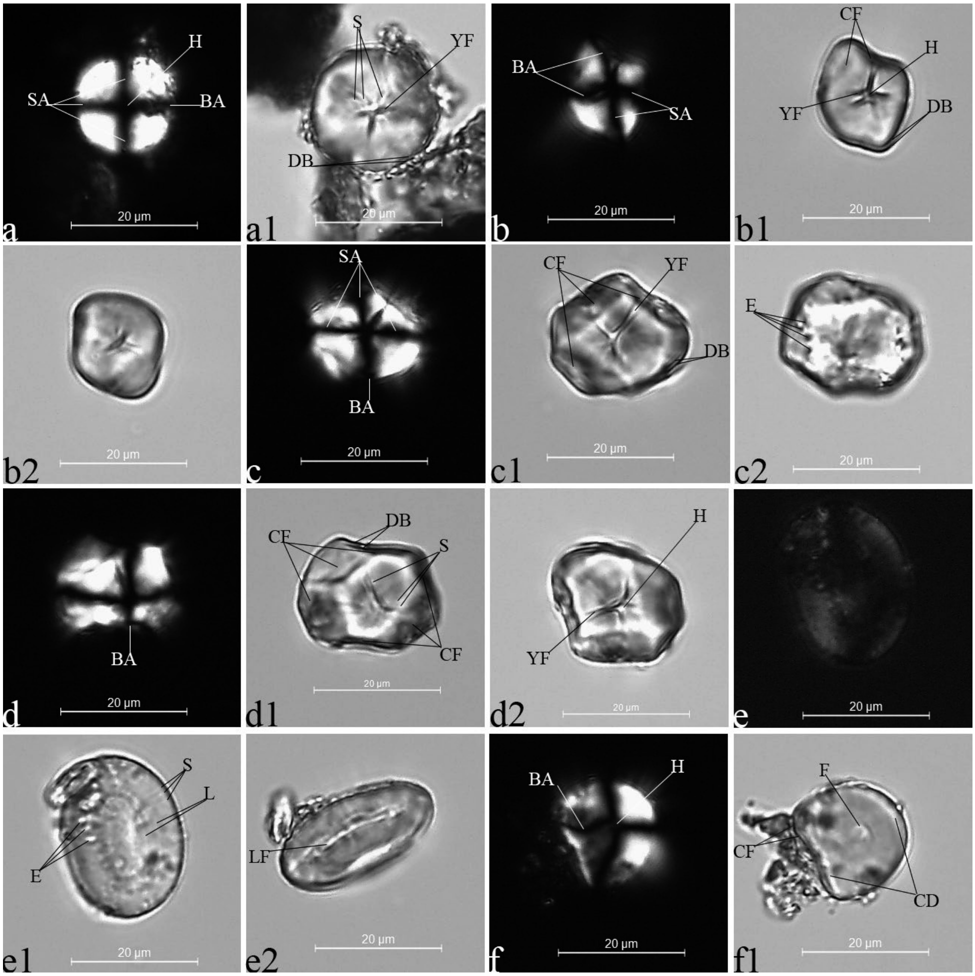

Figure 5.6
Starches recovered from Artifact Sample-5.
a Maize starch under polarized light and dark field view. **a1** The same maize starch under bright field view. **b** Maize starch under polarized light and dark field view. **b1** The same maize starch under bright field view. **b2** The same maize starch under bright field view but rotated. **c** Maize starch under polarized light and dark field view. **c1** The same maize starch under bright field view. **c2** The same maize starch under bright field view but rotated and at a different focal length. **d** Maize starch under polarized light and dark field view. **d1** The same maize starch under bright field view. **d2** The same maize starch under bright field view but rotated. **e** Chili pepper starch under polarized light and dark field view. **e1** The same chili starch under bright field view. **e2** The same chili starch under bright field view but rotated. **f** Manioc starch under polarized light and dark field view. **f1** The same manioc starch under bright field view.
Figure legend: "BA" bent extinction cross arm; "CD" central depression; "CF" compression facet; "DB" double border; "E" enzymatic damage; "F" fold; "H" hilum; "L" lamellae; "LF" lineal fissure; "S" striation; "SA" straight extinction cross arm; "SF" stellate fissure; "UA" undulating extinction cross arm; "YF" Y-shaped fissure.

This sample was taken from one sherd of three articulating fragments, which belonged to a coarse-grained griddle (Fig. 5.2 e) that was excavated off-mound. The vessel measured 42 cm in diameter, with a wall thickness ranging from 7.5 to 12.0 mm. The manufacturing process followed the same local technical signatures as the samples described previously. Six starches were recovered from the surface of this kitchen implement, and more than 50 percent of them had damage signs indicating the plant masses were altered by heat (sensu Henry et al. 2009). Of the recovered starches, the majority have sufficient characteristics to be securely identified as maize (4), one as chili pepper (*Capsicum* sp.), and one as manioc.

The starch grain (Fig. 5.6 a, a1) securely identified as maize, measured 19.9 µm x 19.3 µm, and was spherical in shape with no visible compression facets. No lamellae were present. A Y-shaped fissure and double border were both visible. The hilum was closed and centric. The extinction cross had three straight arms and one bent arm. These characteristics were consistent with our reference collection and documented starches from published sources, which helps secure the taxonomic identification as maize (Holst et al. 2007; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Pagán-Jiménez et al. 2015; Pearsall et al. 2004). There were asymmetrical striations near the fissure indicating this starch was altered by pressure.

The starch grain (Fig. 5.6 b, b1, b2) securely identified as maize, measured 18 µm x 14.8 µm, and had a pentagonal shape. It had at least two concave compression facets. No lamellae were present. A Y-shaped fissure and double border were both prominent. The extinction cross had two straight arms and two bent arms at the compression facets (Fig 5.6 b). These diagnostic characteristics were all found in samples of maize in our reference collection and in published sources (Holst et al. 2007; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007; Pagán-Jiménez 2015a; Pearsall et al. 2004). This starch grain also had a swollen appearance most noticeable in Fig. 5.6 b2 (compared to starches in the reference collection), possibly suggesting it was cooked in a partially humid and hot cooking environment (Crowther 2012).

The starch grain (Fig. 5.6 c, c1, c2) securely identified as maize, measured 21.6 µm x 18.8 µm, and had a pentagonal shape with at least three flat compression facets. No lamellae were present. A Y-shaped fissure and double border were visible. The extinction cross had three straight arms and one bent arm. When the starch was rotated and the focal length was changed (Fig. 5.6 c2), pits on its surface became apparent, which were likely caused from enzyme degradation (Pagán-Jiménez 2015b).

Another starch grain (Fig. 5.6 d, d1, d2), securely identified as maize, measured 21.9 µm x 16.8 µm, and had a hexagonal shape with at least six flat compression facets. No lamellae were present. A Y-shaped fissure and double border were both noticeable. The hilum was open and slightly eccentric. The extinction cross had at least one bent arm. These were all characteristics of maize starch that were found in our reference collection, which helps secure the identification. There were thin asymmetrical striations near the hilum caused from pressure as part of culinary practices.

The third starch grain (Fig. 5.6 e, e1, e2) has been identified as originating from a chili pepper. The starch measured 25.5 µm x 18.6 µm and had an oval shape with no visible compression facets. Concentric oval lamellae were present. When the starch was rotated, a diagnostic lineal fissure was present (Perry et al. 2007). The extinction cross was diffuse and faint. There were thin striations along the border due to applied pressure as part of culinary practices. There were also pits on the surface of this starch likely due to enzyme degradation (Henry et al. 2009).

The last starch grain (Fig. 5.6 f, f1) has been identified as manioc, measured 17.6 µm x 15.1 µm, and had a truncated bell-shape with at least two flat compression facets. No lamellae were present. The hilum was slightly eccentric. The extinction cross had one arm that was bent. These characteristics of manioc starches were found in our reference collection and published sources securing the taxonomic identification as manioc (Cagnato and Ponce 2017; Pagán-Jiménez 2015a; Perry 2002b; Piperno 2006). There was partial loss of optical birefringence (Fig. 5.6 f), the beginning of a fold, and a large central depression, which helped us interpret that the food was prepared in a hot and partially-humid cooking environment (Pagán-Jiménez et al. 2017).

In sum, two of the maize and one chili starch grains had damage from pressure applied as part of culinary practices. The manioc starch had evidence for the beginning of a fold caused by cooking foods in a hot and slightly-humid cooking environment, which is consistent with the way that flatbreads are prepared on griddles (Pagán-Jiménez et al. 2017). Both the chili pepper and one maize starch grain had signs of enzymatic damage (sensu Henry et al. 2009; Pagán-Jiménez 2015b; Wang et al. 2017).

5.5 Discussion

Results from this study contribute towards understanding the distribution of ancient foodways associated with manioc, chili pepper, and maize in southern Central America. This data provides evidence of diverse starchy culinary practices which included several ways of processing foods culminating in a limited, yet enlightening, picture of pre-Hispanic foodways in central Nicaragua. Among our sample spectrum, maize was the most ubiquitous plant represented (Table 5.2). Perhaps foodways were focused on cultivating, processing, and consuming maize, but at this stage of our research, we cannot infer economic or cultural significance of one plant over others at the site or regional levels. For doing so at different chronological and geographical scales, the study of many other types of artifacts, different research methods, or at least the analysis of a larger number of samples must be carried out. In this study area and at the end of the pre-Hispanic period the indigenous communities may have been in a process of significant changes in culinary practices, but we need more studies to conclusively comment on this process. However, the limited number of studied samples provides sufficient evidence to place the identified plants and associated culinary practices in specific chronological and geographical contexts for the first time in central Nicaragua. Important for future research is our additional line of evidence that agrees with Barton (2007) showcasing the type of information still available from washed or museum curated artifacts.

