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Climate Change and the Social History of Food in Ancient Egypt: Between Humanities and Life Sciences

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Climate Change and the Social History of Food in Ancient Egypt:

Between Humanities and Life Sciences

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Archaeology

by

Amr Khalaf Hamed Shahat

2021

ABSTRACT OF THE DISSERTATION

Climate Change and the Social History of Food in Ancient Egypt:

Between Humanities and Life Sciences

by

Amr Khalaf Hamed Shahat

Doctor of Philosophy in Archaeology

University of California, Los Angeles, 2020

Professor Willeke Wendrich, Chair

The effect of climate change on food and water sustainability is an alarming issue worldwide. Food remains found in ancient settlements and mortuary contexts as is the case in ancient Egypt not only embody a list of plant taxa that shaped the people's diet and cultural foodways but also encode the social and climatic history of Egypt and the Nile River, which is relevant to current issues relating to the anthropogenic impact of climate change and the impact of the damming of rivers on social structure and food and water supply. Food is more than a biological need that sustains our body; it is an active agent in the creation of social structure, economy, personal identity, and cross-cultural relationships. Contextualized analysis of food remains from the archaeological record has served

as a powerful lens for archaeologists, anthropologists, and social historians to understand social relations, cultural interactions, and the engendered experiences of individuals in the past. The archaeological record from ancient Egypt has yielded an exceptionally rich array of organic food remains. Indeed, it was the study of botanical materials from Egypt that spearheaded the field of archaeobotany and allowed Willard Libby to invent carbon dating, using seeds from Djeser's pyramid housed in the Field Museum of Natural History in Chicago, eventually winning him the Nobel Prize for his contribution in archaeology, geology and other branches of science. In this dissertation, I continue this interdisciplinary cross-link between life sciences and the humanities by proposing interdisciplinary analyses to study ancient foodways, and ultimately demonstrate the various ways in which ancient botanical remains can expand our knowledge of ancient Egyptian society in terms of social structure, temporal and regional cultural variation, cross-regional interactions, and cultural relationships, especially in non-elite contexts. The interpretations of the results are carried out within the theoretical frameworks of postcolonial and indigenous archaeologies to transcend, and push the field of Egyptology beyond colonial and oriental origins.

Scientific analysis including stable isotope biogeochemistry and ecology applications on well-dated plant-food remains from the archaeological record serve as a scientific tool to record changes in climate, soil fertility, water cycle, and environmental conditions and how they are influenced by different water and agricultural management systems, providing invaluable deep-time data on the anthropogenic impact of climate change on social structure and foodways. First, I present the analysis of unpublished and reanalyzed botanical remains excavated by Reisner and Lythgoe in the early 1900s at the sites of Nag ed-Deir and Deir el-Ballas that are now housed at the Phoebe Hearst Museum at the University of California, Berkeley. This study presents the results of archaeobotanical and molecular isotopic analyses on plant remains from these sites. A nanoarchaeological method was also developed as a non-destructive way to identify the ingredients of a beer mash, which was found to have rich fiber content in addition to residue of wild fruits, used as a natural sweetener. This finding is a region-specific recipe, which demonstrates that there was regional cultural variation in ancient Egyptian cuisine, and a difference in nutritional values of food between the past and present foodways in the Egyptian society. This research also presents the result of a long stable isotope experiment, building a baseline for the Nile River, and introduces a new isotopic method using non-exchangeable oxygen isotopes in fruits to identify the source region of plant-food remains, and the environmental and water conditions in which they grew. Such an approach enables us to reconstruct the elements of a social history of food, regional identities, and cross-cultural interactions, ultimately challenging the simplistic assumption that the ancient Egyptian diet was homogenous and predominantly composed of “bread and beer made of wheat and barley” (Samuel 1997:579). This is also the first stable isotopic study on archaeobotanical remains from Egypt corroborated with AMS carbon dating. This new combination of methods opens a new direction of research into the history of cultural interactions, providing critical implications for historians, bioarchaeologists, hydrologists, and climate change scientists. This research demonstrates that the analysis of plant food remains through interdisciplinary theories and methods not only contributes to social sciences but is also significant in capturing the environmental history of climatic changes in the past and of important relevance to life sciences as well. Contextualized comparison of these changes by contrasting ancient and modern plant species biodiversity and their isotopic composition can be a significant contribution to the next generation of scientists interested in reversing the impact of climate change on social structure and food and water sustainability.

The dissertation of Amr Shahat is approved by.

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2021

Dedication

I dedicate this dissertation to the soul of my mother and for the health of my father. I also dedicate this work for the future and health of rivers on our planet.

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Acknowledgments

I owe all gratitude to my father, siblings, supporting friends, professors, and colleagues who supported me during my doctoral journey at UCLA. Special dedication to the soul of my mother who hoped to see me in UCLA before she passed away. I extend my appreciation to my honorary mother in California for the support and care, and to my friends who held me during the difficult times of Covid-19.

I express my sincere acknowledgment to my supervisor, Prof. Willeke Wendrich, for her extraordinary support and mentorship of this dissertation. I would also like to express special thanks and gratitude to my mentors and my dissertation committee members Prof. Kara Cooney, Prof. Lothar Von Falkenhausen and Prof. Aradhna Tripati at UCLA. Special thanks to Prof. Christine Hastorf for hosting me as a visiting researcher at her lab at the University of California Berkeley and whose critical review of different stages of the paleoethnobotanical and isotopic analyses has been of great contribution to my scientific training and academic research. My sincere thanks and acknowledgement to my colleague Dr. Victoria Jensen, who co-authored the Deir el Ballas materials and provided insightful information on the archaeological contexts of each tomb, and ceramic data.

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- Teaching ANNEA 103 B Ancient Egyptian Civilization sections, Winter quarter 2018.
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- Instructor of record for world civilization courses, University of Memphis Tennessee, Fall 2014 and Spring 2015.

Archaeology Field Experience:

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- Paleoethnobotany and paleodietary analysis from teeth and hair remains for diet and health reconstruction of the population buried in the Theban Tomb of Panehsy**.** (Seasons 2016; 2017–2018; winter 2019).
- UCLA Fayum excavation project, University of California field seasons (2012; and 2017, summer 2018).
- Member of the American–Canadian archaeological mission, at the Karnak Hypostyle Hall project in Luxor, Egypt summer 2013 and winter 2014 and 2015.
- Italian Archaeological Mission at the Tomb of Harwa at Assasif, Luxor, Egypt Fall 2012.

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- Best Paper Award, 3rd place, at the 72nd Annual Meeting of the American Research Center in Egypt "Social History of Food in Ancient Egypt: Between Humanities and Life Sciences."
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- 1st place, Best Poster Award for poster presentation entitled "Social Archaeology of Food in Ancient Egypt: Paleoethnobotanical and Nano-archaeological Methods," Presented at the 69th annual meeting of the American Research Center in Egypt (Tucson, AZ, April 20–22, 2018).

Recent Publications:

- Shahat, Amr, and Victoria Jensen, 2021, Biomolecular Stable Isotope and ^{14}C Dates of Ancient Egyptian Food Offerings: A Case Study from a Provincial Cemetery of Deir el-Ballas, in S. Ikram, J. Kaiser, and S. Porcier (eds.), *The Ancient Egyptians and the Natural World. Flora, Fauna and Science*. Leiden, Sidestone Press.
- Shahat, Amr, 2021. Social History of Food in Ancient Egypt: Case Studies from Nag ed-Deir and Deir el-Ballas, in Kara Cooney, Nadia Ben Marzouk, and Danielle Candelora (eds.), *(Re)constructing Ancient Egyptian Society: Challenging Assumptions, Exploring Approaches.* London: Routledge.
- Shahat, A. and V. Jensen, in press. Social Archaeology of Food at Deir el-Ballas: An Archaeobotanical Study of the Non-Elite Cemetery Food Offerings, in M. El Dorry, (ed.) *Feeding a Civilisation: Food and Drink in Egypt and Sudan.* Cairo: Bibliothèque d'Étude. Cairo
- Shahat, Amr, Social History of Cultural Interaction from Non-Elite Context: Paleoethnobotanical and Isotopic Evidence, presented at Egypt and the Mediterranean World, From the Late Fourth through the Third Millennium BCE, May 27, 2021, Sydney Session, hosted by Center for Ancient Cultural Heritage and Environment, Macquarie University, Australia.

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CHAPTER 1

1. Introduction

1.1 Motivation

In my research in Egyptian archaeology, I have been motivated by the need to challenge existing paradigms in Egyptology. Ancient Egyptian cultures have been homogenized and interpreted as the culture of the oriental other (Said 1978, Reid 2002, Candelora 2018), limiting the scope of research questions, methods, and the dialogue between Western and native Egyptian epistemologies in Egyptian archaeology. Further, this approach has hidden the variation within the culture, social classes, genders, ages, and the social history of cultural interactions. My research aims to reinstate the social history of food and how it expands our understanding of ancient Egyptian society in terms of social structure, temporal and regional diversity within the cultures, and the dynamics of cultural interactions between Egypt and other cultures, by interdisciplinary analysis of ancient plant-food remains. For this, I am using approaches that cross-link humanities and life sciences to broaden our understanding of the social history of cultural interactions in ancient Egypt, especially from under-researched non-elite contexts. The goal of this research is to expand the research tools in Egyptian archaeology and move the field beyond its colonial and orientalist history by integrating native Egyptian and Western epistemologies, with scientific methods to transcend the colonial history of Egyptology. In this endeavor, my attempt is not to contrast native Egyptian and Western epistemologies but rather to transcend this colonial history by emphasizing data-driven, well-established research undertaken from the lens of equity by both native Egyptian and Western European–American scholars. The datasets provided here are also meant to contribute and advance other sciences by presenting deep-time data on climate change, and its impact on social structure, food, and water sustainability. This topic is of high importance to make archaeology relevant to issues of resilience to climate change, as scientists at the National Aeronautics and Space Administration (NASA) and the United Nation Agency of Food and Agriculture (FAO) have expressed (Montanarella et al. 2015). The goal is also not to leave behind Egyptology as an obsolete and colonially originated field, but to expand its methods and theories consciously and highlight its significance and potentials to contribute to and advance other sciences currently.

1.2 Dissertation topic

Food is more than a biological need that sustains our body. Food is an active agent in the creation of social structure, economy, personal identity, and cross-cultural relationships (Hastorf 2016). Contextualized analyses of food remains from the archaeological record have served as a powerful lens for archaeologists, anthropologists, and social historians to deepen our understanding of social relations, cultural interaction, and engendered experience of individuals in the past. An example of native Egyptian scholarship that combines cultural anthropology theory and social history on cultural diversity in Egypt is the work of Mohamad Amin Abdel-Samad, *al-Tanawwu‘ al-thaqafi fi Misr*, in which the diversity of cultures within Egypt and the cross-cultural relationships between Egypt and other societies are discussed from different lens including the role of food in the culture (Abdel-Samad 2015).His work dovetails with recent archaeological theories and methods that bridge native and Western epistemologies in the interpretation of the archaeobotanical record of food remains, such as Christine Hastorf's book on *The Social Archaeology of Food* (Hastorf 2016) and Katheryn Twiss's discussion on "The Archaeology of Food and Social Diversity" (Twiss 2012).

The preservation of organic food remains from ancient Egypt is one of the most exceptional aspects of the archaeology of the region. Indeed, it was the botanical materials from Predynastic layers at Nag ed-Deir that gave rise to archaeobotany as a science (Kunth 1826, Pearsall 2015:29). The study of plant remains has advanced a range of different sciences after Willard Libby's invention of carbon dating using seeds from Djeser's pyramid housed in the Field Museum of Natural History in Chicago, eventually winning him the Nobel Prize for his contribution in archaeology, geology, and other branches of science (Libby 1970). However, since then little research has been conducted on what the actual study of plant-food remains can reveal about ancient Egyptian society. This is tied to assumptions and overemphasis about the role of grain as a staple in the diet of these people.

In this research, I continue this interdisciplinary cross-link between the life sciences and the humanities by presenting interdisciplinary methods to study ancient foodways, and ultimately demonstrate the various ways in which we can bring social questions to food science. First, I will review the unique data of unpublished food remains excavated by Reisner and Lythgoe from non-elite contexts in the early 1900s at the sites of Nag ed-Deir and Deir el-Ballas, housed at the Phoebe Hearst Museum at the University of California Berkeley, and compare them with elite contexts from the tomb of Kha and Merit housed at the Museo Egizio in Turin, Italy. This study presents the results of interdisciplinary analyses using the paleoethnobotanical, molecular isotopic method on food from these sites. Nano-archaeology technology was also used in a new non-destructive method on a beer mash to reconstruct the composition of early beer ingredients, which mixed barley with wild fruits, making a regionally specific recipe of beer. The result of a long stable isotope experiment by the author introduces a new method to identify the source region of the food. Such an approach enables us to reconstruct the elements of a social history of food, regional identities, and cross-cultural interactions. This is also the first stable isotopic study on paleoethnobotanical remains from Egypt corroborated with AMS carbon dating. This new combination of methods opens a new direction of research into regional identity and the history of cultural interaction between Egypt and other regions of the ancient world.

The application of stable isotope on contextualized and confirmedly dated paleoethnobotanical materials from Egypt provides critical implications for the social history of continuity and changes in Egyptian foodways. This first contextualized stable isotope study on Egyptian food offerings from a humanities and life sciences cross-disciplinary perspective challenges previous simplistic story of the Egyptian diet.

The stable isotope application on paleoethnobotanical materials from Egyptian contexts provides a new and powerful method to identify imported versus local plant-food, with implications on ancient food ecology and cultural interaction history. Paleoethnobotanical remains also capture the Nile River's paleo-environmental record as a water source for this plant-food and the higher soil fertility compared to the present. Thus, this study contributes unique data on Egypt's social history of food, with implications for regional identities and cross-cultural interactions (Shahat and Jensen 2021). It also provides life sciences with deep-time data on the anthropogenic impact of climate changes and the damming along the Nile River on the foodways and the larger social structure through time in Egypt.

1.3 Egyptological assumptions on food in ancient Egypt

When we turn to examine the research on food in ancient Egypt, we are confronted with the fact that the field is still missing an important element, in the limited number of studies of the physical food remains. Egyptological studies interested in food predominantly rely on tomb scenes and economic texts about food rations of bread and beer (Tallet 2015:219–21, Peters-Destéract 2005), eventually making their interpretations focused on domesticated food species such as wheat for bread and barley for beer. Paleoethnobotanical studies in Egypt also focus on the role of a grain-based diet, wheat for bread and barley for beer (Samuel 1997:579), and narrow attention has been given to the diversity of wild and domesticated plant-use and regions and the role they play shaping regional cultural identity, and cross-cultural relations through the introduction of new species as part of the social history of cultural interactions and trade networks. Furthermore, we are missing out on the isotopic analysis of local and imported plant-food remains, which can also enrich our views on the history of trade and cultural interactions between Egypt and other regions, in addition to revealing ecological, climatic, and water availability conditions where these plants grow (Shahat and Jensen in press).