Due to the fact that heat and pressure were two of the main causes of alterations for the recovered starches, it is expected that a range of plant derivatives (e.g., *albondigas*, *tamales*, *salsas*, *tortillas*, and other flat-breads) were made from the identified plant sources (Cagnato and Ponce 2017; Pagán-Jiménez et al. 2005; Rodríguez Ramos 2005; Rodríguez Ramos et al. 2013). In the entire 52 km^2 study area, the presence of griddles is exclusive to the Barillas site. Even though Barillas shares a technical ceramic tradition that is present in the area since at least 300 CE, foodways associated with griddles have only been identified at this site (Donner et al. 2018). The recovered starchy residues and their damage patterns from food processing, in conjunction with the analyzed ceramics from this study demonstrate the existence of particular phytotechnological abilities (knowledge and tools to transform plants) that included intersecting operational sequences such as plant procurement, peeling, grinding, grating, flour preparation, fuel acquisition, fire creation, production and employment of different lithic artifacts for these tasks, use of ceramic vessels for cooking, serving, and consumption, as well as practices related to discarding debris.

After plant procurement, interpretations regarding enzymatic damage to these plant organs can shed light on pre-preparation storage practices. On the one hand, the maize cob/peduncle may have been kept in a shady storage area without refrigeration, where the tropical heat could have caused the maize to naturally process through the early stages of fermentation (i.e. enzymatic degradation). The choice to use the “old” (long after being harvested) maize could have been one to prevent the organ from completely spoiling. On the other hand, the chili pepper may have been purposefully used after being partially digested by enzymes (old), due to their potential to transform and enhance flavors, as is still done in *salsa* preparation practices today.

Then, in the case of maize related meals, it is likely that the foods prepared with these tools required the maize kernels to be removed from the cob before further processing (Pagán-Jiménez et al. 2016). Ostensibly, the processed maize and manioc involved pressure from either grating or grinding, or both processes. Samples 3 and 5 exhibited recovered starches with signs of pressure damage combined with heat alterations, possibly suggesting the production of *tortillas* or flatbreads (Pagán-Jiménez et al. 2017). In contrast to the griddles, the starches recovered from the *olla* fragment (Sample 4) only had signs of pressure damage, but no evidence of heat alterations. Due to the collated information from different vessel samples, we can ascertain that manioc was prepared using different types of vessels (griddles and *ollas*), whereas maize was only recovered from griddles and a plate. While these differences in the samples might be related to conservation issues and sample bias, it could also be connected with dissimilar meals, some being prepared on griddles and others in *ollas*.

Regarding ceramic vessel technical traits, Samples 3, 4, and 5 consisted of kitchenware, with shared paste preparation practices involving the addition of quartz as temper. Sample 4 was identified morphometrically as a cooking pot, used for preparing manioc-based foods. Sample 3, 4, and 5 possibly had more starches recovered because they pertained to vessels used for cooking rather than only serving. Samples 3 and 5 were the only samples that had starches affected by a partially-humid cooking environment which is consistent with, but not exclusive to, experimental damage patterns from the use of griddles to prepare flatbreads (Pagán-Jiménez et al. 2017). Sample 5 was used for processing a broad suite of plants as shown by the residue of a variety of plant species recovered from its surface. We propose both Samples 3 and 5 represent novel evidence of ceramic griddles based on the combination of shape, paste, the recovered starches, and their associated damage patterns. As the griddle vessels were flat, the humidity in the cooking environment was likely generated by the plant mass as opposed to an added external liquid cooking environment (i.e. dough, not soup). Manioc recovered from griddles supports the idea that the tubers were first altered by grating to be turned into a flour and thus dough, which, to our knowledge, would be a culinary practice absent from primary European chronicles that mention manioc in Central America (Cortés 1908 [1519]:162; Díaz del Castillo 1844 [1576]:22; Fernández de Oviedo 1851 [1535]).

This reconstruction of central Nicaraguan starchy foodways has been used to identify misconceptions based on the absence of evidence and the lacuna of botanical analyses. Thus, the incorporation of griddles—a completely novel utensil not known in the area before, but with signatures of local production—suggests transformations in kitchenware and their entangled foodways. Our data do not validate, nor indicate, explanations of direct migration or indirect Mesoamerican "influence". The griddles and cooking pot appear to have had intentional addition of tempering materials, which has been interpreted as related to local cooking practices and the desire for adequate thermal transfer and crack resistant kitchenware (Donner et al. 2019). Diachronic studies of culinary practices in the region will shed more light on the local and regional histories of food production and consumption.

5.6 Conclusions

Overall, the results of this study offer a first insight into the phytocultural dynamics of the research area. For example, we are now able to propose that practitioners at the Barillas site consumed chili pepper, maize, and manioc prepared on griddles. These results challenge the bias that equates the use of griddles to the exclusive preparation of maize *tortillas*. Our data reflects previous conclusions that vessel form does not imply function; and function does not determine use (DeBoer 1975; Perry 2002a; Perry 2005). In addition, the technological analysis of the manufacturing choices made by potters to produce the griddles, suggests their local production (Donner et al. 2018). When the manufacturing choices are combined with the inferred culinary practices, this problematizes existing narratives regarding migration and diffusion of practices by Mesoamerican groups after 900 CE, who have been traditionally linked to griddles and maize *tortillas*.

Since at least cal 600 CE, the indigenous communities living in the valley of Juigalpa participated in trade networks that connected them, across Lake Cocibolca, to parts of Pacific Nicaragua, and may have extended as far as central and northern Honduras (Donner 2020; Donner and Geurds 2018). Habitual practices such as the ones linked to technological choices in ceramic manufacture or architectural techniques show strong local signatures, but the occasional incorporation of foreign materials and objects was also part of daily practices. For example, the occurrence of obsidian or imported polychrome vessels from cal 950 CE on did not coincide with archaeological indications of a population shift, but rather reflects changes experienced in long distance relationships between communities (Donner and Geurds 2018).

The griddles recovered at Barillas are significant in light of their hitherto unseen shape, in combination with the association with the culinary practices of special food items (*tortillas*) not made with other types of vessels, spatially connected to centrally located mounds at the site (Donner et al. 2019). Importantly, however, griddles were manufactured using the same technical sequence shared by all other fired clay kitchenware at the site (Donner 2020). The evidence presented here does not provide indication of potential ethnic changes in the region, as was previously suggested (Gorin 1990), and initially raised in the early Colonial Spanish chronicle (Fernández de Oviedo 1851 [1535]). Griddles were absent from the investigated Barillas' residential mounds (Donner et al. 2019), so it is possible that consumption of foods prepared on them was constricted to practices related to the Barillas central open space, or to a circumscribed group that controlled the trade networks.

The recovered starches provide the first empirical evidence of ancient central Nicaraguan foodways, providing an alternative to earlier archaeological ideas regarding plant use that were based on indirect evidence. In light of this novel data, the results from this study help to understand pre-Hispanic botanical foodways in this region of southern Central America. The recovered plant residues have created a direct link among plants, people, and kitchenware, revealing a sophisticated set of locally developed culinary practices that were previously unknown for pre-Hispanic Nicaraguan foodways. Apart from that, this study has demonstrated the appropriateness of starch analysis in environments with limited preservation of organic remains, as well as the ability to obtain microbotanical data from washed artifacts. Concomitantly, these results invalidate the preconception that griddles were tools used exclusively for the production of maize *tortillas*, thereby nuancing straightforward associations drawn between ethnic identity and foodways.

5.7 Acknowledgements

We thank Leiden University for providing support and lab spaces for our work. We would like to thank all the participants of the excavations at the Barillas site. Thank you to Simone Casale for the creation of Fig. 5.1. Special thanks to Dr. Jaime Pagán-Jiménez for his guidance with the starch analysis.

5.8 Funding information

This research was supported by the Netherlands Organization for Scientific Research (NWO) VIDI Grant 016.134.309. The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme

(FP7/2007-2013) / ERC grant agreement n° 319209. In addition, the export of archaeological materials was facilitated by the Instituto Nicaragüense de Cultura, under the technical supervision of the Dirección Nacional de Arqueología (permit Co-DG/01-2017).

5.9 Open Access

5.10 References

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CHAPTER 6

Final Thoughts

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6.1 Starchy foodways prior to the advent of European invasions

Carbohydrates have been fundamental components of most diets throughout history (Larbey 2018). Certainly by the time people reached the Americas, preferences, values, and habits surrounding different starchy foods had formed. Undeniably, the influence of sensory characteristics has always been present when humans consume food, but they likely differentiate between social groups (Epstein et al. 2009). As people moved into the Greater Caribbean the ways to process plants were transported with them, such as grinding plants with handstones (Pagán-Jiménez 2007a:48-49; Rodríguez Ramos 2005; Rodríguez Ramos 2010; Rodríguez Ramos et al. 2013). Perhaps these culinary practices became habituated.

The starchy plant remains identified throughout this dissertation emphasize meal habituation (Appadurai 1986:241), yet suggest some culinary practices varied between sites. The plants used to prepare meals were chosen from a broad spectrum of possibilities. However, poisonous plants were used at every case study site investigated. There are a few possibilities regarding how these potentially poisonous foods were deemed edible. Small bits of the poisonous plants could have been tasted to check for alkaloids (Hastorf 2016:24). Alternatively, watching other animals interact with the plants and the foods produced to see if and when they were safe to consume. This would be similar to what was done with zamia bread and fly larvae in the Greater Antilles (when the larvae grew to a certain size it was understood the zamia poison was neutralized) (Las Casas 1909:60). As well as watching animals (domestic Eurasian fauna) die from drinking the water after washing grated zamia, as was done in The Bahamas during colonial times (Gifford 1912:100). Perhaps during precolonial times, zamia and manioc and their culinary products were fed to domesticated or managed mammals during different processing steps to see when they were safe to eat.

Culinary identities may be united and discussed during the preparation and consumption of commensal meals (Carr et al. 2018). In northwestern Dominican Republic, it appears Indigenous Peoples of La Luperona and El Flaco created variations of similar meals using shells and clay griddle kitchen tools. While the ingredients may have slightly varied between these sites, the methods of preparing meals using bivalve shells and clay griddles were similar. Plants may have been “pre-cooked” before being processed further. This culinary practice could have eased further plant manipulation, or been used to modify flavors and incorporate the resulting product into a larger recipe. Alternatively submitting a plant organ to direct fire could have been viewed as a way to release/exterminate other substances or entities. According to Pané et al. (1999:26), everything was animate and many spirits were entangled with botanical foodways. During the late precolonial period in these spaces that we now refer to as El Flaco, La Luperona, Palmetto Junction, LN-101, and Barillas, there were nuanced differences regarding plant ingredients at the site level and more homogenous culinary practices from regional perspectives.

6.2 Local site culinary practices

Percentage presence or ubiquity analysis does not indicate a plants contribution to diet, but it is a way to quantify this type of data and display potential uses of these plants while generating inferences of access, processing, and other culinary practices. For example, due to the ubiquity of maize and manioc recovered from the LN-101 site, it is possible the people working or living at this site predominantly processed these starchy plants with the sampled artifacts (Figure 6.1). However, the sample size from LN-101 was too small to indicate or suggest patterns of intensely used plants. In contrast, from this dissertation's larger sample size, the ubiquity analysis of El Flaco suggested many households had access to maize and perhaps it was a preferred or valued plant ingredient incorporated into their culinary practices (Figure 6.2).

To emphasize, yet again, clay griddles were multipurpose and not only used to prepare manioc. From the La Luperona griddle samples the use of zamia was the most ubiquitous (Figure 6.2). However, zamia was not recovered from the shell artifacts, which suggests zamia was prepared a different way at La Luperona perhaps using lithic, coral, or wooden tools for this function. In the comparison of griddle use, La Luperona was the exception for an absence of both manioc and maize remains. Yet, from the La Luperona shell artifacts, there was starch potentially identified as manioc. Thus, without sampling multiple types of artifacts the breadth of plant use at these sites would not be revealed. La Luperona had sweet potato starches recovered from shell artifacts that had signs they were processed in hot and humid cooking environments. Thus, it seems some sweet potatoes were lightly baked before being peeled.

The Palmetto Junction assemblage demonstrated provisioning, access, and use of primarily manioc on the sampled griddles, but there was less ubiquity of recovered manioc starch remains on the sampled shell artifacts. The shell artifacts yielded evidence for the use of several types of yam, which were absent from the Palmetto Junction sampled griddle assemblage. Thus, if starchy remains are not recovered from certain types of sampled artifacts it does not mean those plants were absent or insignificant parts of culinary practices. On the contrary, the plant remains ubiquitously recovered from multiple types of artifacts at one site are more likely to have been situated within culinary practices to the point of social habitus[14].

In the Barillas site case study, there was evidence of several ways of processing plants. It is not possible, for now, to infer economic or cultural significance of one plant over others at the site or regional levels. For doing so at different chronological and geographical scales, the study of many other types of artifacts or at least a larger number of samples must be considered. Regarding foodways, it is possible to propose that culinary practices at the Barillas site prepared multiple types of botanical foods on griddles, in *ollas*, and used clay plates (perhaps for serving) (Fig. 6.3). Based upon the enzyme degraded chili pepper remains, we believe the operational sequences involved in the preparation of salsas were practiced. The residues of chili pepper, maize, and manioc on the same griddle may indicate the preparation of *tortillas* and/or breads mixing both maize and manioc flour in combination with the addition of spicy flavors.

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[14] …*habitus* through which the creator partakes of his community and time, and that guides and directs, unbeknownst to him, his apparently most unique creative acts (Bourdieu 2005, 226).

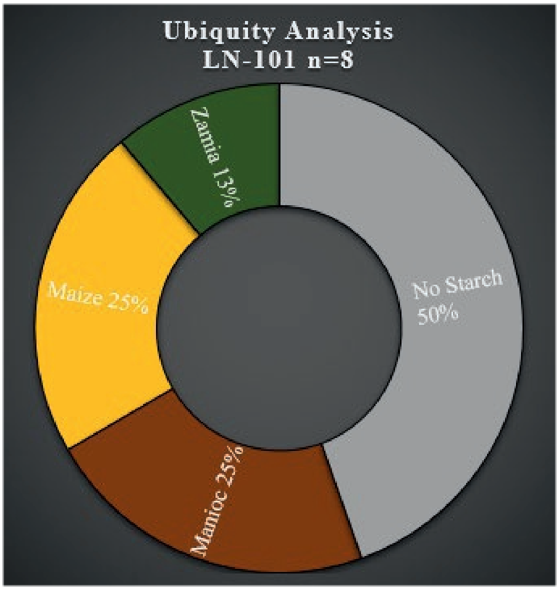

Figure 6.1
Visualized ubiquity analysis for the LN-101 site, Long Island, The Bahamas.

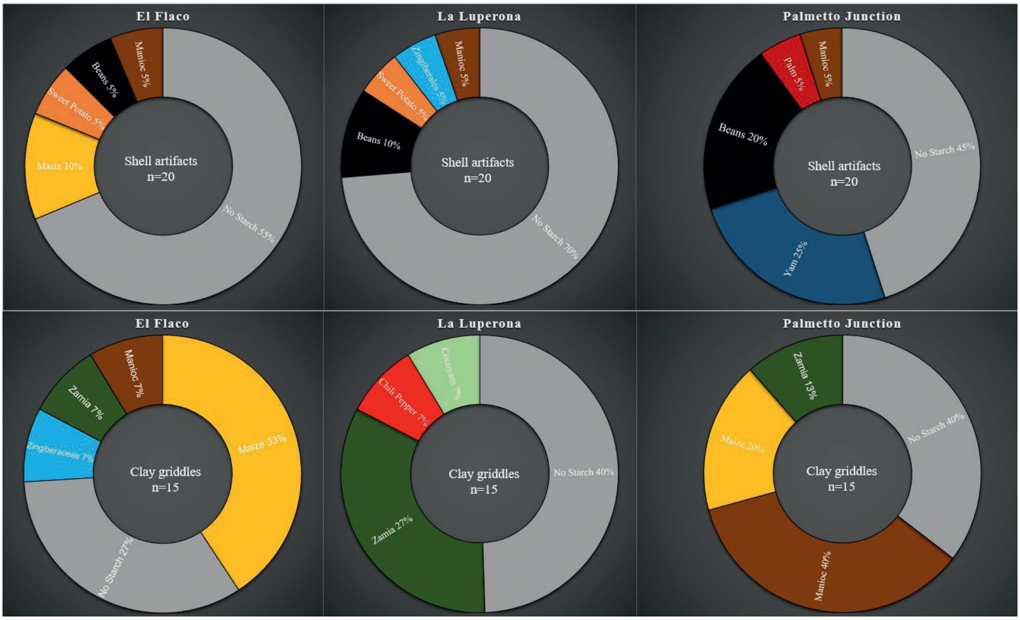

Figure 6.2
Ubiquity analysis for El Flaco, La Luperona, and Palmetto Junction archaeological sites per artifact type.

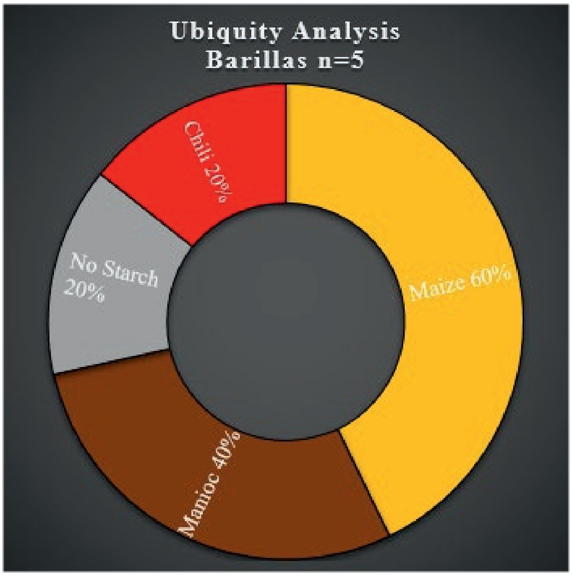

Figure 6.3
Visualized ubiquity analysis for the Barillas site, Nicaragua.

6.3 Regional views of botanical culinary practices

The plant remains found on both shells and griddles in this dissertation include maize, manioc ginger (Zingiberales), and zamia. Because these plant remains were recovered from multiple stages in the food production process, they were likely incorporated within successful culinary practices that were a part of mobility and exchange. These factors combined could suggest the cultural importance of these plants to the people who transported and consistently used them. This type of ubiquity where the plant remains are recovered from multiple artifacts and multiple islands could suggest a scenario of botanical cultural staples.

The use of wild (or semi-managed) plants, including various geophytes, and domesticated seed plants were consistently identified from each sites sampled artifact assemblage. The crops that had to be cultivated by humans and were exogenous to the Greater Antilles and the Bahama archipelago further support intense commitment to production, processing, and likely exchange by the Indigenous Peoples at these sites. Consequently, the evidence of these plants used at the sites in the northern Caribbean suggests they were a part of transported landscapes from other areas brought to these islands. During the late precolonial period, there was a dynamic engagement with poisonous plants, wild vegetation, and cultivated plants at each site studied here in the Greater Caribbean. In addition, the sampled artifacts demonstrate the plants were processed using an assortment of kitchenware, some were used with hot and humid cooking environments, and others processed plants heated in dry cooking environments (Table 6.1).