Recent studies in food archaeology integrating approaches from humanities and life sciences (e.g., paleoethnobotany and stable isotopic analysis) have opened up a path for archaeologists to explore how past foodways unravel social history, cultural identity, social status, and the dynamics of cultural interactions between past societies (Hastorf 2016). More contextualized studies of plant food remains are crucial to advancing our knowledge of the social history of food, and how food contributed to the construct of regional identities through the diversity of Egyptian foodways.

This research explores the social meaning of food and the cultural variability within that, by studying plant remains in Egyptian burials, the broader social meaning of food, and food offerings in different regions to highlight the diversity of ancient Egyptian foodways challenging assumptions about uniform Egyptian foodways that overemphasize the role of domesticated grain in the diet.[1] This research includes analyses of unpublished, analyzed archaeobotanical

[1] For publications on the role of domesticated grain in the Egyptian diet see (Samuel, 1997, p. 579)

assemblages excavated by the author or found in museum collections and studied. The research methods and theories aim at interpreting the diversity of the archaeobotanical materials from different regions and contexts. These have been selected to explore groups of different social status, and temporal and regional variation in the culture based on the type of tomb and material culture. The study of food plants from these selected contexts allows a comparison of group identities, regional histories, and cross-cultural interactions, especially in understudied contexts of non-elite and underrepresented groups of women and children. The case studies present diachronic and regional variation by presenting two non-elite cemeteries, one from Nag ed-Deir dated to the Predynastic and one from the 18th dynasty at Deir el-Ballas. To compare the relationship between foodways and social structure in elite versus non-elite tombs, presentation of the archaeobotanical materials from the Tomb of Kha and Merit is discussed and compared with the non-elite cemetery of Deir el-Ballas dated to the same time period, i.e., the 18th dynasty, and from the same region in Upper Egypt.

1.4 Research outline

I will outline my goals in my research questions section. In the method section I will discuss how I have used stable isotope analysis on paleoethnobotanical materials from Egypt to address those questions. In the course of applying this method in my research, I have bracketed the results of the ancient isotopes with research on present-day Nile water in chapter 2. This allows me to contribute to understanding the deep-time history of water and agriculture management systems, but it has also provided information on the impact of dam construction and industrialization on present day agriculture along the Nile. This is the first time this method has been used with archaeobotanical materials from Egypt to investigate how the interdisciplinary analysis of ancient botanical remains might expand our knowledge of the ancient Egyptian social structure, temporal and regional variation, and cross-cultural interactions. It has also allowed me to explore ancient food ecology, i.e., understanding the ecological conditions and water systems under which a plant species grew. This will be followed by case-study articles on paleoethnobotanical materials previously excavated from the sites of Deir el-Ballas but not yet analyzed, from museum collections, particularly from the Hearst Museum of Anthropology at the University of California, Berkeley in Chapter 3. In Chapter 4, I present an in-depth, follow-up study of the plant-food remains from four tombs in a non-elite, early 18th Dynasty cemetery (1-200 at Deir el-Ballas, Upper Egypt). The AMS- carbon-14 dates and ^{13}C stable isotope values on botanical findings from the tombs are related to the material culture assemblages.

The botanical species encountered in the archaeological site of Deir el-Ballas, in Upper Egypt, consists of local and imported plants including juniper berries *Juniperus phoenicea* L. (Curpressaceae family) from Tomb 128, grapes *Vitis vinifera* L. from Tomb 163, domesticated watermelon *Citrullus lanatus* (Thunb.) Matsum. & Nakai from Tomb 244 or 255, and pomegranate *Punica granatum* L. from Tomb 257. This first stable isotopic study on archaeobotanical remains from Egypt has significant implications for the social history of ancient foodways in non-elite contexts, and the bioarchaeology of diet in ancient Egypt.

To compare continuity and changes in foodways in Upper Egypt, results of archaeobotanical analysis of food remains from the Predynastic site of Nag ed-Deir are presented in chapter 5. The chapter also includes carbon dating and stable isotopic values of the paleoethnobotanical materials, revealing different implications for the social history of food and the impact of climatic changes on foodways and social structure. Further implications are addressed in Chapter 8, presenting significant contributions of the results on the ancient social history of food, Egyptian chronology, bioarchaeology of diet, and ancient food ecology. Particularly the question of how the anthropogenic impact of climate change and the construction of dams along the Nile River impact foodways and social structure. The goal of this dissertation is to present important data on the stable isotopes of paleoethnobotanical materials that will help Egyptian archaeologists and life scientists to understand the social history of food and the impact of climate change in altering native foodways and social structure.

1.5 Theoretical background

This doctoral project on climate change and the social history of food in ancient Egypt seeks to implement post-colonial and indigenous archaeological theories to reformulate the paradigm within which our knowledge about ancient Egypt is produced. On the one hand, I will discuss the colonialist and orientalist origins of Egyptology within Near Eastern Archaeology rather than African Archaeology (Said 1978, Davis 2007, Larsen 2005, Reid 2002), and how similar arguments have been made on the archaeology of other African regions such as Ethiopia. For instance, Niall Finneran discusses the archaeology of Ethiopia, criticizing the de-Africanization of the identities of countries in the Nile basin by archaeologists using diffusionist theories (Finneran 2007). Such theories usually look for origins of plant species and subsistence solely in West Asia (in the case of Egypt) or in South Arabia and the Lower Nile (in case of Ethiopia), and barely use indigenous sources, which are neglected by orientalist and colonialist frameworks (Finneran 2007). Similar criticism of the impact of colonial expansion in Africa on knowledge production is presented by Diana Davis: in her study of North African environmental history and French colonialism, she criticized what she called “environmental Orientalism” (Davis 2007). She uses this term to underline the restrictions on indigenous populations’ agency based on environmental determinism or diffusion models. Such models depict colonial encounters as the only catalysts for cross-cultural relationships and the dynamic development of people, as well as the spread of ideas and cultigens.

More recently post-colonial theory, first introduced in Said's work on "Orientalism" (Said, 1978), has been addressed in relation to Egyptology. Bhabha (2012) and Langer (2017) explicitly questioned the orientalist origins of Egyptology. Meanwhile, the goal of this research is not to reiterate the colonial and orientalist root story of the field but rather to present one major ongoing impact and how to transcend it. First, celebrating the *Description de l'Egypte* and the decipherment of hieroglyphs through the study of the Rosetta Stone by French scholars following Bonaparte's expedition in Egypt of 1798 as the beginning of scientific research on ancient Egypt throws a shadow on the plethora of native Egyptian sources and their value and relevance to modern Egyptology. Not only were there Arabic manuscripts written by native Egyptians attempting to decipher hieroglyphs (e.g., Zul Nun al-Masry al-Ikhmimy, whose name indicates that he was an Egyptian from Akhmim) (El Daly 2005), but also other manuscripts that included important topics such as agriculture and water systems (see ibn Mamaty). Even reports of excavations in the cemetery in Giza, hundreds of years before the French expedition were mentioned by Masoudy who was interested in documenting pre-Islamic native history and aspects of continuity and changes of how this history shapes their cultures.[2] More importantly, the current narrative on the roots of Egyptian archaeology, even if it recognizes the impact of colonial history in Egyptology (Reid 2002), still does not see how the celebration of colonially produced work such as the *Description de l'Egypte* as the first scientific treatise on Egypt does not pay attention to the

[2] Masoudy narrated regional interactions between all Egyptians regardless the religion to celebrate the *Ghotas Day*, celebrating the Nile river in Fustat, in addition to hinting on interactions between Egypt, East Africa and the Indian subcontinent.

knowledge about and the value of native Egyptian sources that existed before the French expedition. The *Description de l'Egypte* itself had a precedent in the Egyptian historian al-Maqrizi (1364–1442), who surveyed both the natural and the human geography of Egypt (Cooperson 2013:203). Arabic manuscripts that represent early attempts to decipher hieroglyphs come from both native Egyptians (e.g., Zul Nun al-Masry) but also other Arabic-speaking scholars such as Ibn Wahshya, (died in 930 CE), whose work was translated into English and published in London in 1806, thus before Champollion's decipherment of the Rosetta stone in 1822 (El Daly 2005). Abu Alkasem al Iraqi from Iraq who was married to an Egyptian and lived in Egypt during the Abbasid period correctly deciphered many letters of hieroglyphs as well (El Daly 2005). Further details on this subject are covered in the seminal work of Okasha el Daly, *Egyptology: The Missing Millennium: Ancient Egypt in Medieval Arabic Writings* (El Daly 2005). Of particular relevance to this dissertation, the work done on ancient agriculture and management of the Nile water systems such as As'ad ibn Mamaty (Ibn Mamaty 1943) on the digging of canals and establishing nilometers, and the management of the agriculture cycle, presents valuable ethnohistorical sources that link the past with the recent present, in how the agriculture and water systems were run before the construction of the first dam on the Nile under British colonialism. Ibn Mamaty's work was of valuable help in understanding the flood and the hydrology of the Nile, guiding interpretations of the isotopic values of the Nile River in Chapter 2.

At the same time, in Egypt by the 1950s, Egyptology was practiced from a nationalistic paradigm, emphasizing the unity of ancient and modern Egypt. The emphasis was on narratives that serve modern state construction of identity following the revolution of 1952, depicting the ousting of the Turkish dynasty of Mohamad Ali and the ascendance of President Nasser as a return to pure Egyptian identity (Jankowski 2002). One caveat in this approach is that cross-regional diversity in the culture is not explicitly discussed. An inspiring work that introduces a balanced theoretical critical approach and brings native voices to the topic can be found in the theme of the book *Before the Throne* written by the Nobel literature laureate Naguib Mahfouz (Mahfouz 2012). Challenging this paradigm is as important as criticizing colonialism, in cases where nationalism sometimes claims to fight colonialism by internalizing it and using the very same "colonialist discursive tools" (Dietler 2010:17). The goal of this discussion is to go beyond colonialism and nationalism and contribute with an interdisciplinary case study as an example of the different ways current research can move beyond and transcend this colonial origin myth of Egyptology, and present a new framework of cross-cultural interactions, bringing to light both native Egyptian and Western (European–American) research, and the diverse scholarship done about Egypt from all over the world.

In addition to the post-colonial theory discussed above I will also employ indigenous archaeological theory created by native or indigenous American scholars (Atalay 2008,[3] Atalay 2012, Collwell-Chanthaphonh 2010 to challenge both orientalist and colonialist paradigms, as both converge to one end: homogenizing the representation of past cultures, undermining the agency of indigenous people, and obscuring the temporal and regional variability within all cultures. Both external colonializing groups and the nation-state model sometimes claim that certain groups that are targeted in either displacement or genocides do not belong and are denied rights. For example, dam projects in Egypt, Sudan, and Ethiopia have displaced many indigenous communities, muting their voices and silencing their culture under nationalistic themes. Dam projects were born within the colonialist idea of "Western progress," which maximizes the exploitation of resources of

[3] Sonya Atalay is also interested in reclaiming traditional knowledge and the importance of engaging with indigenous epistemologies, person.com, 2018, "*Branding Strands of Wellbeing: Reclaiming, Healing and Sending Knowledge into the Future*", University of California Berkeley Anthropology Department lecture series.

colonized lands and disdains indigenous means of life (Adas 2015, Lansing 2009). As demonstrated in this research, dams have had a radical impact on altering the Nile water cycle and foodways.

1.5.1 New directions

The integration of post-colonial and indigenous archaeological theories with Western epistemologies and advances in archaeological sciences enables us to expand our data and ontological apparatus to transcend the colonial history of the field.

New directions are to be found in recent research in Egyptian archaeology that integrate different lines of archaeological evidence and theories to retell the story of Egyptian food and agriculture. An example is Holdaway and Wendrich, who criticize the diffusionist approach relating to the origins of agriculture and food production in ancient Egypt during the Neolithic. Their work on *The Desert Fayum Reinvestigated* emphasizes the importance of introducing alternative questions and theoretical frameworks for the social integration of agriculture and subsistence in a way that acknowledges temporal and regional variabilities (Holdaway and Wendrich 2017). In this case study, Holdaway and Wendrich discuss the introduction and development of agriculture and subsistence economy in the Fayum by putting it in the context of North Africa and using Smith's "low-level food producer" model to argue against a linear development of agriculture in Egypt from hunter–gatherer to agriculturalist based on a Neolithic package from the Near East (Holdaway and Wendrich 2017:12). They criticize how Egyptologists discussing such a topic have adhered to old questions generated in the 20th century without being explicit about their theoretical framework. In my dissertation, I build upon this new theoretical approach, and take the issue one step further to argue that not only do Egyptologists need to introduce alternative research questions and theoretical concepts, they also must integrate native Egyptian sources in their interpretational framework with new advances in scientific methods.

For instance, stable isotope analysis of the paleodiet of humans and animals, when done with sound theory in mind, integrating native and Western epistemologies, can lead to new grounds of interpretations of the social history of food. Thompson et. al (2008) published a case-study that challenges Reisner's interpretation of Kerma as an Egyptian colony. Based on isotope evidence they proved that Kerma civilization had grown from indigenous local roots, yet had regular trade and cultural interactions with Egypt. Kerma's population was not homogenous, its diversity including people from the Nile Valley and from southerly latitudes into the African Sahara (Thompson et al. 2008:383–84). Similarly, Arnold et al. (2016) challenged narrowly understood interactions with the Levant through stable isotope analysis of animals buried in Tel es-Safi, in the southern Levant, concluding that these donkeys were Egyptian imports, arguing therefore for bi-directional interactions between Egypt and the Levant during the Egyptian Old Kingdom (Arnold 2016).

Furthermore, outside of Egypt, applications of stable isotopic analysis into archaeological studies interested in the social meanings of food have significantly expanded our theories and methods of exploring how food creates identity, social status, and community relationships (Ambrose 2003, Hastorf 2016). Carbon stable isotope applications in archaeology are the most commonly used to differentiate between C3 (e.g., wheat and barley) and C4 plants (e.g., sorghum, millet, and maize), a distinction based on how these plants process carbon dioxide from the air during the photosynthetic cycle, and how these plant types (i.e., C3 or C4) are incorporated into human and animal tissues as food.[4] Nitrogen isotope studies are also applied to human remains to evaluate access to protein consumption. An interesting case study outside Egypt comes from the Native American Mississippian site of Cahokia dated to 1050–1150 CE, the most intensive period of urban occupation and reflecting the greatest social complexity, as revealed by the stable isotope analysis on human remains (n=272) (Ambrose 2003). In this study, while nitrogen isotopic values showed that high-status individuals had relatively more meat in their diet, the carbon isotope values reflected how the low-status individuals had a much higher C4 component in their diet, suggesting they were eating more maize (Ambrose 2003). Correlating the stable isotopic results to the pathologies in the bodies revealed that the low-status individuals were mainly young adult females who were apparently sacrificed at the site and interred in mass graves (Ambrose 2003). This example shows the significance of applying molecular methods of stable isotope to reconstruct ancient diet, to bring to light a more textured view about status- and gender-related differences in health and diet among different classes in the society, challenging assumptions in social history and unraveling debated issues about social status.

1.6 Research questions

In this thesis I address four research questions focused on how ancient botanical food remains expand our knowledge about ancient Egyptian society in terms of social structure in the past and present, temporal and regional variation and cross cultural relationships. My research questions address the topic from the lens of "food habitus" by looking at the role of food in the society (see Atalay and Hastorf 2006).

[4] However, interpretations of carbon stable isotope values should take into consideration changes associated with climate change, and the impact of the annual combustion of 10^{15} gallons of fossil fuel, depleted in ^{13}C (Faure and Mensing 2005:754–55).

1- How do climate change and the damming of the Nile River alter foodways and social structure in the present (see Chapter 2)?

2- How does the combination of domesticated and wild plant species in ancient foodways reveal regional cultural identities, especially in non-elite contexts (Chapters 3–5)?

3- How do aspects of continuity and change in foodways reflect cross-cultural interactions, by comparing elite to non-elite cemeteries in the Predynastic and the New Kingdom to elite tomb from the same region of Upper Egypt (Chapters 3–5, compared to chapter 6)?

4- How does the isotopic analysis of plant food remains reveal cross-regional interaction and cultural relationships in elite versus non-elite contexts (Chapters 4 and 5)?

The goal of this project is to emphasize the social agency of food and challenge the notion of Egyptian regional history as a fixed entity. My intent is to investigate the role of inter-regional and cross-cultural interactions as driving the link between different cultural groups and influencing changes in cultural practices.

This choice of food as a proxy to research regional cultural diversity is based on an emic perspective of how ancient Egyptians represented their diversity of regions and aspects of continuity in regional food cultures through the Old Kingdom and New Kingdom times, while changes associated with cross-cultural interactions and how they reshaped this culture are also discussed. In the Old Kingdom tomb scenes in Saqqara, a recurring theme is the so-called *phw*-list, which is a row of women as personified estates carrying the food products of the region to the capital in Memphis, illustrating the importance of food tribute in relation to identity. The emphasis on studying food and how it was stored in different media (e.g., basketry, or ceramics) in various contexts in settlements or in cemeteries is derived from Hastorf's social archaeology of food. As

Hastorf wrote, “society is created and re-created in each storage cycle” (Hastorf 2016:109). This is evident in the ancient Egyptian textual sources, on calendars in which the division of seasons and the naming of the months are centered on the growing, harvesting, and storage cycles of food and in particular wheat and barley (see Murray 2001).

1.7 Research material and methods

To answer my research questions, I integrate interdisciplinary methods to problematize the interpretations of textual sources, and allow their reinterpretation, based on archaeobotanical and stable isotope analyses of food remains. First, I present the results of creating a baseline of oxygen stable isotope of Nile water and the plant species grown with this water, to test if we may differentiate between local and imported species based on water source and variation on ecological conditions (Chapter 2). In Chapters 3, 4, and 5, I present a new dataset from two non-elite cemeteries of the Predynastic Period, at Nag ed-Deir and Deir el-Ballas, dated to the New Kingdom, both located in Upper Egypt (Figure 5). These three chapters include the results of the paleoethnobotanical analysis, radiocarbon dating, and stable isotopic results. In this way, rather than using dynastic periods as a baseline, I examine regional cultural identities by comparing continuity and change in the diet of each region by time period. To compare variation in the food of different social structures, I present an analysis of differences or similarities in foodways between the elite and the non-elite in Chapter 6. In this chapter, I explain the primarily results of the paleoethnobotanical materials from the Tomb of Kha, the overseer of workers at Deir el-Medina, in Luxor Egypt during the New Kingdom, and his wife Merit.

The dataset in Chapter 3 and 4 presents in detail a case study from a non-elite context from the settlement of Deir el-Ballas in Upper Egypt. This chapter presents the results of an archaeobotanical study of food remains found by the Hearst Expedition's excavations (1900–1901) at the site of Deir el-Ballas, Upper Egypt, currently held at the Phoebe A. Hearst Museum of Anthropology (PAHMA), University of California Berkeley. The plant remains were discovered in a non-elite cemetery, Cemetery 1-200, that dates from the late 17th Dynasty to the early 19th Dynasty, with the most usage occurring in the early 18th Dynasty. To contextualize the archaeobotanical remains found in the cemetery, we looked at archival information from the original early 20th-century excavations regarding the burial situations and associated material culture assemblages. Detailed information on 12 tomb contexts that contained food offerings is presented in Chapter 3 to explain the paleoethnobotanical assemblage in relation to the material culture with which it is associated.

Of significant interest in these archaeobotanical results is the presence of local and imported fruits. Example of local fruits are doum (*Hyphaene thebaica* (L.) Mart), date (*Phoenix dactylifera* L.), persea (*Mimusops laurifolia* L.), desert date (*Balanites aegyptiaca* (L.) Delile, 1812), Christ's thorn *(Ziziphus spina-christi* (L.) Willd), sycomore figs (*Ficus sycomorus* L.), which are native to the Theban region and common in the geographical landscape in Upper Egypt (South). Meanwhile, the Deir el-Ballas dataset includes interesting data such as a large number of grapes (*Vitis vinifera* L.), the earliest evidence of some species of historical origin outside Egypt such as pomegranate (*Punica granatum* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), and juniper berries (*Juniperus phoenicea* L.), which will be addressed in detail in Chapter 4. These data also present evidence of use of underground geophytes (tubers and rhyzomes) among the plant offerings. In this case, evidence of tiger nut rhizome (*Cyperus esculentus* L.) is important, as in ethnographic and ecological evidence it is a Lower Egyptian plant that grows in northern Egypt. Chapter 4 explores the meanings of these funerary offerings in a non-elite cemetery of the early

18th Dynasty at Deir el-Ballas and the implications for cultural interactions with other regions within and outside Egypt from a non-elite context during the New Kingdom, as opposed to the elite context from the Tomb of Kha and Merit explored in Chapter 6.

1.7.1 Methods

The methods regarding each dataset begin with the non-destructive, visual analysis of the paleoethnobotanical materials for species identification using a stereo-microscope and a statistical record of the weight and count of each species at the site. Since some of the plant remains were discovered during Reisner's excavations, before the development of dry-sieving or water flotation techniques, it was important to radiocarbon date them, providing stronger contextualization and confirming that they were not intrusive or deposited through bioturbation (Pearsall 2015:35–37).

Paleoethnobotanical visual analysis for species identification to species level and carbon stable isotope analysis on the plant-foods were conducted in two different labs at UC Berkeley and UC Irvine to estimate the ancient food ecology and the climate conditions under which the plant-food grew. This is very useful for archaeologists interested in identifying the provenance of imported versus local food and the environmental conditions in Egypt at the time. For species that are rarely attested before the early 18th Dynasty, such as the pomegranate and domesticated watermelon, Accelerator Mass Spectrometer (AMS) carbon testing was conducted at UC Irvine on the fruit part of the botanical specimen (Table 8 for the New Kingdom Deir el-Ballas botanical materials and Table 10 for the Nag ed-Deir Predynastic materials).

Ethnographic observations conducted by the author interacting with local communities on the uses of plants are also integrated as an important source of interpretation on the uses of plants. This integration of scientific methods with native knowledge not only helps us transcend the colonial beginnings of Egyptology but also enriches its theoretical and methodological framework. In the realm of foodways, these combinations of methods have provided a powerful tool to unpack the social history of food and demonstrate variation and diversity in foodways and regional histories, especially from non-elite contexts lacking textual and iconographic sources. Contextualizing local and imported species with material culture and tomb architecture in both non-elite and elite case studies shifts our understanding of cultural interactions between other regions within or outside Egypt.

While carbon and nitrogen isotope applications in paleoethnobotany have been increasingly used, Chapter 2 presents a background experiment to test the potentials of the less applied oxygen isotope in paleoethnobotany for paleoenvironmental reconstruction and identifying source regions of food remains and the underlying meanings of the associated history of cultural interactions through experimentation on modern reference collections. The results also contribute to paleoecology, plant physiology, and paleoethnobotany in the understudied arid region of East Africa.

1.8 Research contributions

In this interdisciplinary study, methods from humanities and life sciences including paleoethnobotanical data and stable isotope analysis are integrated to open new areas of research on the social history of food in ancient Egypt, especially in non-elite contexts where textual and iconographic materials are scarcely available. Although plant-food remains are often well preserved in Egypt, the close analysis of archaeobotanical data are either overlooked within the structure of archaeological fieldwork or rarely discussed from an Egyptological lens, leading to the misinterpretation that the data are not available. As a consequence, standard statements about the Egyptian diet start with the stereotype that the ancient Egyptians' main staples are wheat for bread and barley for beer, implying a high emphasis on economic plants of domesticated species, ignoring the richer use of plant sources in ancient Egyptian foodways and beverages. A cross-disciplinary perspective, as seen in the case studies below, challenges this simplistic story of the Egyptian diet, demonstrating that the food supply was indeed varied—and not just for the elite sector of society. This new approach contributes significant implications for the social history of ancient foodways in a non-elite context and the regional variation in food culture to advance research on Egyptian foodways from the humanities side.

To contribute to life sciences, stable isotope analysis on ancient botanical remains was used to identify the number of ancient local and imported species, in addition to understanding the climatic conditions and water availability under which these plants grew in the past. Comparing the stable isotope results on ancient and modern plant species grown along the Nile Valley in Egypt highlights the impact of climate change and damming along the river on the social structure of native communities and their cultural heritage. More relevant to the topic of this dissertation are the changes over time of native foodways, and the alteration of the Nile water oxygen isotope cycle and soil fertility due to damming along the river, which presents damaging danger to plant biodiversity and food and water sustainability in Egypt and the Nile basin regions.

CHAPTER 2

2. Methodology: Stable oxygen isotope analysis and its application to plant ecology and paleoethnobotany in ancient Egypt[5]

2.1 Introduction

This project builds a baseline for oxygen and hydrogen stable isotope values in the Egyptian Nile region with the aim to use these values to interpret the growing location of ancient botanical samples (see Chapters 4 and 5). The goal is to differentiate between local and imported plant remains in order to understand plant-food ecology, i.e., the growing conditions of plants cultivated in Egypt along the Nile. The isotopic data from the Nile River region provide a much-needed baseline for interpreting stable isotope values from the region, which in turn benefits advances in life sciences and environmental sciences, and also highlights the impact of dams on the water oxygen isotope composition. In addition, the highly enriched oxygen isotope values of the Nile water and of the non-exchangeable oxygen in seeds and fruits grown in this region indicate the severe impact of climate change and dams along the river nowadays.

The primary purpose of this project was to build a much-needed baseline for Nile water oxygen and hydrogen isotope values for environmental and archaeology applications. The baseline was then applied to test a model to differentiate between local plant-foods grown along the Nile River in Egypt and those of similar species that were imported and grown in other regions with a different water source. This reasoning is based on the assumption that local plants (wheat, doum, and date)

[5] This chapter is accepted as a conference paper in the 12th International Conference on the Applications of Stable Isotope Techniques to Ecological Studies, Gaming, Austria. Conference postponed due to covid-19. Many thanks to my colleague Danielle Perryman, UC Berkeley for her immense help sampling the modern plant materials from Egypt during spring 2019.

obtained their water from the Nile River and thus reflect the $\delta^{18}O$ composition of the Nile. The oxygen isotope values of the fruits, however, are expected to reflect both the source water as well as fractionation between the plant water source and the fruit plant part (Barbour 2007). The offset between the local water source and oxygen isotope values of organic matter was calculated for three modern plants: doum fruits (*Hyphaene thebaica*), dates (*Phoenix dactylifera*), and wheat (*Triticum aestivum*) collected at different sites along the Nile River.

In this study, the results of stable oxygen isotope analysis of fruits are presented and discussed. This includes date fruit pits (n=34) from two sites within Egypt (Luxor and Aswan) that were irrigated with Nile water as well as date pits from Deglet Nur in Tunisia, Medina date pits from Saudi Arabia, and Medjouli date pits from California, USA. The purpose was to see if the water source-tissue offset in $\delta^{18}O$ values was different between plants grown in different regions in Egypt and outside of Egypt for the same species to help predict the source water or at least differentiate between local Egyptian dates and the ones that came as imports based on variation in the ecological conditions under which the plant grew. The method is then applied on ancient plants in chapters 3 and 4. Comparing ancient and modern doum from Luxor for instance suggests increased evaporative conditions associated with climate change and damming of the river.

2.3 Materials and methods

Water samples were collected along the Nile River from Aswan to the Delta as well as Lake Qarun in the Fayum oasis (n=51), representing values that reflect high evaporative conditions. The values are all reported relevant to the international standard VSMOW (Vienna Standard Mean Ocean Water) (see collection sites noted on Figure 2 in the map) (Figure 1). The oxygen isotope composition of the water samples was determined by Isotope Ratio Infrared Spectroscopy (IRIS) in three different labs at the University of California, Berkeley and Simon Fraser University. The data obtained by IRIS were consistent with testing the water samples using the Isotope Ratio Mass Spectrometer technique done at the University of Utah, Salt Lake City.

The Nile water data served as a baseline, which was then used to calculate the offset between oxygen isotope values of the Nile water and the non-exchangeable $\delta^{18}O$ values bonded in the organic matter of the fruits and wheat kernels in modern botanical samples (n=84 total). The oxygen values of the Nile river water and the $\delta^{18}O$ of the carbonyl group bonded in the organic matter of the fruits are all reported relevant to the international standard VSMOW.

The goal was to find if there is a constant offset or consistent differences between local plants (grown with Nile water) and imported plants which would have different oxygen isotope values of other water sources, taking into consideration that the water source would have gone through isotopic enrichment by the plant-leaf and further enrichment in the fruits which formed from the leaf-water. Three species common to the region of study in Deir el-Ballas and commonly found in ancient Egyptian archaeobotanical assemblages were studied. Dates (*Phoenix dactylifera*) (n=34), doum fruits (*Hyphaene thebaica*), and wheat (*Triticum aestivum*) kernels and fruit parts of the plants (total n=84 duplicates) were sampled from different regions along the Nile to measure the non-exchangeable $\delta^{18}O$ stable isotope value in fruit organic matter.

In this study, I present the oxygen isotope values of Nile River surface waters and the measurement of the non-exchangeable oxygen in organic matters of fruits and seeds collected from the same sampling sites. As a background study, (n=51) Nile water samples were collected in acid free vials in duplicates along gradients of elevation and humidity from Upper Egypt and the Nile Delta in the north of Egypt. The analysis of $\delta^{18}O$ and deuterium isotope in water was measured using a L2140-*i* (Picarro Inc.) analyzer (UC Berkeley). The Nile water showed extremely high

$\delta^{18}O$ and δD values in Egypt compared to Sudan and source regions in Ethiopia. The average $\delta^{18}O_{vsmow}$ values = +2.45 ± 0.27 ‰ and the average δD values = 23.7 ± 1.78 ‰. These values are higher than values presented in a previous study by Nada (2013:137), who collected samples in the 1990s and reported the impact of dams on increasing the evaporative conditions of the Nile water. Closer results to this research come from unpublished materials by Thure Cerling (Cerling 2008, pers. comm. Isotope camp 2018) and Buzon and Bowen who reported $\delta^{18}O$ values of +2.3‰ from Cairo (Buzon and Bowen 2010). However, the Nile water did not vary significantly along the different sites, as the variation was within 1 to 2‰.