Table 6.1
Summarized findings of dissertation with interpreted culinary practices per plant type on kitchenware

		Archaeological site				
		LN-101	**El Flaco**	**La Luperona**	**Palmetto Junction**	**Barillas**
Plant types identified	**zamia**	microlith	clay griddle-	clay griddle+	clay griddle	
	manioc	shell- microlith+	shell clay griddle-	shell	shell clay griddle-+	clay griddle- clay *olla*
	sweet potato		shell	shell-		
	yam				shell-+	
	cocoyam					
	beans		shell-	shell+	shell-	
	palm				shell	
	chili pepper			clay griddle+		clay griddle
	maize	shell- microlith	shell- clay griddle-+		clay griddle-+	clay griddle-+ clay plate
	Zingiberales		clay griddle	shell		

Interpreted culinary practice -= Humid heat damage += Dry heat damage

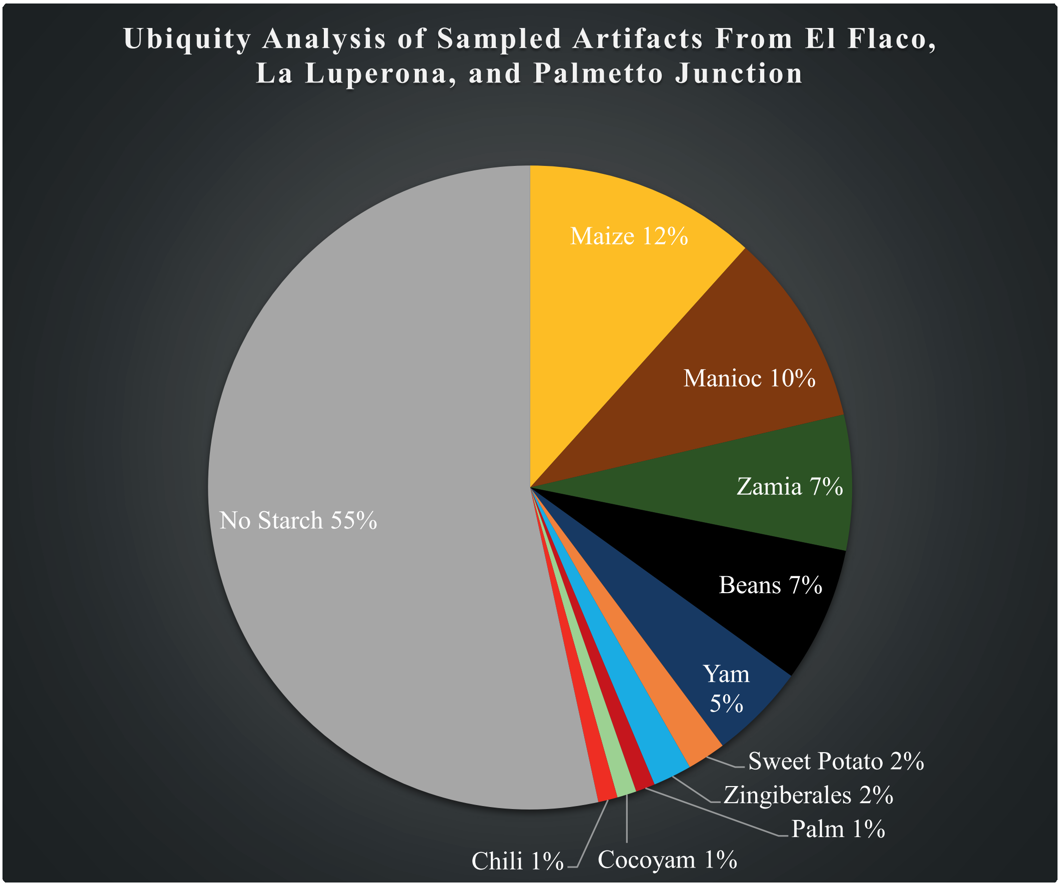

Figure 6.4
Visualized ubiquity analysis for three of the investigated northern Caribbean sites.

Culinary practices have the power to completely change the taste of food. Specific tastes delineate dishes, meals, cuisines, and sometimes group identities. Cuisines may be conservative, in terms of the consistency and limited variation of plant types. This conservatism could be based upon cultural memories of past meals created with specific culinary practices, available technologies, imbedded bodily gestures, or certain ingredients. When ingredients are used consistently, they may eventually become a reminder of personal or group identity. Repetitively adding combinations of ingredients associated with specific culinary practices creates regional cuisines that were constructed around specific core tastes. For example, flavors from three of the northern Caribbean sites in this study incorporated tastes from zamia and manioc, as well as sweet potato, beans, and maize (Table 6.1 and Figure 6.4). However, sweet potato was not recovered from the sites located in the Bahama archipelago, which may be due to sample size, preservation, or alternatively, the sites in the Bahama archipelago could have had different culinary practices and prepared sweet potato with different types of kitchenware. This proposition is probable because sweet potato was recovered from other types of clay vessels at Palmetto Junction (Ciofalo and Graves 2018). Likewise, maize remains were not recovered from the sampled La Luperona artifacts, which does not mean maize was not prepared at this site, but it was absent due to different culinary practices. Finally, because maize, manioc, zamia, and Zingiberales remains were recovered from both shell artifacts and clay griddles it is possible these types of plants contributed towards regional culinary identities.

From a microbotanical view, Indigenous Peoples of the northern Caribbean had access to and used a diverse breadth of plants. The picture of culinary practices is becoming more robust and more diverse particularly with the identifications of Zingiberaceae at El Flaco, Zingiberales at La Luperona, and several types of yam as well as an exogenous palm at Palmetto Junction. Palmetto Junction and LN-101 both had remains of zamia recovered and identified, which is novel evidence for the Bahama archipelago. The meals created with these plant ingredients were possibly imbedded in the cultural memories of Indigenous Peoples. However, the foodways including exogenous plants at the case study sites from the insular Caribbean were likely translocated from other areas of the Greater Caribbean. In fact there is evidence for similar methods of preparing some of the same plants in Panama (Dickau et al. 2007; Piperno 2009), Nicaragua (Ciofalo et al. 2020a), French Guiana (Pagán-Jiménez 2012), and Venezuela (Perry 2002a; Perry 2005). These findings contribute more evidence for the deliberate use of plants in the Greater Caribbean and the discovery of culinary practices at the case study sites.

6.4 Reconsidering late precolonial botanical foodways

Because of the nature of archaeology, we must always rely on incomplete data sets and snapshots of precolonial lifeways. As archaeobotanists push forward, there are revealing pictures of human-plant interactions for nutritional sustainment. However, more than caloric needs and simple dietary reconstructions, a foodways approach for archaeological investigations helps expose social lives and enables discussions of economies, politics, as well as symbolic features of meals (Dietler 1996; Dietler 2007; Hastorf 2016; Pagán-Jiménez 2013).

The findings of this dissertation contribute towards a growing database of identified starchy plants, their quotidian and possible uses on special occasions of the past. Because there was a focus on the ~500 years prior to the advent of European invasions, an enhanced comprehension of time-space systematics as they relate to Greater Caribbean culinary practices during this period has been proposed. In the case studies, we incorporated discussions including interpretations of cultural niches, related human-plant adaptation strategies, and transported landscapes based upon the inferred culinary practices.

Perhaps the findings that are due primary attention include limestone microliths processed poisonous plants, which included the first certain identification of manioc in The Bahamas (Ciofalo et al. 2018). Clay griddles from El Flaco, La Luperona, and Palmetto Junction were multipurpose, which included the first evidence of manioc (cassava bread) being prepared on clay griddles in the insular Caribbean (Ciofalo et al. 2019). Shell artifacts from these three sites were used to prepare manioc but not zamia (Ciofalo et al. 2020b). However, zamia was prepared with a shell at the LN-101 site (Ciofalo et al. 2018). With the first attempt at analyzing starchy residues from clay Griddles in Nicaragua we can state they and other types of clay vessels from the Barillas site were multipurpose and used in diverse culinary practices.

6.5 Summary and implications of primary outcomes

The culinary practices in the Greater Caribbean incorporated plants, which nurtured, supported, and enabled people to function during their daily lives and on special occasions. Not all types of plants that were processed with shells were cooked on clay vessels, which mean there was likely a host of other kitchenware that culinary practices entangled. Culinary practices at the LN-101 site had a limited use of clay vessels. Preparing food without clay vessels is a practice that has continued from pre-ceramic times in the Greater Caribbean (Boomert 2019; Pagán-Jiménez et al. 2015; Sturtevant 1969). Similarly, the Barillas site has suggested that intensively processed botanical meals were prepared without the use of shells, which was probably due to the distance of the site from the coast and access to other raw materials for kitchen tools. LN-101, El Flaco, La Luperona, and Palmetto Junction incorporated both exogenous domesticates and endogenous wild or semi-managed plants into their culinary repertoires.

Humans are not just the sum of their genetic traits but rather integrated wholes into the groups and areas they live within, containing suites of practices interacting with their environments (Earle and Christenson 1980; Smith 2015). Some patterns recognized from the insular Caribbean case studies were consistent with transporting exogenous plants into new environments and proceeding to produce meals from those plants possibly for multiple generations. The variations of culinary practices inferred through this dissertation presumably relate to the level of resolution, but the data appears to suggest varied preferences and culinary practices delimiting yam and beans, at least from these sampled griddles (Ciofalo et al. 2019). Which is why it is essential to sample more than one type of artifact. The sampling strategy enabled the diversity of plants used and variations of culturally constructed niches to be revealed.

Sampling shell, lithic, and clay artifacts and analyzing them for starch content effectively supported the established utility of this method for providing novel insights into precolonial culinary practices and associated foodways (Berman and Pearsall 2008; Pagán-Jiménez 2007a; Pagán-Jiménez et al. 2015; Perry 2004; Piperno and Holst 1998). More specifically, the application of this approach to artifacts recovered in association with earth ovens, a previously unreported feature in The Bahamas and clay griddles, a previously unreported artifact type in central Nicaragua produced results that suggested patterns of intensive food processing activities at sites in the Greater Caribbean. Advantages of starch analysis include its ability to produce direct evidence of human-plant interactions as well as the ability to recover botanical remains from plant species that do not produce pollen and/or have few phytoliths.