Wheat, doum, and date fruit pits were dried in an oven at 70°C for two days. After drying, the samples were ground and homogenized using a bead beater for the wheat and a low speed Dremel for the date pits to avoid heating the sample. As for the doum fruits, they were sawn to make a cross-section and then sub-sampled into four different portions reflecting different fruit tissues using the Dremel tool. After homogenizing the sample into powder, they were weighed into 0.35 milligram samples to measure the non-exchangeable oxygen in the organic matter of fruit and grain tissues. It is important to note that the measurement of $\delta^{18}O$ values is very sensitive to weight error. The samples were packed into silver capsules and analyzed using an Elemental PYRO Cube interfaced to a Thermo Delta V mass spectrometer at UC Berkeley. For statistical analysis, normality was assessed using skewness and kurtosis values.

2.4 Results

2.4.1 Nile water

Modern water samples were collected in the summer of 2018, during the summer flood season. To test for seasonal variation in the winter, samples were collected on January 21, 2019, a date known in ancient Egyptian and native Egyptian Arabic manuscripts as the "Ghotas day," the day reported to have the coldest water throughout the year (Shahat, unpublished translation of Masoudi, Muruj al-dhahab manuscript). The average $\delta^{18}O$ value of Nile water is $\delta^{18}O$ = +3.01‰, except for the Fayum, where $\delta^{18}O$ values are $^{18}0$ of +8 ‰. The seasonal difference shows slightly depleted values with average $\delta^{18}O$ values of +2 ± 0.4 ‰, compared to the flood season in August, in which the average $\delta^{18}O$ values can be as high as 4 ‰ (Figure 1). The only difference is the high evaporative conditions reflected in Lake Qarun, which is fed from the Nile through Bahr Yusuf, having $\delta^{18}O$ value of +8 to 9‰. This high evaporative condition of the Nile River in contrast to the values inferred from ancient Egyptian tooth enamel indicates that the modern high evaporative conditions and alteration in the oxygen isotopic ratio of the Egyptian Nile Valley are most likely as an impact of increased dams along the river.

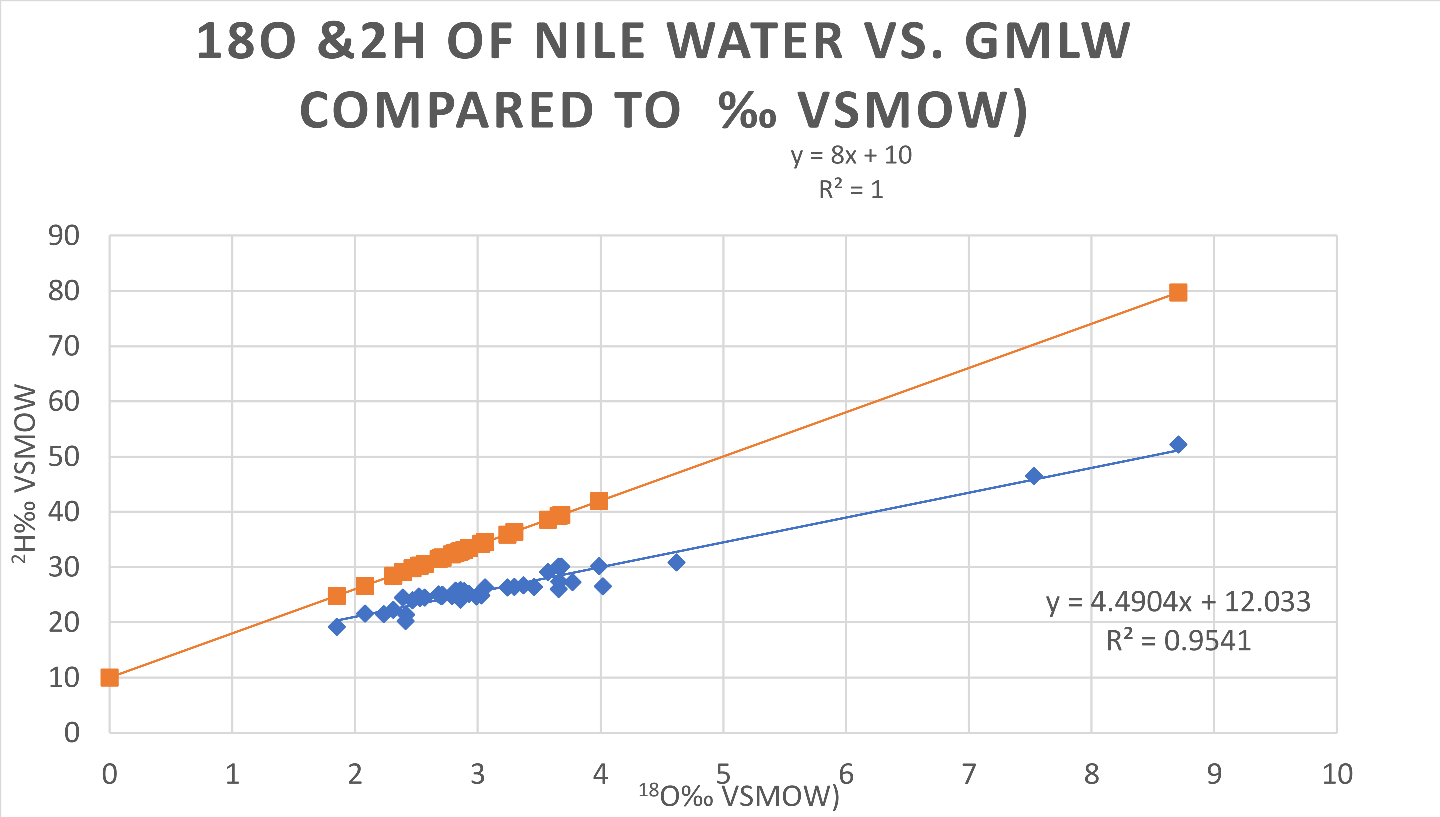


Figure 1. Modern Nile water $\delta^{18}O$ and $\delta^{2}H$ isotope values.

Modern Nile water stable oxygen ($\delta^{18}O$, x axis) and deuterium ($\delta^{2}H$, Y axis) stable isotopic values from Aswan to the Delta (n=54 in blue) reported relative to GMWL (Global Meteroic Water Line in orange). All values reported according to VSMO standard.

2.4.2 Date pits *Phoenix dactylifera*

The date pits from Egypt were collected from four different sites. Three of the sites were different areas of the region of Aswan, the southernmost region of Egypt, and the fourth site was 40 km north, in Luxor. Total sample size was n=34 including duplicates from the two regions. The results show an offset of $\delta^{18}O$ values between 41 to 47 ‰ between the fruits and the source water.

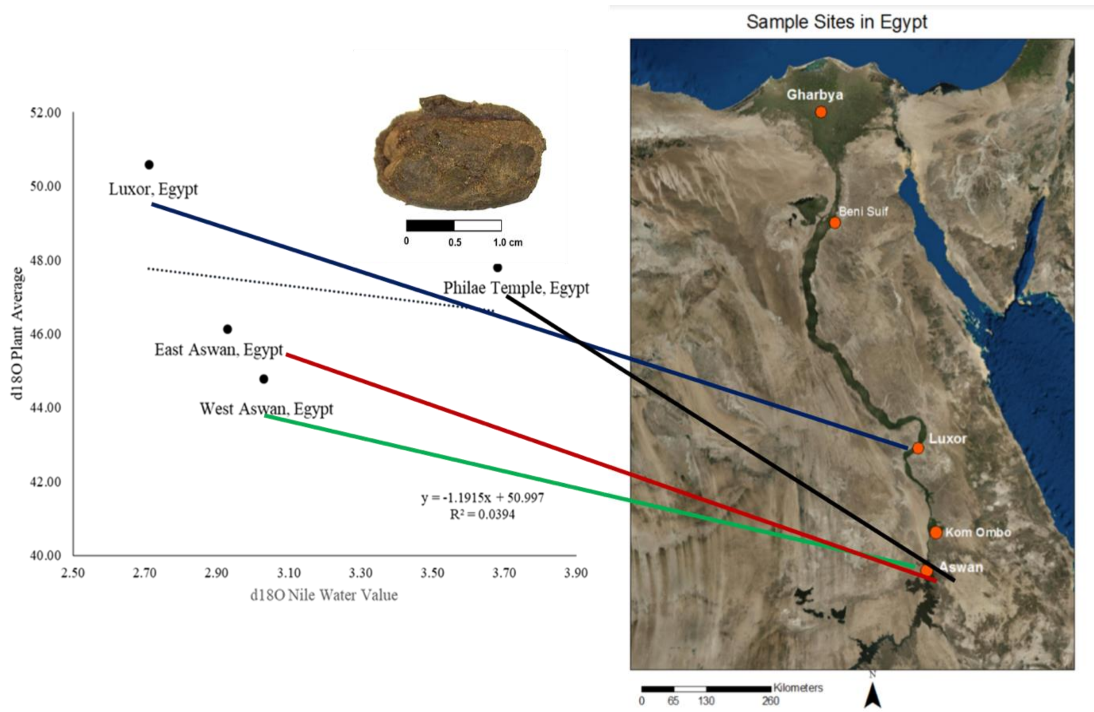


Figure 2. Date fruit pit δ^{18}O values of plant samples recovered from the study locations.

The dotted lines indicate increased evaporative enrichment conditions and hence higher δ^{18}O values moving downstream from Aswan to Luxor.

The dates from Luxor show the highest evaporative enrichment values (+50.58‰) despite having water value less enriched than Aswan (+44.77 ‰), relative to the source water δ^{18}O value of 3.03‰ (Figure 2). The relationship between source water and oxygen in organic matter is not direct. As noticed by Barbour (2007), water in leaves is enriched by around 20 to 25‰ compared to source water and then further evapotranspiration enrichment happens as fruit uses this enriched leaf water to form organic tissues of the fruit (Barbour 2007). The evapotranspiration enrichment may therefore be dependent on eco-physiological variation and temperature, in addition to the source water. As we see in figure 1, the R^2 is very low, which means there is no linear relationship between evapotranspiration enrichment in the fruit and the source water. Statistical single factor analysis on the dates from the four sites analyzed did not reveal any significant statistical difference for dates grown along the Nile in Egypt ($F_{3,7}$ = 1.84, *p = 0.228), species offset = 44.23‰*) see table 1.

Statistical SUMMARY:				
Groups	*Count*	*Sum*	*Average*	*Variance*
West Aswan, Egypt	3	134.30	44.76	0.43
Philae Temple, Egypt	3	143.36	47.78	4.65
East Aswan, Egypt	3	138.39	46.13	10.51
Luxor, Egypt	2	101.16	50.58	25.50

ANOVA single factor for date fruit pit:

ANOVA single factor						
Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between groups	44.74	3	14.91369	1.840644	0.227795	4.346831
Within groups	56.71	7	8.102431			
Total	101.45	10				

Table 1. Statistical summary of date pits samples

To test this local growth model against other dates that were imported, $\delta^{18}O$ of dates from Medina in Saudi Arabia were measured which had a value of +42.27‰ which seems a high evapotranspiration enrichment value, but still slightly lower than the results from date samples from Aswan, Egypt. Comparisons were also made to samples of dates from Deglet Nur, Tunisia, which were irrigated with oasis spring water $\delta^{18}O$ of source water unknown to the author) and dates from California, both of which seemed significantly different than the ones from the Nile Valley, with values of +38.07‰ for the Deglet Nur and 33.82‰ for the California date pits. However, since the offset between the oxygen in the water source and in plant organic matter is not linear, it is not possible to predict the $\delta^{18}O$ values of the dates from California and Tunisia.

Meanwhile based on the statistical difference, it can be concluded that these dates have grown in ecological conditions and using a water source different from the Egyptian Nile River region.

2.4.3 Wheat: ***Triticum aestivum***

Ancient Egyptian texts often differentiated between wheat from the north of Egypt (which is more humid) and wheat from the more arid southern region of Egypt. Ethnographic fieldwork conducted by the author revealed differences in the color and size of the grains. In the north, the grains are lighter and thicker, and this is associated with higher cultural and economic values assigned to this crop in the local cuisine. Southern grains are darker in color and thinner, and concomitantly assigned a lower culinary value. To account for this difference, samples of wheat irrigated with the same water source (Egyptian Nile water) were compared (n=12 samples). Wheat seeds (*Triticum aestivum*) were collected from two different sites within Egypt (Figure 3). The average $\delta^{18}O$ in four samples of wheat coming from Beni Suef (south) is +37.30 with a little variance of 0.65. The site of Gharbiya in northern Egypt (more humid), n=6 duplicate samples, had an average $\delta^{18}O$ value of 36.205‰ with a variance of 1.48, while the average of $\delta^{18}O$ of the non-exchangeable oxygen in the wheat from Beni Suef in the south was $\delta^{18}O$ 37.30 ‰. The p-value of both sites is 0.11718, which means there is no significant variation between the two sites (Table 2). There is no observed statistical difference in the two wheat types in terms of the non-exchangeable oxygen in the carbonyl group of the grain kernels ($F_{1,14} = 2.79$, $p = 0.117$). *Species offset = 34.91‰* (Figure 3 and Table 2).

Statistical Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Beni Suef, Egypt	4	149.2333	37.30832	0.65166
Delta region	12	434.4669	36.20558	1.487729

ANOVA single factor for wheat from North and South sample locations:

ANOVA						
Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between groups	3.648099	1	3.648099	2.787849	0.11718	4.60011
Within groups	18.32	14	1.308571			
Total	21.9681	15				

Table 2. Statistical summary and ANOVA single factor for wheat samples.

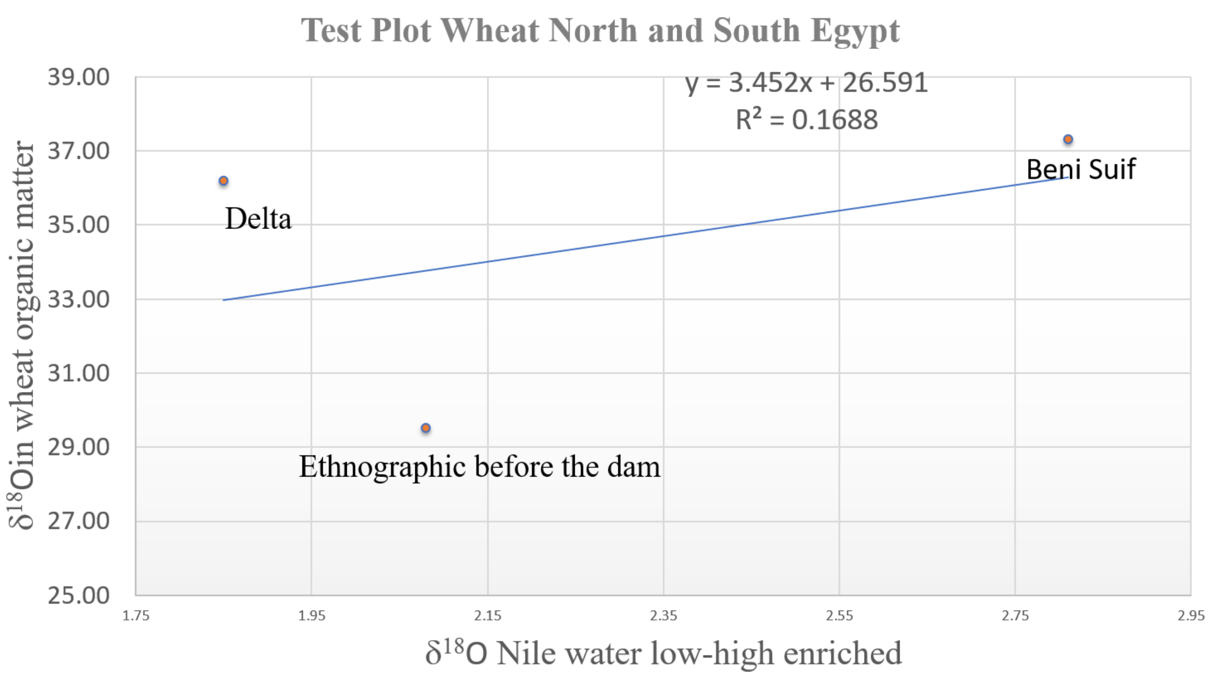


Figure 3. Test plot of wheat from north and south Egypt shows no siginificant statistical difference in the two wheat types that are both irrigated with Nile water.

However, comparing these values to Egyptian wheat samples from the Charleston Museum archive predating the construction of the High Dam, we see a much lower value of the $\delta^{18}O$ value in organic matter in the pre-dam material of +29.99‰ closer to the oxygen values from the ancient samples. This indicates better relative humidity conditions and less evaporative conditions existed prior the dam closer to ancient Egypt urging us to reconsider the role of the Nile flood and past water and agricultural sustainable management. In the Egyptian grain collected for the Charleston Museum 100 years ago, oxygen value of Nile water in Cairo as of summer 2018 was enetered to test the predictivity of the model (Table 3). Considering the caveats of such a model for not knowing the exact $\delta^{18}O$ value of Nile water when these wheat samples were collected, it is likely that the $\delta^{18}O$ was lower in the past, and that the evaporative enrichment in the wheat in modern samples might be to some extent driven by the effect of dams on the Egyptian Nile.

Two imported samples of wheat were used to test the efficiency of the model to differentiate between grain grown with Nile water and that grown with other water sources. The first sample (n=2 measured in duplicates) comes from Turkey, with an average $\delta^{18}O$ value of +32.52‰, and another wheat sample comes from California, USA, which showed a $\delta^{18}O$ value of +30.29‰. Statistical analysis demonstrates that these two are statistically different from those coming from Egypt. However, it is difficult to predict the $\delta^{18}O$ value of the source water, as the relationship between the enrichment in $\delta^{18}O$ in the seed organic matter compared to the $\delta^{18}O$ of source water does not show a direct or linear relationship and is confounded by other eco-physiological factors such as temperature and humidity and plant physiology. However, grains grown with the same water and in similar ecological conditions seem to have no statistical difference, as we saw in the case of Egyptian grain. So this method helps differentiate locally grown grain versus imported but it does not help determine the source region of the imported grain without using another isotopic proxy such as strontium, which is out of the scope of this study.

Wheat site in Egypt And test samples outside Egypt	Plant average $\delta^{18}O$ value	std +/- $\delta^{18}O$ value	$\delta^{18}O$ value of Nile water	Offset $\delta^{18}O_{plant-Nile\ water}$
Beni Suef, S. Egypt 1	36.71	0.12	2.81	33.90
Beni Suef, S. Egypt2	37.9	0.72	2.81	35.09
Gharbiya 1, N. Egypt	37.35	0.14	1.85	35.50
Gharbiya 2, N. Egypt	35.78	2.12	1.85	33.93
Gharbiya 3, N. Egypt	36.49	0	1.85	34.64
Gharbiya 4, N. Egypt	35.87	0.36	1.85	34.02
Gharbiya 5, N Egypt	34.6	0.39	1.85	32.75
Gharbiya 6, N. Egypt	37.15	1.12	1.85	35.30
Charleston Museum 1	30.58	0.45	2.08	28.50
Charleston Museum 2	28.01	2.11	2.08	25.93
Charleston Museum 3	29.99	0.61	unknown	27.91
Turkey	32.52	1.04	unknown	unknown
USA	30.28	0.28	unknown	unknown

Table 3. Data summary of wheat sites in Egypt and the test samples from Turkey and USA

2.4.4 Doum fruits *Hyphaene thebaica* (L.) Mart.

Three doum fruits were collected from three sites in East Africa: one fruit from Luxor (Egypt), one fruit from Sudan, and the third one was collected by Thure Cerling in Kenya along the Turkwell river. The purpose of this analysis is twofold: one is to differentiate between doum fruit grown with Nile water and doum fruit that grew with a different water source, the Turkwell river with $\delta^{18}O$ -0.7‰ (Thure Cerling pers. comm. May 2019).

The second goal is to understand variation in $\delta^{18}O$ values of different tissues of the doum fruits. To do this, $\delta^{18}O$ of four different components of the fruit were measured. The reason is that when this experiment is extrapolated and applied on archaeological materials, different parts of this fruit were preserved. This is also the first study in life science and plant physiology to measure oxygen isotopic differences in different plant-tissues in the same fruit (Figure 4).

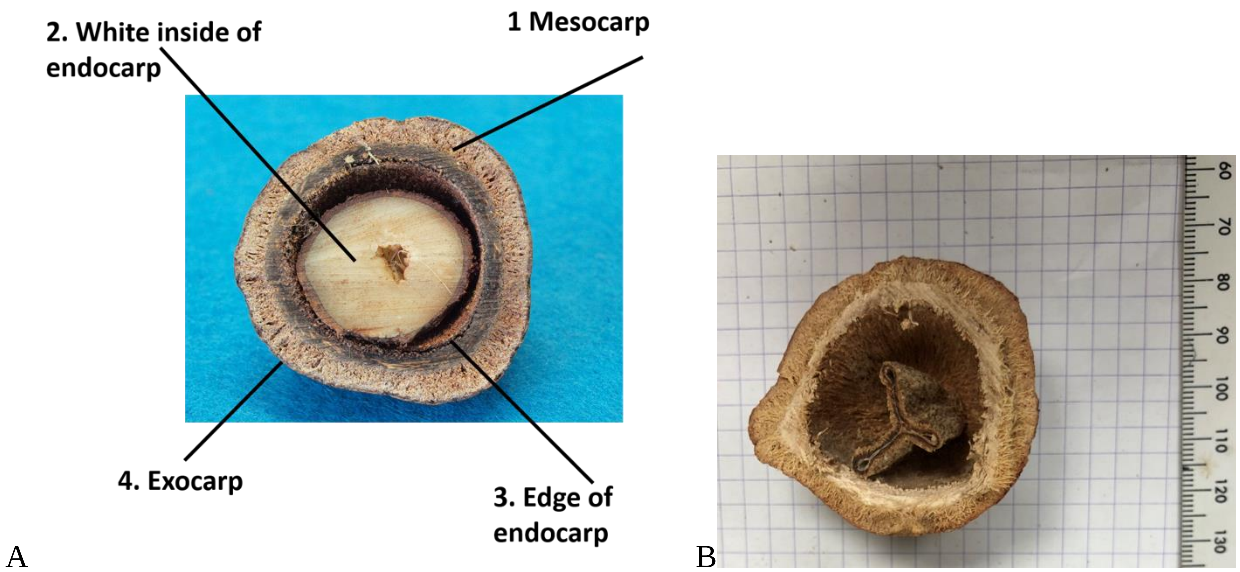


Figure 4. A. Doum fruit cross-section shows the different fruit tissues samples for their $\delta^{18}O$ isotopic composition. B. Doum fruit from Kenya, the white inside of the endocarp is thinner, showing eco-physiological difference in the same species from different regions in Africa.

Statistical ANOVA of single factor summary for the doum fruit different tissues:

While the source Nile water in Luxor $\delta^{18}O$ was constant at +2.7 ‰, the four different components of the fruit (component 1 doum mesocarp; component 2 white inside endocarp; component 3 edge of endocarp; component 4 doum exocarp) showed variation in $\delta^{18}O$. However, the statistical difference between the individual plant parts of the doum fruit was not significant, and showed minor difference in the $\delta^{18}O$ value compared to the other components of the fruit ($F_{3,11} = 2.522$, $p = 0.131$). *Species offset = 35.32‰* (Table 4).

Plant part	Count	Sum of $\delta^{18}O$ values	Average $\delta^{18}O$ value	Variance in $\delta^{18}O$ values
Component 1	3	21.22404	7.07468	0.07495
Component 2	3	25.80426	8.60142	3.890253
Component 3	3	19.21612	6.405373	0.09468
Component 4	3	21.47697	7.158989	0.006088

Table 4. Statistical summary of oxygen isotope values within the doum fruits from Luxor Egypt.

Comparing doum in East Africa: Egypt, Sudan, and Kenya:

The doum fruit that showed the highest $\delta^{18}O$ values is the one from Luxor (Table 4), followed by Sudan and then Kenya. The average of the whole doum fruits shows the highest value for Luxor with $\delta^{18}O$ at 38.02‰, followed by the average $\delta^{18}O$ of Sudan doum at 30.7‰, and the lowest average of the whole fruit is the doum from Kenya at 29.62‰. As for the different components in the same fruits, among all the four doum, component 2 is the most enriched compared to the three other components of the same fruit, and component 3 is the least enriched compared to the other tissues of the same fruit. For example, Luxor doum component 1 is 38.10 ‰ with 0.63 STD, which means it has 35.40 offset from source water which is +2.7 from Luxor Nile water. Component 1 in Kenya shows a similar pattern of high enrichment compared to source water. Kenya doum component 1 is 31.34 ‰ with 0.64 STD, which means it is in offset from the -0.7 of source water by 32.04‰. As for component 2, the Luxor and Kenya doum show higher enrichment than the other tissues. In the Luxor doum component 2's $\delta^{18}O$ is 42.91 with 0.14 STD, which means it has an offset from the source water of 40.21 and thus is more enriched than the source water. Component 2 in the Kenya doum is similarly more enriched than the rest of the same fruit with a $\delta^{18}O$ value of 32.34‰ with STD 1.53, which is offset from the source water by 33.04‰. The least enriched component, however, is component 3 in the Luxor doum (32.69‰ with 0.32 STD), which is offset from the source water by 29.99 ‰. The $\delta^{18}O$ of component 3 in the Kenya doum is 27.22 ‰ with 0.29 STD and offsets from the source water by 27.92‰. These two examples of Kenya and Luxor doum show that the doum fruit enrichment over the source water varies not only among anatomical components more than others but also in the components that have lower $\delta^{18}O$ ‰ than others, and their offset between the source water and these components decreases. Analysis of the Sudan doum shows a value lower than the Egyptian Nile and higher than Kenya. However, the $\delta^{18}O$ of the source water is not yet known, which hinders our attempt at interpretation (Table 5).

Dom fruit site	**Comp 1**	**Comp 2**	**Com p 3**	**Com p 4**	**Whole fruit averag e**	$\delta^{18}O$ **sourc e water**	**Offset** $\delta^{18}O$ **plant-water**	**Offset comp1**	**Offset comp 2**	**Offset comp 3**	**Offset comp 4**
Sudan	30.46	32.11	26.49	33.72	30.7	unk	unk				
Sudan STD	0.49	o.49	1.76	1.81							
Luxor Egypt	38.10	42.91	32.69	38.37	38.02	2.7	35.32	35.40	40.21	29.99	35.67
Luxor STD	o.63	0.14	0.32	o.62							
Keny a	31.34	32.34	27.22	27.59	29.62	-0.7	30.32	32.04	33.04	27.92	28.29
Keny a STD	0.64	1.53	0.29	0.76							

Table 5. Summary of $\delta^{18}O$ doum fruits oxygen isotope results from Egypt, Sudan, and Kenya

2.5 Discussion

2.5.1 Nile water

This study presents the first extensive study of the oxygen and hydrogen isotopic composition of modern Nile water as a baseline for life sciences, plant ecology, and environmental studies. The average $\delta^{18}O$ value of Nile water today is +3.01‰ with variability of +/–0.4 ‰ driven by seasonal fluctuations. In ancient Egypt and pre-dam, values were much lower compared to the present, the ancient average $\delta^{18}O$ value of Nile water was 0.3 ‰ in Asyut (1st Intermediate Period 2150–2050 BCE) and Gebelein (Predynastic 3500–2600 BCE) in Upper Egypt, and –0.9‰ from Greco-Roman Mendes downstream in the Delta (332 BCE – 395 CE). These oxygen isotopic values of the Nile River were inferred from bone carbonate and enamel carbonates of human remains in bioarchaeological studies) Buzon and Bowen 2010:862)**.** This may indicate that the high evaporative enrichment may have been caused by the dams built during British colonialism and the High Dam built under President Nasser's nationalism in Egypt during the 1960s.

The interpretation of the high enrichment value of the Nile River can be found in Arabic manuscripts such as those of As'ad ibn Mamaty, dating to the 12th century, describing the Nile flood and its water cycle (Ibn Mamaty 1943). In this manuscript, Ibn Mamaty reports that the flood of the Nile is unlike many rivers he experienced, in the way it floods from south to north, and during the hot summer in August during the monsoon rains. From an isotopic perspective, the Nile floods not from a snow melt that is depleted in its oxygen isotope ratios. Rather, it floods under a hot temperature and evaporative conditions that contribute to the highly enriched values of the oxygen isotope of the Nile water. This effect could be heightened by the increased construction of dams along the Nile in Sudan and Ethiopia as well. For archaeological and paleoenvironmental consideration, published data from tooth carbonates and bone collagen of mummies found in

Egypt, which help estimate the Nile water with some caveats, suggest much lower values in the past. They also suggest that the Nile oxygen isotope differed from one-time period to another. For example, $\delta^{18}O$ at Mendes in the northern Delta during the Greco-Roman period was –0.9 relative to VSMOW and –0.3 in the south, and there was a much lower value of –4.6 in the Dakhla oasis during the pharaonic period in Egypt (Buzon and Bowen 2010:862). However, it is important to note that the enriched value of $\delta^{18}O$ estimated under the Greco-Roman period was already enriched +1.5 to +2.3 (Buzon and Bowen 2010) (Table 2). An alternative interpretation to the dam as the only driver to the evaporative enrichment can be found in the Ibn Mamaty 12th-century manuscript (unpublished translation by the author) in which he observes that the Nile is different than most familiar rivers in the way it floods in the hot summer, being filled by the monsoon rain from the "Moon Lake" (i.e., Lake Victoria),[6] rather than flooding in winter through snow melt as most other rivers (c.f. the Orontes river in Syria, which runs in the opposite direction). From an isotopic perspective, this observation helps to explain that the Nile flood starts with highly evaporative conditions already at its source region and more evaporative enrichment in the oxygen-18 composition increases downstream in Egypt (Thure Cerling and Todd Dawson pers. comm. 2019). The pH of the Nile water is also of particular interest, as average pH among the n=51 samples is 8.2, showing that unlike most rivers, the Nile water is alkaline rather than acidic (Todd Dawson, pers. comm. spring 2019).