The demonstration of starch preservation and recovery from limestone artifacts, underscores the implicit argument that such artifacts are worthy of more detailed investigations because they may reveal patterns of resource procurement. This was likely a local adaptation to the absence of high quality lithic materials in addition to possibly unique botanical culinary practices of the Bahama archipelago. The identifications of maize recovered from several types of artifacts throughout the case studies contribute additional lines of evidence supporting other recent studies (Chinique de Armas et al. 2015; Corteletti et al. 2015; Morell-Hart et al. 2019; Pagán-Jiménez et al. 2015), which suggests many precolonial households had access to maize in the Greater Caribbean.

Each case study produced evidence for physical changes of starches represented by damage caused from particular scenarios of culinary practices. These findings combined with the presence of earth ovens in The Bahamas and clay griddles in central Nicaragua offer views of culinary practices that were previously unknown at those sites (Ciofalo et al. 2020a; Ciofalo et al. 2018). Overall, this contributes to richer understandings of Greater Caribbean foodways by moving beyond early European writings, which distort the relative importance of certain staple crops over others and clearly failed to capture the diversity of plants and culinary practices used amongst precolonial communities in these areas. Reconstructions of Caribbean foodways have been pushed beyond relying upon ethnographic analogies and ethnohistorical written sources (Laffoon et al. 2016; Mickleburgh et al. 2019; Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007a; Pagán-Jiménez et al. 2005; Pagán-Jiménez et al. 2015). This must continue to be the way forward because there are lost, forgotten, or changed culinary practices for which an archaeobotanical approach to their reconstructions provides substantial insights based upon empirical evidence (Pagán-Jiménez et al. 2016; Pearsall 2018; Piperno 1998a).

The starchy shell residue analyses reported direct evidence for a diversity of plants processed with bivalve shell artifacts from four archaeological sites in the Caribbean (Ciofalo et al. 2018; Ciofalo et al. 2020b). The main points of those case studies included: 1) bivalve shell artifacts in the Caribbean were previously assumed to have been used almost exclusively to process manioc, while the results demonstrated many starchy plants were processed; 2) use-wear (wear trace) and lack of use-wear on shell artifacts are not always reliable indicators of plant processing, and therefore an interdisciplinary approaches should be used; 3) worldwide, shell artifacts should receive more attention from residue analysts seeking to investigate ancient foodways (Ciofalo et al. 2020b).

6.6 Limitations

A primary concern for archaeobotanical investigations is always organic preservation, especially in the tropics (Babot 1996). For example, preservation conditions may inhibit the recovery of macrobotanical remains and the recovery of plant microfossils—pollen, phytoliths, or starch—from sediments, cooking vessels, or other kitchenware artifacts. In conjunction with the issue of preservation is the general lack of reports on failed microbotanical recoveries (Hernandez 2015). Because of the limited amount of reported failures, the causes of failures have not been properly assessed. Additional studies that report success and failure to recover starch associated with starch preservation, extraction methods, including artifact contexts are needed to increase comprehension of ideal starch recovery parameters. The inability to recover starch remains could be a true representation that the artifact never contacted starchy plant matter (evidence of absence), or possibly an indication that during artifact use and post depositional processes microfossils were removed or destroyed (absence of evidence). Furthermore, other plants without diagnostic microbotanical remains, with few starches produced, such as squash (*Cucurbita* spp.), pineapple (*Ananas comosus* L.), fruit trees in the sapodilla family (Sapotaceae) (Newsom and Wing 2004), could be undetected but still have been a part of foodways. In addition, there was an absence of use-wear analysis in this dissertation, which has the possibility to complement and bolster results related to the lithic and shell artifacts (Barton et al. 1998; Breukel 2019; Lammers-Keijsers 2007; Walker 1980).

For some scholars, a reason for caution with starch analysis is that starch taphonomy is not well understood (Barton and Matthews 2006; Barton and Torrence 2015; Delwen 2006; Henry et al. 2011; Louderback et al. 2015). However, archaeologists are teaming up with chemists, soil scientists, and cell toxicologists to improve our understanding of post depositional factors affecting starch taphonomy (Barton 2009; Barton and Matthews 2006; Hutschenreuther et al. 2017; Zavareze and Dias 2011). There are many taphonomic issues that starch researchers must approach and question. To address these issues a combination of proxies from other research fields, including soil chemistry, chemical biology, food science, and ancient starch research should be consulted. An issue with artifact deposition and starch recovery is that so many factors play a role in taphonomic preservation, such as the type or combination of plants processed with the artifact (Hutschenreuther et al. 2017), microcontexts of artifact deposition, soil moisture fluctuations, soil texture, pH (Haslam 2004), bacteria, fungal, and enzyme varied environments (Barton 2009). It is impossible to recreate the specific archaeological contexts for experimental analysis. However, experiments have provided information on which postdepositional processes affect starch recovery, such as excavation, curation, and lab procedures (Henry 2015; Mercader et al. 2018).

Another limitation includes the acknowledgement that extinct plant species may be represented in the archaeobotanical record but not able to be added to the reference collection (Appendix) and thus become unidentified (Newsom 2008). However, the only case study with a statistically significant proportion of unidentified starches (40%) was from Chapter 2- Late precolonial culinary practices: Starch analysis on griddles from the northern Caribbean, thus it is likely this limitation has been marginalized (Ciofalo et al. 2019). The success of starch analyses is greatly influenced by reference collections, excavation procedures, the contexts of recovered artifacts, and methods for starch extraction because they all may affect recovery, identification, and interpretations. Despite admitted limitations, all samples processed for starch analysis have been retained for preservation and future microbotanical, aDNA, or unconceived analyses. An ideal interdisciplinary research design focused on core archaeobotanical questions should include several analytical techniques for recovering data with a robust representation of the botanical spectra includes analyses of macrobotanical, microbotanical (pollen, phytolith, and starch), aDNA, and chemical (Henderson et al. 2007; Mann et al. 2018; Pearsall 2015; Pestle and Laffoon 2018; Piperno and Holst 1998; Santiago-Rodriguez et al. 2013; Ziesemer et al. 2015). This dissertation would have benefitted from further integration into an interdisciplinary research design from the beginning, but due to multiple factors including timing, schedules, and funding it was not possible for each case study to have the same interdisciplinary design.

6.7 Future research

Discussions with colleagues at the Faculty of Archaeology and above all Dr. Jaime Pagán-Jiménez, have led to several concrete ideas on how to advance the field of archaeobotanical investigation. Future research goals include expanding research geographically (global tropical archaeobotany), diachronically (early colonial archaeobotany), and methodologically, by investing more effort into integrating macrobotanical, other microbotanical analyses, and more experimental archaeology. This expansion of research will also help integration into interdisciplinary research projects.

Certain types of artifacts from the Greater Caribbean region, such as flaked lithics, lithic griddles, and coral artifacts have not been extensively sampled and analyzed for starch content. It is these types of artifacts that should be further investigated, which would generate a more robust picture of precolonial foodways in the Greater Caribbean. These future investigations would be particularly suitable in the Bahama archipelago, which is notorious for limited geological resources for tool making and an abundance of coral artifacts recovered from archaeological sites (Keegan 1997 45,55,59). Furthermore, coral artifacts possibly used as abraders are commonly recovered from Ceramic Age archaeological contexts throughout the Caribbean. It would also be insightful to spot sample or divide samples taken from shell artifacts to increase the disciplines comprehension of where starch preserves on shell tools.

The study of archaeobotanical remains recovered from dental calculus persists as a key area for expounding a new research line. Previous studies of starch residues from dental calculus remains were compelling but some of them lacked sophisticated interpretations of cultural practices (Boyadjian et al. 2007; Hardy et al. 2009; Li et al. 2010; Power et al. 2018; Power et al. 2015; Tao et al. 2015), which is certainly possible from more in depth studies, analysis, and experiments to better understand compound processing starch damage patterns (Johnson and Marston 2020; Li et al. 2020; Liu et al. 2015; Mickleburgh and Pagán-Jiménez 2012; Piperno and Dillehay 2008; Valamoti et al. 2008; Wesolowski et al. 2010). It would be ideal to continue along this path of interpretations using a data set generated from human dental calculus remains because starch recovered from dental calculus had a more intimate and thus direct correlation to the persons recovered human remains.

Because foodways is an immense investigation approach containing a plethora of research topics, an overarching project of human-plant interactions would need a multifaceted research design to integrate key analytical techniques. First, identify the human remains with the greatest number of separate dental calculus deposits and sample each tooth for starch and phytolith remains, which has the possibility to effectively determine how representative each tooth's dental calculus was of the assemblage of preserved microbotanical remains. This procedure is novel and vital for advancing microbotanical interpretations. Second, from a statistically significant amount (30%) of burials sample dental calculus for starch, phytolith, as well as dental enamel for analysis of carbon ($\delta^{13}C_{en}$) isotope values, and aDNA remains (Henry et al. 2011; Henry and Pipemo 2008; Mickleburgh et al. 2019; Modi et al. 2020; Nieves-Colón et al. 2015; Power et al. 2018; Roberts et al. 2018). These sampling and analysis strategies are reflexive enough to be effectively applied to multiple regions and periods with archaeologically recovered human remains.

Through other archaeological, paleoethnobotanical, and ecological techniques evidence of past anthropogenic environmental modifications can be recovered. Sediment cores should be targeted both within and outside settlement areas to generate temporal resolution of multi-proxy analyses. The cores may be sampled and analyzed for phytolith, pollen, and macrofossil remains as well as possibly aDNA (Crowther et al. 2018; Faegri et al. 1989; Gugerli et al. 2013; Piperno et al. 2009; Watson et al. 2013). The results can reveal human-plant management activities in various degrees, such as intentional dispersal of agroeconomic taxa, intentional vegetative environmental destruction, and other anthropogenic effects on their environments (Castilla-Beltrán et al. 2018; Hooghiemstra et al. 2018; Siegel et al. 2015). Phytolith analysis of these cores can also determine the types of vegetation that existed before human arrival (McMichael et al. 2012; Pearsall 2002). The ability of these integrated research methodologies enables comprehension of cultural and natural botanical landscape modifications (Bush et al. 1989; McMichael et al. 2015; Pagán-Jiménez et al. 2020; Parducci et al. 2015; Pearsall et al. 2016). Archaeological data should be compared with contemporary anthropological data from the study regions, which can provide a more complete picture regarding how landscapes were and are managed by ancient and modern societies (Jean 2019). Finally, conceptions concerning what extent anthropogenic modifications changed ecologies may be created. The datasets from these analyses and subsequent interpretations will improve research methodologies, create a more refined understanding of ancient lifeways, and provide inferences regarding human-plant interactions.