Meanwhile, the increased evaporative conditions in modern times, compared to the results that Nada reported for the samples collected in the 1990s (Nada 2013), are most likely driven by the increased dam projects along the river, altering its oxygen cycle. Evidence of that comes from

[6] Lake Victoria was known in Arabic manuscripts since the 13th century as "Lake of the Moon" as it has tides in response to the moon.

measuring surface water samples from the Nile in Nuri, Sudan (January 2020), which shows more depleted values of $\delta^{18}O$ = +0.8 ‰; while the $\delta^{18}O$ of Tekezé, a tributary to the Nile in Ethiopia is even more depleted, with a value of –0.66 ‰. This means that the high evaporative conditions starting in Aswan $\delta^{18}O$ = +2.8 are most likely driven by the dam effect. The exceptionally high value of the Fayum lake seen in Figure 1 (+8 to 9 ‰) is even more concerning, as it indicates a rapidly drying lake.

2.5.2 **Potentials of non-exchangeable $\delta^{18}O$ in fruit organic matter**

Previous studies on oxygen isotope values and water-plant tissue fractionation factors (Roden et al. 2000) provided a predictive model relating water sources and humidity, including the relationship between source water and xylem tissues in plants. However, their model focuses on oxygen-18 from alpha-cellulose in tree rings, where the assumption is that there is no fractionation between source water and the plant tissue. For archaeological applications, fruits, date pits, or wheat seed kernels are what survive in the archaeological record. Testing on modern samples of these species in this study serves as a test model to understand the offset between the oxygen of the water source and the $\delta^{18}O$ in organic matter of the fruits, rather than assuming direct applicability to archaeological samples. While the hypothesis in this study expects a constant offset between the source water and $\delta^{18}O$ in organic matter, the offset between the water source and plant tissues varied from one species to another, even though the three types of plants discussed here are C3 plants.

Barbour (2007) has reported similar high offset values between source water and fruit tissue, i.e., an offset between 25 and 30‰ for the oxygen atoms that bond with the carbonyl group (Barbour 2007:86). However, the highly enriched values among the three species (wheat, doum, and date fruits) from the Egyptian Nile show the highest values of isotopic enrichment ever reported to date in life science literature. The offset between the source Nile water and the fruit tissue is a substantial one (average across species, 40.3 ± 5.3‰).

One possible interpretation can be inferred from Barbour (2007), who mentions that there is a relation between non-exchangeable oxygen-18 in fruit organic tissues and source water. However, this relationship is non-linear (Barbour 2007:86). She also cites an experiment by Helliker and in Ehleringer 2002 in which the water source was controlled, as in our case from Egypt and Kenya, and variation in $\delta^{18}O$ values was attributed to differences in species driven by leaf morphology and/or variation in humidity conditions upon growth, as well as by temperature (Barbour 2007:86, 87, 89).

Based on Barbour's argument, the $\delta^{18}O$ in the fruit organic matters is most likely relatable to the $\delta^{18}O$ of the leaf water, which provides nutrient-rich water to the fruit, rather than being a signature of the source water uptake. The fruit uses sucrose from leaf water to form the different tissues, which makes the fruit tissue $\delta^{18}O$ even more enriched than leaf water. This is also stated by Barbour, giving examples of variability in $\delta^{18}O$ driven by structural and non-structural components of the leaf and the variability in $\delta^{18}O$ of the sucrose in different species (Barbour 2007:87). These examples help interpret the eco-physiological factors that contribute to the non-linear relationship of the offset between Nile water source and wheat $\delta^{18}O$ in organic tissues of the wheat kernels.

The archived sample of ethnographic Egyptian wheat from the Charleston Museum is intriguing, as it shows lower values of evaporative enrichment in $\delta^{18}O$. Even though the $\delta^{18}O$ of the source water is not known, it suggests that the Nile Valley in Egypt might have had lower $\delta^{18}O$ and less isotopic enrichment before the High Dam was built. So even after considering all the caveats discussed by Barbour such as the $\delta^{13}C$ and $\delta^{18}O$ in water vapor in the plant site should be controlled for, and there is little discussion about the urban effect of dams as a possible driver of such isotopic enrichment.

Another interesting observation in this study is the variation between the different doum fruit components. Each doum fruit was sectioned for four different tissues (exocarp, mesocarp, white endocarp, and the brown coating layer surrounding the endocarp) of the fruits (total n=24). The white endocarp was 4‰ to 5 ‰ lower in its $\delta^{18}O$ values compared to the other tissues in the same fruit. Average $\delta^{18}O$ of the whole doum components in the Sudan sample = 30.70‰, for the Egyptian doum 38.02 ‰, and 29.62‰ from the doum from Kenya. Different tissues varied in their $\delta^{18}O$. Component 3, the white endocarp, is consistently enriched less than the rest of the tissues of the same fruit. One explanation is found in Barbour (2007), where she notes a small variation in fractionation dependent on which atoms the oxygen bonds with or is close to. She reports a $\delta^{18}O$ enrichment value of 19.6‰ for oxygen bonding with carbon-2 of the cellulose, and 28.8‰ for oxygen atoms bonded to carbon-3-6 (Barbour 2007:86). However, other reasons may have caused these intra-fruit tissue variations such as the exchange between the oxygen in organic matter and the water in molecules, as the rate of this exchange for the larger molecule would be slower to reach equilibrium compared to smaller molecules (Barbour 2007).

Statistical analysis of the results show that among the three species wheat has the closest $\delta^{18}O$ value to the river water, having an offset of +34.91‰ higher than source water. Doum and date fruits showed an even higher offset between the $\delta^{18}O$ of Nile water and the $\delta^{18}O$ in the fruits (average of all species, 40.3 ± 5.3‰) higher than Nile source water. These results are the highest evaporative enrichment reported in fruits. Considering that the oxygen isotope in the carbonyl groups is influenced by plant physiology and presents species-specific variations, it also varies depending on temperature and relative humidity (Dawson and Siegwolf 2011, Loader et al. 2007). Under increased arid conditions in Egypt driven by the construction of the High Dam, relative humidity decreased and temperature increased, driving the evaporative enrichment values of the non-exchangeable oxygen in the carbonyl group of the fruit parts. As demonstrated in Chapter 4, examining the results of oxygen isotope analyses on the ancient fruits as compared to the modern samples, the difference in the ecological conditions between the past and the present are clear. The average $\delta^{18}O$ of ancient plant remains = +29.53‰, showing better water availability and relative humidity conditions than in modern botanical samples, which have an average $\delta^{18}O$ of +40.29‰, indicating increased aridity and evaporative enrichment of ^{18}O as a consequence of that increased aridity, and highly evaporative conditions resulting from the dams along the river. From this, one infers the huge impact of climate change and damming of the river on altering the oxygen isotope of the Nile water and plants irrigated with the Nile water.

2.6 Conclusion

This project offers preliminary results of a new method for food sourcing, based on source water variation, using the fruit parts of the plants for application in paleoethnobotany, and a baseline of isotopic composition of Nile water as an under-surveyed watershed area in Africa.

The study tests a new method in life sciences and experimental paleoethnobotany for the validity of using oxygen isotope ^{18}O analysis on fruits and other non-stem plant components to differentiate between local versus imported fruits based on different water source and ecological conditions.

The $\delta^{18}O$ from organic matter of fruits of three C3 species collected from Egypt (wheat, doum, and date) and from other regions to test the relationship between $\delta^{18}O$ source water and $\delta^{18}O$ in the fruit organic bulk tissues showed non-linear offset, and hence predicting source water based only on $\delta^{18}O$ in fruit organic tissue poses some difficulty to interpretation. Of the three species, wheat had the closest $\delta^{18}O$ value to the river water, (*species offset = 34.91‰*). However, there was a substantial offset (average across species, 40.293 ± 5.260‰) between the fruit/seed bodies and the source water in modern plants. A possible interpretation is that $\delta^{18}O$ in fruit tissues does not only reflect source water, but rather source water as routed differently in various species due to leaf physiology, and eco-physiological conditions such as humidity and temperature (Dawson and Siegwolf 2011).

Future steps in this experiment will incorporate dual isotopic methods such as $\delta^{13}C$ to test water use efficiency in relation to source water, and the photosynthesis rate to better understand the driver of the enrichment between source water and the $\delta^{18}O$ plant organic matter. Meanwhile, by comparing these results of the non-exchangeable $\delta^{18}O$ in organic matter between ancient botanical samples (Chapter 4), and the modern ones from Egypt, the ancient botanical samples had an average $\delta^{18}O$ of +29.53‰ in contrast to the average across modern plant species in which the $\delta^{18}O$ of organic matter has a value of 40.293 ± 5.260‰. Based on this comparison, it can be generally concluded that ancient botanical remains experienced better water availability and relative humidity conditions along the Nile in Egypt compared to the modern ones, which reflect increased aridity and high evaporative conditions. One interpretation of this isotopic enrichment is that the dams built along the river cause more enriched values of $\delta^{18}O$, the more you move downstream. Egyptian samples of doum fruit from Luxor, for instance, show higher $\delta^{18}O$ values compared to the doum fruits from Aswan and from Sudan, despite the higher temperature in these southern regions, indicating the experience of more arid conditions and evaporative conditions.

Furthermore, the three doum fruits from Egypt, Sudan, and Kenya showed an interesting case in which the different tissues of the same fruit varied in their $\delta^{18}O$ compositions, which means that the offset between the $\delta^{18}O$ of source water and the $\delta^{18}O$ of the fruit is dependent on what tissue is formed out of the leaf water. But the general pattern is still consistent, the fruits that grow downstream having higher $\delta^{18}O$. In order to differentiate between the various factors, future steps can benefit from further advances in stable isotope standards and measuring technique in order to measure the extremely rare in abundance $\delta^{17}O$. The reason is that $\delta^{17}O$ is not affected by humidity and evaporation from rivers and atmosphere and only influenced by temperature (Dawson, pers. comm. 2018). This experiment is the first to test the potentials of the non-exchangeable oxygen-18 bonded in the organic compounds in fruit tissues in relation to the source water to invite future applicability in life science, paleoethnobotany, and environmental archaeology. The overall goal is to use archaeology and the unique preservation of paleoethnobotanical materials from Egypt to harness knowledge from past agriculture and River water management systems to serve modern communities build resilience against climate change.

CHAPTER 3

3. Case study 1: Social history of food offerings in Deir el-Ballas paleoethnobotanical analysis[7]

3.1 Introduction

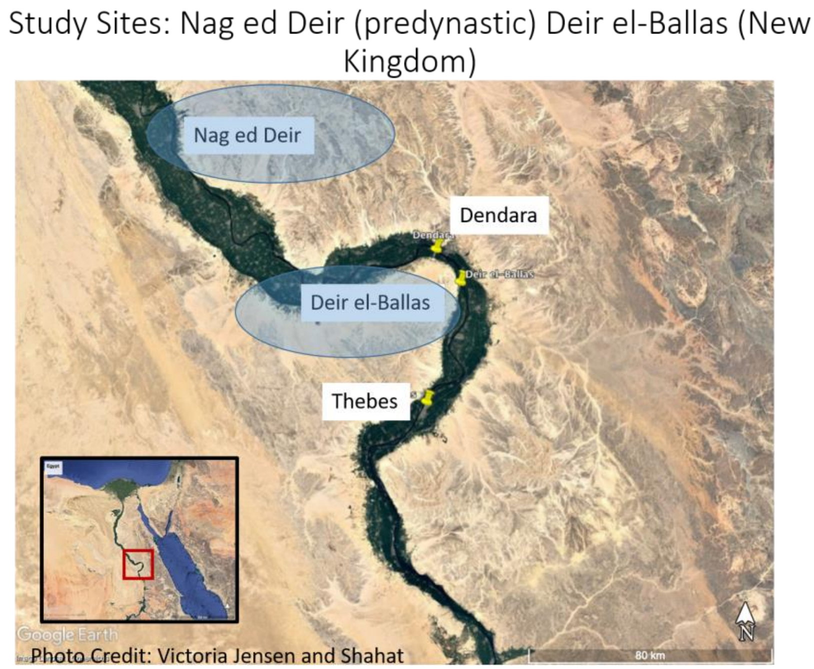
This project[8] presents results of the archaeobotanical study of food remains from the non-elite Cemetery 1-200 at Deir el-Ballas, Upper Egypt (Figure 5), dating primarily to the early 18th dynasty (ca. 1525–1425 BCE) (Jensen 2019).[9] The site was excavated in 1900–1901 by G. Reisner, A. Lythgoe, and F.W. Green, but their work was never published. Most of the artifacts (including the surviving botanical remains) as well as copies of the unpublished field notes, maps, and photographs are currently held at the Phoebe A. Hearst Museum of Anthropology, University of California Berkeley (PAHMA) (Shahat and Jensen in press).[10]

[7] This chapter will appear as peer-reviewed book chapter in press, with some modifications and updates following the field season in Deir el-Ballas in 2020 and 2021. **chapter citation**: **Amr Shahat and Victoria Jensen, *Social Archaeology of Food at Deir el Ballas: an archaeobotanical study of the non-elite cemetery food offerings,* Institut Français d'Archaeologie Orientale Monograph (in press)**. My co-author Victoria Jensen contributed with important information on tomb contexts and ceramic data. All paleoethnobotanical analysis is done by the dissertation author.

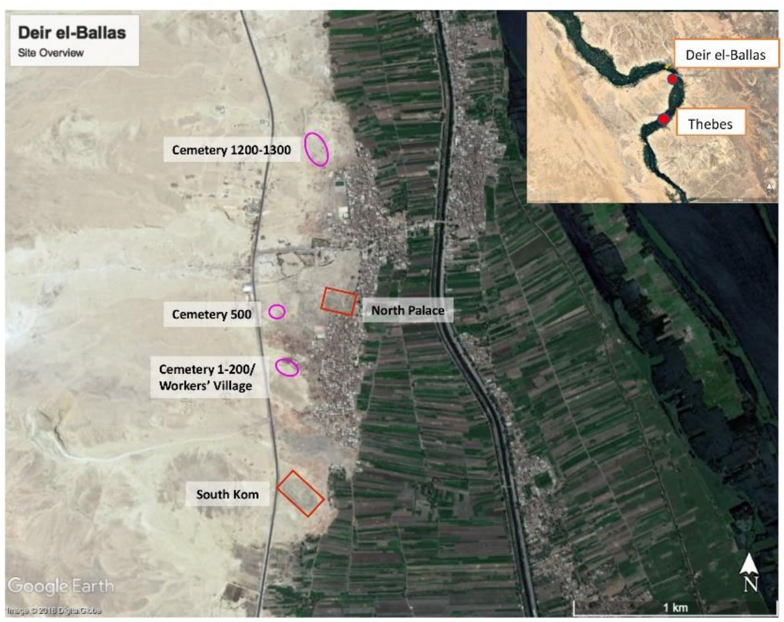
[8] We thank C. Hastorf and P. Lacovara for their mentorship, C. Newton and M. Van der Veen for help with sample verifications, L. Freund at PAHMA for her invaluable support, V. Slotten at the UC Berkeley McCown Archaeobotany Laboratory for her assistance with the botanical photos, as well as Menna El-Dorry and the two anonymous reviewers whose critiques helped strengthen this paper. Any remaining errors are the authors' responsibility.

[9] Dates are approximate and are based on Shaw 2000:484–485.

[10] The original archival documentation is housed at the Museum of Fine Arts, Boston.



A.



B.

Figure 5. A. Map of the study sites of New kingdom site of Deir el-Ballas and the Predynastic site of Nag ed-Deir. B. Map of Deir el-Ballas showing cemetery 1-200. Image Credit: Google Earth 2018, adapted by Victoria Jensen and Amr Shahat.

The botanical assemblage from the site is desiccated, with some of the plants found in ceramic bowls[11] and small beaker-shaped jars.[12] The authors have identified 345 specimens of archaeobotanical remains at PAHMA that represent 13 different species belonging to 11 different families, including interesting findings of fruit such as pomegranate (*Punica granatum* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), doum (*Hyphaene thebaica* L.), dates (*Phoenix dactylifera* L.), grapes (*Vitis vinifera* L.*)*, Phoenician juniper *(Juniperus phoenicea* L.*)*, sycomore figs (*Ficus sycomorus* L.), Christ's thorn *(Ziziphus spina-christi* (L.) Willd), desert date (*Balanites aegyptiaca* (L.) Delile, 1812), tiger nut rhizome (*Cyperus esculentus* L.*)*, and persea (*Mimusops laurifolia* L.).[13] The only prior archaeobotanical study of plant remains from Deir el-Ballas focused on one context in the settlement. In 1980, W. Wetterstrom retrieved samples by flotation from a refuse dump near a house west of the North Palace, revealing wheat (*Triticum dicoccum* Schrank ex Schübl.), barley (*Hordeum vulgare*), and linseed (*Linum usitatissimum*), as well as wild canary grass (*Phalaris* sp.) typical of Egyptian settlements (Wetterstrom 1990:25). Further archaeobotanical remains were retrieved from the 2019–2020 field season by Shahat under the directorship of Peter LaCovara. In this field season, soil samples were taken from House E by Nick Brown. Archaeobotanical materials were retrieved by the author using the hand-pump flotation system and dry sifting (Shelton and White 2010). The species recovered included emmer wheat (*Triticum dicoccum* Schrank ex Schübl), six-row barley (*Hordeum vulgare* (L.)), flax, sycomore fig, dates, doum, grape, bean (*Vicia faba* L.), and acacia pod (*Acacia nilotica* (L.) Del.), and condiments including coriander (*Coriandrum sativum* (L.) and others of the Apiaceae family.

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[11] Seiler 2005:143.

[12] These narrow containers are cylindrical in shape with a rounded bottom and direct rim. They range from 14–16 cm in height and 5–6 cm in maximum diameter. For examples, see Seiler 2005:152, Falttafel 6 and Bourriau 1982:78.

[13] Photos of all material discussed here are available on the PAHMA website and searchable by museum numbers provided in Table 1 (https://portal.hearstmuseum.berkeley.edu/).

Beside the archaeobotanical materials, fish bones and housefly (*Musca domestica* Linnaeus, 1758) were also found.

To contextualize the archaeobotanical remains found in Cemetery 1-200, we researched archival information about the original excavation to identify the associated material culture assemblages to assist the data interpretation. Information on 12 contexts is presented in this chapter in detail (see Table 6). Other botanical remains from Deir el-Ballas at PAHMA whose exact provenances are uncertain are also presented in Table 6 as part of the dataset but not discussed in detail here. The site is currently the subject of further excavation and conservation under the direction of P. Lacovara; the authors are part of Lacovara's team currently preparing a full publication of the Deir el-Ballas materials.

Botanical Remains at the Phoebe A. Hearst Museum of Anthropology from Deir el-Ballas

Tomb #	Family	Genus	*species*	Common Name	Count	Plant part	PAHMA museum number*
Pit east of tomb 59	Moraceae	*Ficus*	*sycomorus*	Sycomore fig	1	Whole fruit dried	6-8128
Pit east of tomb 59	Arecaceae	*Phoenix*	*dactylifera*	Date	2	Date pit one with date skin preserved	6-8128
80	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	3	Fruit endocarp	6-6435
89	Arecaceae	*Phoenix*	*dactylifera*	Dates	21	Parthenocarpic whole dates	6-6469
105	Arecaceae	*Phoenix*	*dactylifera*	Dates	1	Whole date with skin preserved	6-6507
105	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	6	Fruit endocarp fragments; one endocarp punched with hole	6-6507
105	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	33	5 whole fruit, 2 large & 26 smaller fragments	6-6509
128	Rhamnaceae	*Ziziphus*	*spina-christi* (L.) Willd	Christ's thorn	7	Whole fruit with pedicel	6-6626
128	Vitaceae	*Vitis*	*vinifera*	Grape	21	Grape pips	6-6626
128	Cupressaceae	*Juniperus*	*phoenicea*	Juniperus berry	36	Whole fruits	6-6626
128	Lythraceae	*Punica*	*granatum*	Pomegranate	52	Small fragments of rind	6-6626
128	Arecaceae	*Phoenix*	*dactylifera*	Dates	6	Seed pits	6-6626
163	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	2	Large endocarp	6-6895
163	Arecaceae	*Phoenix*	*dactylifera*	Dates	1	Date skin mostly preserved without the seed pit	6-6896
163	Vitaceae	*Vitis*	*vinifera*	Grapes	34	Grape pips, some with skin preserved	6-6895
190	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	Whole fruit	6-7043
190	Balanitaceae	*Balanites*	*aegyptiaca* (L.) Delile	Desert date	2	Fruit pits	6-7049
192	Poaceae	*Hordeum*	*vulgare ssp. Distichon*	Barley	1	Spikelet	6-7070
205	Balanitaceae	*Balanites*	*aegyptiaca* (L.) Delile	Desert date	1	1 fruit exocarp and mesocarp including 4 fragments	6-8895
244/255	Vitaceae	*Vitis*	*vinifera*	Grapes	2	Grape pips	6-7482
244/255	Cyperaceae	*Cyperus*	*esculentus*	Tiger nut	1	1 whole rhizome	6-7482
244/255	Cucurbitaceae	*Citrullus*	*lanatus*	Watermelon	11	5 whole seeds and 6 fragments	6-7482
244/255	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	Mesocarp	6-7482
257	Lythraceae	*Punica*	*granatum*	Pomegranate	1	Fragmented fruit endocarp and red seeds	6-7517
257	Rhamnaceae	*Ziziphus*	*spina-christi* (L.)Willd	Christ's thorn	4	Whole fruits with part of the fruit pedicel preserved	6-7517
257	Vitaceae	*Vitis*	*vinifera*	Grape	7	Grape pips	6-7517
257	Arecaceae	*Phoenix*	*dactylifera*	Dates	3	Two dates with fruit skin mostly preserved and one date pit	6-7517
257	Poaceae	*Triticum*	*turgidum ssp. dicoccon*	Emmer wheat	8	2 whole spikelets (one of them is the apical spikelet) and 6 chaff	6-7517
257	Poaceae	*Hordeum*	*vulgare*	Barley	1	Spikelet	6-7519
257	Poaceae	*Triticum*	*turgidum ssp. dicoccon*	Emmer wheat	1	Spikelet	6-7519
257	Sapotaceae	*Mimusops*	*laurifolia*	Persea nuts	30	14 whole nuts, 1 inside of the nut; and 15 fragments	6-7519
uncertain prov.	Arecaceae	*Phoenix*	*dactylifera*	Date	25	Date pits	6-9176
uncertain prov.	Moraceae	*Ficus*	*sycomorus*	Sycomore fig	1	Whole fruit	6-8297
uncertain prov.	Balanitaceae	*Balanites*	*aegyptiaca* (L.) Delile	Desert date	7	Endocarp	6-8297
uncertain prov.	Poaceae	*Triticum*	*turgidum ssp. dicoccon*	Emmer wheat	2	Mass of cereal husk and fine chaff, only two spikelet forks	6-8455
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	3	Dom fruit, 1 complete and 2 mostly intact	6-8492
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	Dom fruit, mesocarp preserved	6-8711
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	Whole dom fruit	6-8712
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	Macro-fossilized dom fruit (completely preserved)	6-8276
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	2	1 fruit significantly large 7.5X5.0cm & 1 exocarp	6-6510
uncertain prov.	Arecaceae	*Hyphaene*	*thebaica* Mart.	Dom Fruit	1	One whole fruit and tiny fragments	6-8259

*Images of the specimens are available on the museum's online collection website and searchable by museum numbers provided in this Table (https://portal.hearstmuseum.berkeley.edu/).

Table 6. Identification of botanical remains at the Phoebe A. Hearst Museum of Anthropology from Deir el-Ballas Cemetery 1-200 (Shahat and Jensen in press).

3.2 The site and its excavation history

Located 40 km north of Luxor on the west bank of the Nile, Deir el-Ballas features a royal palace (North Palace) dating to the reigns of Seqenenre Taa (c.1560 –1553 BCE) and Nebpehtyra Ahmose (c. 1550–1525 BCE). Immediately west of the palace's enclosure wall are several building complexes (Houses A–F), one of which (House D) appears to have been a bakery while another (House E) shows evidence of textile production (Lacovara 1990). At the southern end of the site, a high hill was transformed into a huge two-level platform (South Kom) with a monumental staircase connecting the two levels.[14] While its function remains enigmatic, this structure may have served as an observation platform to safeguard the surrounding desert and the Nile Valley. Approximately 70 large houses were scattered across the settlement, administrative facilities have been identified, and a compact workers' village stood on a hillside overlooking the North Palace from the south (Lacovara 1990:1–5)

Three cemeteries have been identified at the site: Cemetery 1-200 where over 200 tombs were dug among the walls of the former workers' village, Cemetery 500 consisting of 14 tombs directly west of the palace, and Cemetery 1200-1300 consisting of approximately 60 tombs at the northern end of the site.[15] There are only a few tombs that may possibly complement the 17th Dynasty settlement. After Ahmose's court moved to Thebes along with most of the attendant population, there may have been a brief period of complete abandonment followed by "squatter occupation" during the 18th dynasty (Lacovara 1997:15) or perhaps a small contingent of individuals remained

[14] The monument was termed "South Kom" by Reisner (1904:1) and the actual excavator, Lythgoe (unpublished field notes) acknowledged the uncertain function of this monumental two-level platform. The South Kom was later termed a palace by Reisner (1908: V–VI) and Stevenson Smith (1998:159–60), a term that was followed by Lacovara but enclosed in quotation marks, as the latter notes that this is certainly a misnomer for the monument (1981:121).

[15] As of this writing, Cemetery 1-200 has been almost entirely bulldozed due to the expansion of the modern village.

at the site and moved into the abandoned homes. In either case, the area of the workers' village was reused as a cemetery, beginning early in the 18th Dynasty (Lacovara 1981), with a floruit in the reigns of Hatshepsut/Thutmose III (Jensen 2019:431–43). A few burials can be dated by their material culture to the late 18th or early 19th Dynasty, after which no datable activity occurred until the Coptic era, when the palace was reused as a monastery (Jensen 2019:25, 409–10). Such reuse of domestic spaces as a necropolis including Cemetery 1-200, from which these botanical materials were retrieved, is rarely published but not unknown (Jensen 2019:70–73). The walls may have served as convenient, ready-made dividers delineating cultic space for funerary rites, and the fact that the settlement faced the abandoned palace may have been a factor in selecting this area for use as a necropolis (Jensen 2019:6–10).

The excavation history of Deir el-Ballas began in the late 19th century. Georges Daressy found a stone lintel in the village near the North Palace with the cartouche of Seqenenre Taa in 1894 (Daressy 1894:44). Two years later, James Quibell recorded that he "turned over a considerable part of the ruins" but noted that the site "had been thoroughly plundered, worked by a dealer at Qeneh as well as others" (Petrie and Quibell 1896). Quibell published no list of finds or further description of his work. In 1900–1901, a more systematic excavation was undertaken with funding from Phoebe Apperson Hearst on behalf of the University of California, led by George Andrew Reisner assisted by Albert M. Lythgoe and Frederick W. Green, but their work was never published: we only have field notes housed in the Phoebe Hearst Museum of Anthropology (PAHMA), University of California, Berkeley.

The Hearst Expedition only recorded two of the three cemeteries at the site well enough that they describe many of the tombs' contents. Reisner oversaw the excavations in Cemetery 1-200, while Lythgoe supervised the work at Cemetery 1200-1300. In both cemeteries, the most common grave good was pottery, with a few burials preserving stone kohl jars, bronze toilet implements, and scarabs, amulets, and beads made of faience, stone, and glass, all modest items for burials (Jensen 2019:64, 296, 308–56).

At Deir el-Ballas, Reisner began his excavation procedure by taking photographs of tombs as they were being excavated as well as the assemblages of objects from particular tombs, but he was not consistent in doing this (Lacovara 1997:7). However, Reisner was usually careful to record his observations of botanical remains from the tombs in his field notebook. Lythgoe's recording of Cemetery 1200-1300 was less thorough than Reisner's. Our study of the archaeobotanical remains is confined to the samples retrieved from Cemetery 1-200 that were sent to the University of California, Berkeley by Reisner (Jensen 2019:48–50). Given the limited standards of recording in 1900 used by this Hearst Expedition, we cannot reconstruct the specific stratigraphy of Cemetery 1-200 to differentiate between the workers' village settlement and the later burial shafts that were found throughout these houses. Information regarding human remains was very cursorily recorded in Reisner's records and the current location of the remains is unknown (Jensen 2019:78–80), so detailed analysis of sex and age and their relationship to the grave goods including the botanical offerings is not possible.

Peter Lacovara worked at the site in the 1980s and published a preliminary report (Lacovara 1990) as well as an analysis of the architecture in comparison with other royal cities (Lacovara 1997). He cleared and planned several areas of the site including part of the North Palace, several houses, and a possible chapel. As part of this project, Wilma Wetterstrom conducted a flotation of organic samples from one rubbish deposit in the settlement (Wetterstrom 1990:25). The cemetery areas were not revisited by Lacovara's team. Since 2017, Lacovara has resumed work at the site to restore and protect certain areas, particularly the two large mudbrick monuments (North Palace and South Kom), and several settlement structures located to the west of the palace. Additional archaeobotanical remains were retrieved from one of these buildings, House E, in the 2019–2020 season by the author; the species recovered included emmer wheat, six-row barley, flax, sycomore fig, dates, doum, grape, bean (*Vicia faba* L.) and acacia pod (*Acacia nilotica* (L.) Del.) (Shahat unpublished field report 2019).