6.8 Final remarks

This dissertation has painted a dynamically diverse picture of Indigenous Caribbean Peoples' culinary practices. The results provided significant insights into culturally constructed niches of the case study areas that involved clay vessels, limestone artifacts, and bivalve shells. There were discussions of human-plant adaptation strategies that involved exogenous plant translocations. Each chapter helped demonstrate that culinary practices from these case study sites incorporated poisonous and non-poisonous plant manipulation to produce edible meals.

6.8.1 Proposed phytocultural organization

A combined phytocultural system can be proposed for the case study sites that had recovered remains of manioc, sweet potato, beans, chili peppers, yams, and maize. At some time, these plants were transported to the Greater Antilles and the Bahama archipelago for:

1) The development of house gardens "*conucos*", which produced maize, beans, possibly together with manioc and other fruity or spicy plants such as chili pepper. It was these gardens where experimentation and cultural acceptance of exotic plants conceivably occurred they were integrated as significant culinary sources (Boivin et al. 2012).

2) The use of open plots for the production of maize and manioc, which are efficient in sunny areas.

3) Tropical dry forest management for the procurement or management of zamia and yam.

4) In addition, the use of clay vessels, limestone tools, and shell kitchen tools for the production of a diverse array of plant-based meals. Interpretations also offer further explanations regarding how cultural niches were constructed i.e. how and which plants were prepared with the kitchen technology to reproduce successful culinary practices that offered modes of stability in dynamic environments.

Earlier preconceptions viewed microliths as associated with manioc processing in the Greater Caribbean (DeBoer 1975; Lathrap 1970; Roosevelt 1980:235), clay griddles as exclusively entangled with the production of manioc flatbread in the insular Caribbean (DeBoer 1975; Rouse 1992; Wilson 2007), and clay griddles as exclusive producers of maize *tortillas* in Nicaragua (McCafferty 2011). Yet, these supposed "manioc-only" artifacts have consistently had multiple plants identified from their microbotanical remains, but usually an absence of manioc starch residue (Berman and Pearsall 2008; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2013; Perry 2002a; Perry 2005; Rodríguez Suárez and Pagán-Jiménez 2008). However, during this research, manioc starch grains were recovered from eight out of 47 sampled griddles. Regarding clay griddles from the Greater Caribbean region, the new total is now 13 out of 82 that were used to process manioc (Bel et al. 2013; Ciofalo et al. 2020a; Ciofalo et al. 2019; Hellemons 2018; McKey et al. 2010; Pagán-Jiménez in Oliver 2014; Pagán-Jiménez in Ulloa Hung 2014:115,138; Pagán-Jiménez 2008; Pagán-Jiménez 2009; Pagán-Jiménez 2011a; Pagán-Jiménez 2011b; Pagán-Jiménez 2012; Rodríguez Suárez and Pagán-Jiménez 2008). The survey from this dissertation also identified manioc from four shell artifacts that brings the total to four out of 63 shell artifacts sampled, analyzed, and reported for starch content from the insular Caribbean (Ciofalo et al. 2018; Ciofalo et al. 2020b; Pagán-Jiménez 2007b). While previous assumptions considered manioc a staple cultigen (Rouse 1992:12, 84, 133; Wilson 2007:83, 109, 160), starch investigations could not support this idea and instead demonstrated broad-spectrum plant use in the Greater Caribbean (Mickleburgh and Pagán-Jiménez 2012; Pagán-Jiménez 2007a; Pagán-Jiménez et al. 2015; Perry 2005). We must remember that starch analysis helps us interpret "cultural" staple plants (i.e. plants preferred, targeted, or used ubiquitously) regardless of their presumed dietary contributions.

The remains of plant complexes recovered from the case study sites in the northern Caribbean suggest vibrant culinary practices were carried out for centuries emanating from human-plant interactions that likely originated in other areas of the Greater Caribbean (Isendahl 2011; McKey et al. 2010; Oliver 2001; Pagán-Jiménez in Oliver 2014; Pagán-Jiménez et al. 2015; Piperno 1998b). The recovered starch remains from Nicaragua also evince that a diverse plant complex and dynamic culinary practices were used that involved at least clay griddles, *ollas*, and plates to prepare plants in both humid and dry cooking environments. This study has invalidated the preconception that griddles were tools used exclusively for the production of maize *tortillas* in pre-Hispanic Central America, thereby nuancing culinary practices in this region (Ciofalo et al. 2020a).

The information generated from these case studies argues for a continued comprehensive application of starch research, particularly in research areas with limited organic preservation. The identified remains of a diversity of cultigens that were exogenous to the case study areas was generally consistent with previous findings and interpretations of transported landscapes, signifying access, procurement, management, and other culinary practices that involved plants which were transported to the case study areas (Berman and Pearsall 2008; Dickau 1999; Pagán-Jiménez 2013; Pagán-Jiménez et al. 2019; Rodríguez Ramos et al. 2013). Diverse starchy meals were prepared at the five case study sites. The more sites investigated and artifacts analyzed, the greater the possibilities are for revealing evidence of diverse and dynamic culinary practices. These culinary practices were rooted in the deep history of the Greater Caribbean (Dickau 2005;

Pagán-Jiménez et al. 2015; Pearsall 2006; Perry 2002b; Piperno and Holst 1998). This dissertation has enriched our understandings of Indigenous Caribbean Peoples' foodways during the late precolonial period by contributing to the discoveries of culinary practices at these sites, which helped illustrate a picture of phytocultural complexes that were framed by elements of culinary identities. Hopefully, it was conveyed how identifying culinary practices has the potential to reveal one of the most vital junctures ever produced by a cultural niche — the humanization and literal devouring of the botanical landscape. This discussion does not include the final words on surveying starchy foodways in the Greater Caribbean, research will continue. However, the reconstructed starchy culinary practices may be reflected upon, celebrated, and enjoyed.

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Appendix

Table A1.
Plants and organs of interest included in the starch reference collection

Family	Genus	species	Common name	Sampled section	Place of collection	Collectors name
Acanthaceae	*Ruellia*	*tuberosa* L.	Minnieroot	Tuberous roots	San Juan, Puerto Rico	Pagán-Jiménez
Alismataceae	*Echinodorus*	*berteroi* Spreng. Fassett	Upright burhead	Rhizomes	San Juan, Puerto Rico	Pagán-Jiménez
Alismataceae	*Sagittaria*	*latifolia* Willd.	Broadleaf arrowhead	Rhizomes	Toa Baja, Puerto Rico	Pagán-Jiménez
Amaranthaceae	*Amaranthus*	*cruentus* L.	Amaranth	Seeds, C011	Native Seeds search, Tucson, Arizona	Ciofalo
Araceae	*Xanthosoma*	*undipes* K. Koch	Cocoyam	Corm	Aibonito, Puerto Rico	Pagán-Jiménez
Araceae	*Xanthosoma*	*sagittifolium* L. Schott.	Cocoyam	Corm	San Juan, Puerto Rico	Pagán-Jiménez
Araceae	*Xanthosoma*	*sagittifolium* L. Schott.	Cocoyam	Corm, briefly fermented	San Juan, Puerto Rico	Pagán-Jiménez
Arecaceae	*Acrocomia*	*media* O.F. Cook	Corozo palm	Mature stem, pith	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Acrocomia*	*media* O.F. Cook	Corozo palm	Young stem, pith	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Acrocomia*	*media* O.F. Cook	Corozo palm	Pith from newer, upper section of stem	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Acrocomia*	*media* O.F. Cook	Corozo Palm	Pulp from fresh mesocarp	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Acrocomia*	*media* O.F. Cook	Corozo Palm	Heart of palm	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Aiphanes*	*acanthophylla* Mart. Burret, Notizbl.	Coyor Palm	Pulp from white endosperm	San Juan, Puerto Rico	Pagán-Jiménez
Arecaceae	*Aiphanes*	*acanthophylla* Mart. Burret, Notizbl.	Coyor Palm	Pulp from fresh mesocarp	San Juan, Puerto Rico	Pagán-Jiménez
Arecaceae	*Elaeis*	*oleifera* Kunth Cortés	American oil palm	Pulp from endosperm	Aibonito, Puerto Rico	Pagán-Jiménez
Arecaceae	*Prestoea*	*acuminata* var. montana Graham	Sierra palm	Pulp from fresh mesocarp	Cayey, Puerto Rico	Pagán-Jiménez
Asparagaceae	*Agave*	*sisalana* Perrine	Sisal	Leaf section close to heart	Wild, Providenciales, Turks & Caicos Islands	Ciofalo
Basellaceae	*Anredera*	*vesicaria* Lam.	Texas madeiravine	Tuberous roots	Culebra, Puerto Rico	Pagán-Jiménez
Bixaceae	*Bixa*	*orellana* L.	Achiote/annatto	Seeds	Market, Tubac, Arizona	Ciofalo
Bixaceae	*Bixa*	orellana L.	Achiote/annatto	Seeds	San Juan, Puerto Rico	Pagán-Jiménez

Family	Genus	species	Common name	Sampled section	Place of collection	Collectors name
Cactaceae	*Opuntia*	sp.	Prickly pear	Cladode	Wild, Providenciales, Turks & Caicos Islands	Ciofalo
Cannaceae	*Canna*	*glauca* L.	Maraca amarilla	Rhizomes	Vega Baja, Puerto Rico	Pagán-Jiménez
Cannaceae	*Canna*	*indica* L.	Achira	Green seeds	San Juan, Puerto Rico	Pagán-Jiménez
Cannaceae	*Canna*	*indica* L.	Achira	Dry seeds	San Juan, Puerto Rico	Pagán-Jiménez
Cannaceae	*Canna*	*jaegeriana* Urb.	Wild achira	Rhizomes	Adjuntas, Puerto Rico	Pagán-Jiménez
Convolvulaceae	*Ipomoea*	*batatas* L.	Orange Sweet potato	Tuber	San Juan, Puerto Rico	Pagán-Jiménez
Convolvulaceae	*Ipomoea*	*batatas* L.	White Sweet potato	Tuber	San Juan, Puerto Rico	Pagán-Jiménez
Convolvulaceae	*Operculina*	*turpethum* var. ventricosa Bertero Staples & D.F. Austin	St. Thomas lidpod	Seeds	Netherlands national herbarium, K.M.N°: 2083-224-1905, St. Eustatius	Ciofalo
Cyperceae	*Cyperus*	*odoratus* L.	Fragrant flatsedge	Corm	Aibonito, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*alata* L.	Water yam	Tuber	Lares, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*altissima* Lam.	Dunguey	Tuber	Luquillo, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*bulbifera* L.	Air potato	Tuber	Luquillo, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*cayennensis* Lam.	Yellow yam	Tuber	Barranquitas, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*pilosiuscula* Bertero ex Spreng.	Bulbous yam	Tuber	St. Thomas	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*polygonoides* Humb. & Bonpl. ex Willd.	Lesser spearwort	Tuber	Luquillo, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	sp.	NA	Tuber	Patillas, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Dioscorea*	*trifida* L.f.	Yam	Tuber	IGA supermarket, Providenciales, Turks & Caicos Islands, produced on a farm in northern Haiti	Ciofalo
Dioscoreaceae	*Dioscorea*	*trifida* L.f.	Yam	Tuber	San Juan, Puerto Rico	Pagán-Jiménez
Dioscoreaceae	*Rajania*	*cordata* L.	Himber	Tuber	Arecibo, Puerto Rico	Pagán-Jiménez
Euphorbiaceae	*Manihot*	esculenta Crantz	Manioc	Tuber	Street market in	Ciofalo

Family	**Genus**	**species**	**Common name**	**Sampled section**	**Place of collection**	**Collectors name**
					Providenciales, Turks & Caicos Islands, produced on a farm in North Caicos	
Euphorbiaceae	*Manihot*	*esculenta* Crantz	Manioc	Tuber	Lares, Puerto Rico	Pagán-Jiménez
Fabaceae	*Anadenanthera*	*peregrina* L. Spreg	Cojoba	Dry seed, slightly parched	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Anadenanthera*	*peregrina* L. Spreg	Cojoba	Green seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Caesalpinia*	*bonduc* L. Roxb.	Gray nickerbean	Seeds	Anse a la gourde, Martinique	Ciofalo
Fabaceae	*Caesalpinia*	*bonduc* L. Roxb.	Gray nickerbean	Seeds	Culebra, Puerto Rico	Pagán-Jiménez
Fabaceae	*Canavalia*	*ensiformis* (L.) DC.	Jack bean	Seeds, PJ001	Native Seeds search, Tucson, Arizona	Ciofalo
Fabaceae	*Canavalia*	ensiformis (L.) DC.	Jack bean	Seed	Aibonito, Puerto Rico	Pagán-Jiménez
Fabaceae	*Canavalia*	*gladiata* Jacq. DC.	Sword jackbean	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Canavalia*	*nitida* Cav. Piper	Bahama baybean	Dry seeds	Le Gosier, Guadeloupe	Ciofalo
Fabaceae	*Canavalia*	*rosea* Sw. DC.	Bay pod	Dry seeds	Anse a la gourde, Martinique	Ciofalo
Fabaceae	*Canavalia*	rosea Sw. DC.	Bay pod	Dry seeds	Loiza, Puerto Rico	Pagán-Jiménez
Fabaceae	*Ceratonia*	*siliqua* L.	Carob	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Galactia*	*striata* Jacq. Urb.	Florida hammock milkpea	Green seeds	Aibonito, Puerto Rico	Pagán-Jiménez
Fabaceae	*Galactia*	*striata* Jacq. Urb.	Florida hammock milkpea	Dry seeds	Aibonito, Puerto Rico	Pagán-Jiménez
Fabaceae	*Lens*	*culinaris* Medik.	Lentil	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Macroptilium*	*lathyroides* L. Urb.	Wild bushbean	Green seeds	Aibonito, Puerto Rico	Pagán-Jiménez
Fabaceae	*Macroptilium*	*lathyroides* L. Urb.	Wild bushbean	Dry seeds	Aibonito, Puerto Rico	Pagán-Jiménez
Fabaceae	*Mucuna*	*sloanei* Fawc. & Rendle	Horse eye bean	Seeds	Culebra, Puerto Rico	Pagán-Jiménez
Fabaceae	*Phaseolus*	*lunatus* L.	Butter bean	Seeds, PL010	Native Seeds search, Tucson, Arizona	Ciofalo
Fabaceae	*Phaseolus*	lunatus L.	Butter bean	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Phaseolus*	sp.	Unidentified	Seeds	Aibonito, Puerto Rico	Pagán-Jiménez

Family	Genus	species	Common name	Sampled section	Place of collection	Collectors name
Fabaceae	*Phaseolus*	*vulgaris* L.	Pinto bean	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Phaseolus*	*vulgaris* L.	Black bean	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Phaseolus*	*vulgaris* L.	Red bean	Seeds	Market, Providenciales, Turks & Caicos Islands, farmed in northern Haiti	Ciofalo
Fabaceae	*Phaseolus*	vulgaris L.	Red bean	Seeds	San Juan, Puerto Rico	Pagán-Jiménez
Fabaceae	*Pithecellobium*	*unguis-cati* (L.) Benth	Catclaw	Seeds	St. Maarten	Pagán-Jiménez
Heliconiaceae	*Heliconia*	*caribaea* Lam.	Wild plantain	Rhizomes	Luquillo, Puerto Rico	Pagán-Jiménez
Hypoxidaceae	*Hypoxis*	*decumbens* L.	Star-grass	Corm	Aibonito, Puerto Rico	Pagán-Jiménez
Hypoxidaceae	*Hypoxis*	*decumbens* L.	Star-grass	Corm	San Juan, Puerto Rico	Pagán-Jiménez
Marantaceae	*Calathea*	*lutea* Aubl. E.Mey. ex Schult.	Pampano	Rhizome	Luquillo, Puerto Rico	Pagán-Jiménez
Marantaceae	*Calathea*	*rufibarba* Fenzl.	Velvet calathea	Tuber	Aibonito, Puerto Rico	Pagán-Jiménez
Marantaceae	*Maranta*	*arundinace* L.	Arrowroot	Tuber	Lares, Puerto Rico	Pagán-Jiménez
Marantaceae	*Maranta*	*arundinace* L.	Arrowroot	Rhizome	Lares, Puerto Rico	Pagán-Jiménez
Marattiaceae	*Danaea*	*nodosa* L. Sm.	Nodeless danafern	Rhizomes	Luquillo, Puerto Rico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: cateto	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: chandele/Cuba	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: chandele/Venezuela	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: costeno	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: cotretz/coastal tropical flint	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: dzit bacal	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez

Family	Genus	species	Common name	Sampled section	Place of collection	Collectors name
Poaceae	*Zea*	*mays* L.	Maize/corn race: dzitba	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: early Caribbean	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: Guarijio Maiz Amarillo	Kernel, ZT045	Native Seeds search, Tucson, Arizona	Ciofalo
Poaceae	*Zea*	*mays* L.	Maize/corn race: Haitian yellow	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: Navajo Copper	Kernel, ZP098	Native Seeds search, Tucson, Arizona	Ciofalo
Poaceae	*Zea*	*mays* L.	Maize/corn race: negrito de Colombia	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: parviglumis Mexican annual teosinte	Kernel, Z122	Native Seeds search, Tucson, Arizona	Ciofalo
Poaceae	*Zea*	*mays* L.	Maize/corn race: parviglumis	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: pollo	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: Tarahumara Maiz caliente	Kernel, ZT039	Native Seeds search, Tucson, Arizona	Ciofalo
Poaceae	*Zea*	*mays* L.	Maize/corn race: Tarahumara Serape	Kernel, ZT044	Native Seeds search, Tucson, Arizona	Ciofalo
Poaceae	*Zea*	*mays* L.	Maize/corn race: tuson	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Poaceae	*Zea*	*mays* L.	Maize/corn race: tuxpeño	Kernel, ZD083	Native Seeds search, Tucson, Arizona	Ciofalo

Family	**Genus**	**species**	**Common name**	**Sampled section**	**Place of collection**	**Collectors name**
Poaceae	*Zea*	*mays* L.	Maize/corn race: tuxpeño	Kernel	CIMMYT/ El Batán, Texcoco, Mexico	Pagán-Jiménez
Polypodiceae	*Niphidium*	*crassifolium* L. Lellinger	Calaguala	Rhizomatous roots	Luquillo, Puerto Rico	Pagán-Jiménez
Smilacaceae	*Smilax*	*coriacea* Spreng.	Sarsaparilla	Rhizomes	Arecibo, Puerto Rico	Pagán-Jiménez
Solanaceae	*Capsicum*	*annum* L.	Chiltepin	Fruit	Market, Tubac, Arizona	Ciofalo
Solanaceae	*Solanum*	*tuberosum* L. Sp. Pl.	"Finger" potato	Tuber	San Juan, Puerto Rico	Pagán-Jiménez
Zamiaceae	*Zamia*	*floridana* A.DC.	Coontie/guáyiga	Fertilized seeds	San Juan, Puerto Rico	Pagán-Jiménez
Zamiaceae	*Zamia*	*integrifolia* L.f. ex Aiton	Coontie/guáyiga	Tuberous stem	Orlando, Florida	Pagán-Jiménez
Zamiaceae	*Zamia*	*lucayana* Britton	Coontie/guáyiga	Tuberous stem	Montgomery Botanical Center Coral Gables, Florida/ original plant from Long Island, The Bahamas	Ciofalo
Zamiaceae	*Zamia*	*pumila* L.	Coontie/ guáyiga	Tuberous stem	San Juan, Puerto Rico	Pagán-Jiménez
Zingiberaceae	*Renealmia*	*alpinia* (Rottb.)	Garden ginger	Rhizomes	Toa Baja, Puerto Rico	Pagán-Jiménez

*The letters and numbers following the sampled section for samples from Native Seeds search can be explored for further information on their website https://www.nativeseeds.org/

Summary

The foodways approach to archaeobotanical investigation is used in this dissertation for reconstructing lost or forgotten lifeways. Food is a social lubricant that deeply engages with identity. As such, understanding culinary practices contributes towards inferring elements of group identity. The deep history of the Greater Caribbean is rich with culinary practices. Through different forms of plant management, the foundations for diverse and distinct culinary practices were created that the Europeans started to exploit in 1492 and afterwards spread across the world. In this research, microbotanical residues (starches) were recovered from different types of presumed plant-related artifacts excavated in three geographic regions: the northwestern Dominican Republic, the Bahama archipelago, and central Nicaragua. Four case studies from five archaeological sites were examined. The first case study is a residue analysis of shell and limestone artifacts from the archaeological site LN-101 (cal. 1088 ± 68 CE) on Long Island, Commonwealth of The Bahamas. This case study contributes the first examination of limestone tools and the first certain identification of manioc (cassava) in the Bahama archipelago. The second case study is a starch analysis of shell artifact samples from three archaeological sites: El Flaco (cal. 1309 ± 81 CE) and La Luperona (cal. 1352 ± 60 CE) in the northwestern Dominican Republic, and Palmetto Junction (cal. 1391 ± 41 CE) on Providenciales, Turks & Caicos Islands. This case study provides additional evidence for the use of exogenous plants in the northern Caribbean and recognizes culinary practices according to which certain plants were pre-cooked before being processed further using bivalve shells. In the third case study, the recovered material remains derived from the same sites, but the artifacts represent fired clay griddles. This case study provides the first evidence of manioc being prepared on such griddles in the insular Caribbean. The fourth case study expands the scope of this dissertation to mainland Nicaragua. From unique finds of pottery griddle fragments at The Barillas site (cal. 1261 ± 37 CE) in central Nicaragua, it challenges preconceived views of ancient foodways in the region. These results invalidate the preconception that griddles were tools used exclusively for the production of maize *tortillas* in pre-Hispanic Central America, which helps explicate associations drawn between ethnic identities and culinary practices. Overall, this dissertation creates a more refined insight into how starchy culinary practices varied in the Greater Caribbean prior to the advent of European invasions.

Nederlandse Samenvatting

De culinaire benadering in archeobotanisch onderzoek wordt in dit proefschrift gebruikt om verloren of vergeten bestaanswijzen te reconstrueren. Eten is een sociaal glijmiddel dat sterk verbonden is met identiteit. Daarmee draagt het begrijpen van culinaire praktijken bij aan ons begrip van groepsidentiteit. De geschiedenis van de mens in het Caraïbisch gebied is rijk aan etenswijzen. Door middel van verschillende vormen van plantmanagement werd het fundament voor diverse en onderscheidende culinaire praktijken gelegd die de Europeanen, en later de rest van de wereld, vanaf 1492 uitgebreid hebben benut. In dit onderzoek zijn microbotanische resten (zetmeel) gebruikt, verkregen van verschillende soorten verondersteld plant-gerelateerde artefacten die werden opgegraven in drie geografische regio's: het noordwesten van de Dominicaanse Republiek, de Bahama-archipel en centraal Nicaragua. Vier casestudy's van vijf archeologische sites werden uitgevoerd. De eerste casestudy betreft een residu-analyse van artefacten van schelp en kalksteen van de archeologische vindplaats LN-101 (cal. 1088 ± 68 n.Chr.) op Long Island in de Bahama's. Deze casestudy vormt het eerste onderzoek van kalkstenen werktuigen in de Bahama-archipel en de eerste zekere identificatie van maniok in deze groep eilanden. De tweede casestudy is een analyse van zetmeelmonsters genomen van schelpen artefacten van drie archeologische vindplaatsen: El Flaco (cal. 1309 ± 81 n.Chr.) en La Luperona (cal. 1352 ± 60 n.Chr.) in het noordwesten van de Dominicaanse Republiek, en Palmetto Junction (cal. 1391 ± 41 n.Chr.) op Providenciales, Turks- en Caicoseilanden. Deze casestudy levert aanvullend bewijs voor het gebruik van exogene planten in de noordelijke Caraïben en herkent culinaire praktijken waarbij tweekleppige schelpen werden gebruikt voor het bewerken van bepaalde planten die mogelijk voorgekookt waren voordat ze verder werden verwerkt. In de derde casestudy kwam het verkregen materiaal van dezelfde vindplaatsen, maar de artefacten zijn aardewerken bakplaten. Deze casestudy levert het eerste bewijs dat maniok (cassavebrood) op deze ceramische bakplaten in het Caraïbisch gebied werd bereid. De vierde casestudy breidt de reikwijdte van dit proefschrift uit naar het vasteland van Nicaragua. Uit unieke vondsten van fragmenten van aardewerken bakplaten opgegraven in The Barillas (cal. 1261 ± 37 n.Chr.) in centraal Nicaragua, wordt een oud vooropgesteld idee over de culinaire praktijken in de regio betwist. Een en ander ontkracht de theorie dat bakplaten uitsluitend gebruikt werden voor de productie van maïstortilla's in prekoloniaal Midden-Amerika, waardoor de hier bestaande simplistische associatie tussen etnische identiteit en culinaire traditie kan worden genuanceerd. In het algemeen creëert dit proefschrift een meer verfijnd

inzicht in hoe zetmeelrijke culinaire praktijken varieerden in het gebied rond de Caraïbische Zee voorafgaand aan Europese invasies.

Curriculum vitae

Andrew Joseph Ciofalo was born on the 14th of July, 1984 in Colorado Springs, Colorado, United States of America. From 2003 to 2007, he attended the University of Massachusetts, Amherst campus and graduated with a Bachelor's degree in Business management and a minor in Anthropology. He then began graduate studies in 2009 at the University of Central Florida with a focus on Maya archaeology. During 2011, he participated in and helped lead his first Caribbean archaeological field schools in The Bahamas. Upon receiving his master's degree in 2012, he could not stay away from his love of teaching anthropology and Caribbean archaeology. This motivated him to begin college lecturing in Valhalla, New York. He moved to New Jersey in 2014 and kept lecturing at local colleges and participating in Caribbean archaeology now in the Turks & Caicos Islands. After reaching out to Prof. dr. Corinne Hofman, he wrote a proposal for a PhD dissertation focused on archaeobotany. Prof. dr. Corinne Hofman invited him to participate in her archaeological work on Martinique in 2015. This introduction to Leiden archaeology solidified his decision to enroll as a self-funded PhD at Leiden University. His dissertation Starchy Foodways, sought to enrich our understandings of Indigenous Caribbean Peoples' starchy food histories, valorize their heritage, and reconstruct parts of their botanical culinary practices. This dissertation was co-supervised by Prof. dr. Corinne Hofman and Dr. Jaime Pagán-Jiménez. The four years of research culminated in four articles published in peer reviewed international journals and six conference presentations. During his PhD, he was a teacher's assistant as part of Bachelors' and Masters' Seminars and he was requested to provide several guest lectures at Leiden University. During 2019, Andy was hired by the NEXUS1492 project.

Starchy Foodways

The foodways approach to archaeobotanical investigation is used in this dissertation for reconstructing lost and forgotten lifeways. The deep history of the Greater Caribbean is rich with culinary practices, which is explored through microbotanical residues (starches). They were recovered from different types of kitchen-related artifacts excavated in three geographic regions: the northwestern Dominican Republic, the Bahama archipelago, and central Nicaragua.

The first case study focused on shell and limestone artifacts from the archaeological site LN-101 (cal. 1088 ± 68 CE) on Long Island, Commonwealth of The Bahamas. This case study contributes the first examination of limestone tools and the first certain identification of manioc (cassava) in the Bahama archipelago.

The second case study focused on shell artifact samples from three archaeological sites: El Flaco (cal. 1309 ± 81 CE) and La Luperona (cal. 1352 ± 60 CE) in the northwestern Dominican Republic, and Palmetto Junction (cal. 1391 ± 41 CE) on Providenciales, Turks & Caicos Islands. This case study provides additional evidence for the use of exogenous plants in the northern Caribbean and recognizes culinary practices according to which certain plants were pre-cooked before being processed further using bivalve shells.

In the third case study, the recovered material remains derived from the same sites, but the artifacts represent fired clay griddles. This case study provides the first evidence of manioc being prepared on such griddles in the insular Caribbean. In addition, these griddles were used to prepare maize, chili pepper, cocoyam, and Zamia (guáyiga/coontie). This diversity of prepared plants was expected, but the discovery and amount of manioc was remarkable.

The fourth case study expands the scope of this dissertation to mainland Nicaragua. From unique finds of pottery griddle fragments at The Barillas site (cal. 1261 ± 37 CE) in central Nicaragua, it challenges preconceived views of ancient foodways in the region. These results invalidate the preconception that griddles were tools used exclusively for the production of maize tortillas in pre-Hispanic Central America, which helps explicate associations drawn between ethnic identities and culinary practices.

This dissertation paints a dynamically diverse picture of Indigenous Caribbean Peoples' culinary practices. The results and discussions of human-plant adaptation strategies involved exogenous plant translocations. Each chapter demonstrates that culinary practices from these case study sites incorporated some poisonous plant manipulation to produce edible meals. Overall, this dissertation creates a more refined insight into how starchy culinary practices varied in the Greater Caribbean prior to the advent of European invasions.