Other researchers have investigated sectors of the Deir el-Ballas cemetery material held at PAHMA over the years (Aston 1994; Bourriau 1982:78–81, 1990; Lilyquist and Brill 1993:24; Merrillees 1968:199, Plate XXXIII; Minor in press). Victoria Jensen's dissertation (Jensen 2019) is the first holistic publication and analysis of a large quantity of the cemetery material, synthesizing the Hearst Expedition's archival notes, maps, and photographs as well as information gleaned from examination of the artifacts held at PAHMA. A thorough publication of the Hearst Expedition work at the cemeteries is currently being prepared by a team led by Lacovara that includes Jensen and Shahat.

3.3 The archaeological context

Located on the west bank of the Nile 40 km north of Luxor, the site of Deir el-Ballas features a palace ("North Palace") dated to the reigns of Kings Seqenenre Tao and Ahmose (ca. 1560–1525 BCE), a mudbrick platform built on a hill that may have served as an observation post to watch the Nile as well as the desert to the west ("South Kom"), a workers' village, administrative structures, and over 70 houses (Lacovara 1981). Three cemeteries were discovered by the Hearst Expedition, two of which were recorded with some precision. Cemetery 1-200 consists of 197 tombs dug in the vicinity of the abandoned workers' village, while Cemetery 1200-1300 is located at the north end of the site and contains 54 tombs (Jensen 2019). Burials in both cemeteries date almost exclusively to the early 18th Dynasty (Ahmose – Thutmose III, ca. 1550–1425 BCE), with only a few tombs possibly dating to the late 17th Dynasty (ca. 1560–1550 BCE) or the late 18th – early 19th Dynasties (ca. 1390–1279 BCE). The most common grave good in these non-elite burials is ceramic vessels, with a few burials preserving stone kohl jars, bronze cosmetic implements, and scarabs, amulets, and beads made of faience, glass, and stone. Also, Kerma beaker ware, Nubian cooking ware, and Cypriot/Eastern Mediterranean wares (base-ring juglets and spindle bottles) were found in a few of the tombs (Jensen 2019). Almost all of the botanical remains at PAHMA that are identified with specific tombs originated from Cemetery 1-200.

Wooden artifacts such as coffins were extremely decayed and many were reduced to a cast on the dirt. In contrast, the botanical remains—which were all desiccated—showed good preservation. Whole fruits such as doum, dates, sycomore figs, and Christ's thorn have the pedicel preserved, and pomegranate rind fragments and date testa were intact. This uneven preservation of organic materials must be borne in mind when we consider the representativeness of the surviving archaeobotanical assemblage in relation to the original burials. Another consideration is to what extent the materials collected by Reisner and his team fully represent the plant taxa and their quantities that were originally deposited in the tombs. Is the overall limited quantity that was gathered indicative of the non-elite social status of the deceased, or were there originally more botanical assemblages that disappeared through natural taphonomic processes or looting? Additionally, some small botanical remains could easily have been missed due to the limited techniques of Reisner's time when flotation or dry sieving were not yet incorporated in field excavation, let alone sieving sediment. Another factor is the history of the curation and the treatment of the botanical materials after their discovery. Some plant materials—such as what Reisner called "grain husks" (Reisner 1900: D-2, D-3, D-4, D-5, and passim)—were commonly found in ceramic beakers but unfortunately these have been cleaned out. Luckily, the extant plant samples at the museum were not treated with alcohol or formaldehyde; such treatment would have altered the isotopic composition and hindered plans for carbon dating or stable isotope analysis.

The recovered zooarchaeological remains include bovine horn as well as bivalve, cowrie (Cypraeidae), conus, and nerite shells (Neritidae) and ostrich eggshell (*Struthio camelus* Linnaeus, 1758) fragments that came from tombs, houses, or the North Palace (Jensen 2019). Human remains were only skeletons, most of which were badly disturbed by looting activity in antiquity. Only half of the tombs in Cemetery 1-200 had any human remains recorded, so it is uncertain if the other interments were thrown out of the tombs during looting or if Reisner did not record human remains thoroughly (Jensen 2019). The current location of the human remains is unknown; they were not sent to PAHMA and Reisner's records do not inform us whether they were reburied at the site or sent to Cairo (Reisner, 1908).[16]

3.4 The archaeobotanical food offerings: archival and paleoethnobotanical lab analysis

According to Reisner's field notes, 65 of the 197 tombs (33%) in Cemetery 1-200 contained some sort of food offering (Jensen 2019). Within these select tombs there is a range of both quantity and diversity of botanical offerings. The highest number of tombs contained doum fruit (n=32) and grain offerings (n=29). Twelve tombs contained dates, while just a few tombs recorded a wider range of foods such as grapes (n=4), pomegranate (n=3), fig (n=3), Christ's thorn (n=2), desert date (n=2), juniper (n=1), persea (n=1), watermelon (n=1), tiger nut rhizome (n=1), and other organic remains of honeycomb (n=1) (Jensen 2019).

[16] Reisner offered all of the human remains from his excavations to G. Elliot Smith at the Khedival School of Medicine for analysis, but it is unknown if the Deir el-Ballas skeletons were among those sent to Smith (Reisner 1908: vii).

The most common food offering that was observed was husk of cereal grain. Reisner noted the presence of “vegetable husks” or “grain husks” in 71 small beaker-jars and “organic stuff” or “vegetable dust” in another seven beakers.[17] As noted above, these beakers have been cleaned out, so the species or their more specific plant parts remain uncertain. This now-lost and therefore unidentifiable material will be subsequently referred to here as simply “husks.”

In addition to husks, small beaker-jars were used to contain other foodstuffs and objects. Several contained fruit only; three beakers contained husks in addition to fruit; one had a scarab as well as husks; and a final one had fruit and a scarab. A few occurrences of rachis of emmer wheat and barley mingled with fruit remains.

3.5 The archaeobotanical remains in their tomb contexts

The following descriptions of 12 archaeological contexts provide background for the extant archaeobotanical remains from Cemetery 1-200 that are housed at PAHMA (Figures 6 and 7). The contextual descriptions are derived from Jensen’s archival research on the Hearst Expedition’s field notebooks, photographs, and maps, and are part of her forthcoming dissertation. Descriptions of the botanical remains are the result of Shahat’s examination of the samples in the museum (Shahat and Jensen in press).

[17] Reisner 1900: D-2, D-3, D-4 and D-5.

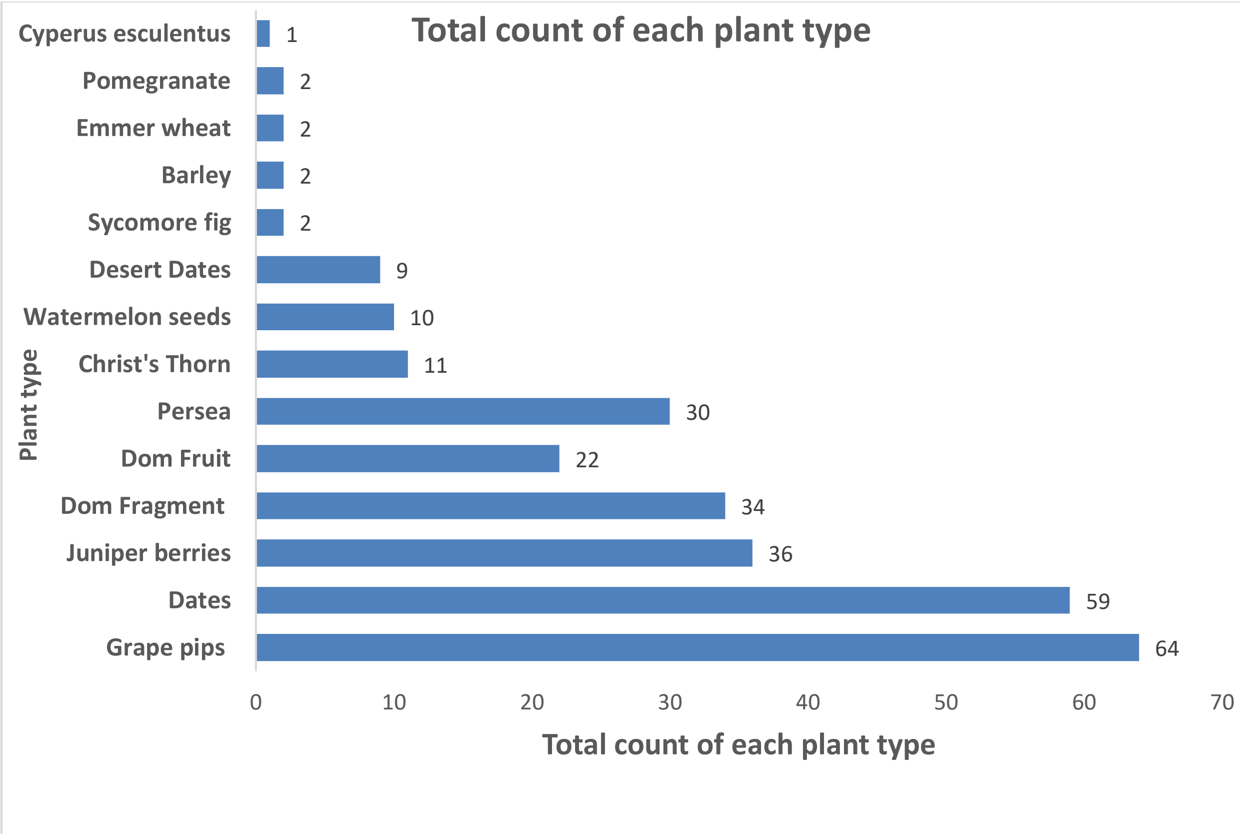

Figure 6. Plant species and their quantities in each tomb on context.

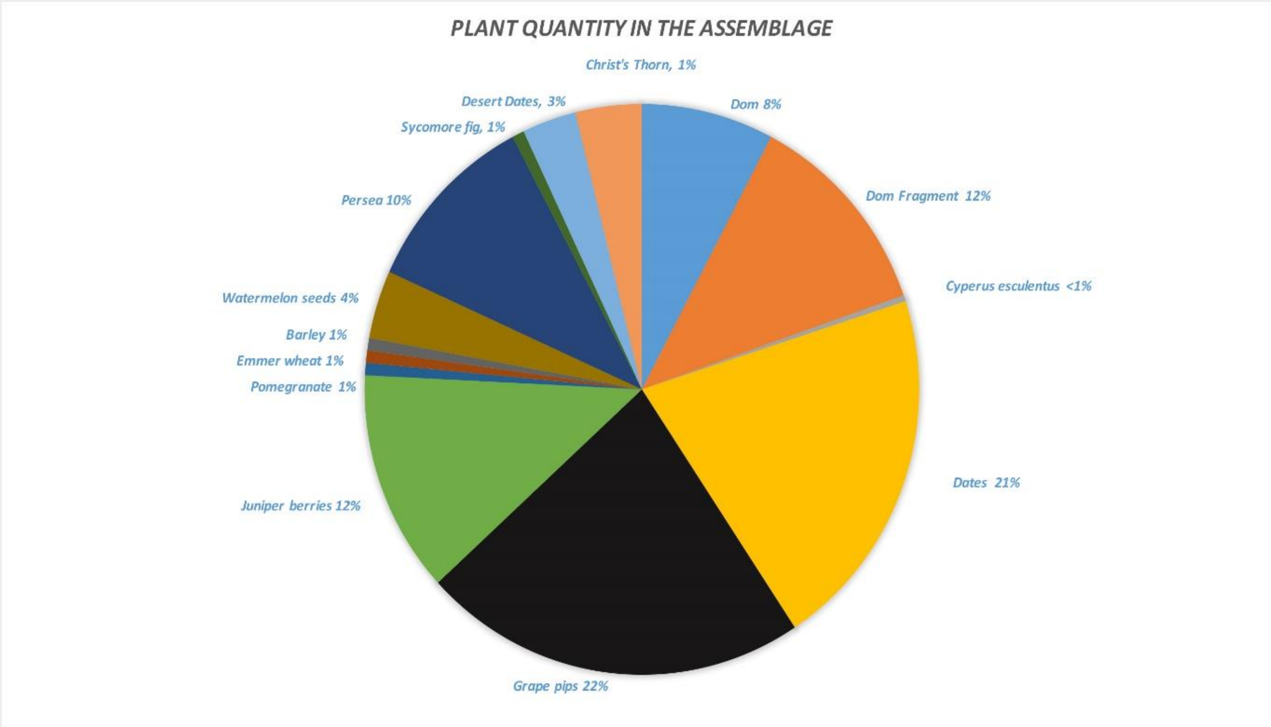

Figure 7. Plant species quantity in the assemblage

3.5.1 Pit east of Tomb 59:

This small, shallow pit 100 cm in length was located close to a plundered tomb.[18] It contained a small potsherd, a group of small beads, one whole sycomore fig[19] and two date pits, one with its testa preserved. Given the proximity to Tomb 59, this may have been an associated ritual deposit. Another possibility is that it might have been a child's burial, but without any surviving human remains, this can only be suggested.

[18] Reisner described the pit as being "just east" of Tomb 59; based on the dimensions in his sketch it appears to have been about 50 cm from the tomb (Reisner 1900:151, D-2).
[19] Reisner described the sycomore fig as a "small fruit" as apparently, he was unfamiliar with the species (Reisner 1900:151, D-2). Shahat has identified it as *Ficus sycomorus* (Shahat and Jensen in press].

3.5.2 Tomb 80

No elevation or plan sketch was provided by Reisner for this tomb in his notes (Reisner 1900).[20] There was a minimum number of individuals (MNI) of four in the tomb. Traces of one coffin made of plastered wood with a rounded top edge were noted. The pottery included carinated jars, beer jars, tall storage jars, and ten small beaker jars, most of which contained "vegetable husks." One of the beakers was Nile silt ware with a black-painted rim, a decoration that appeared in the late Second Intermediate Period and died out soon after the reign of Thutmose III (ca. 1560–1425 BCE) (Bourriau 1982:78, Seiler 2005:154). The botanical remains in this beaker contained "vegetable husks" and fragments of doum endocarp and the seed inside the endocarp.[21] Several faience beads were recorded. A small sherd of Nubian scratched ware, charcoal, and two flint chips were also found; these may have been part of the intentional burial deposit but more likely entered intrusively when the tomb was looted. The Nubian ceramic fragment shows evidence of burning and this type of pottery was used for cooking (Bourriau 1990: 17–18), so it likely originated in the domestic area near the tomb.[22]

3.5.3 Tomb 89

The tomb was a simple shaft oriented N–S (Reisner 1900).[23] It contained one interment, in which only the legs of the mummy were undisturbed; the head was at the northern end and a scarab was found in the vicinity of the ribcage. The burial goods included a partial Cypriot base-ring juglet

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[20] Reisner 1900:D-2, 131, 132, 137.
[21] Specimen identification by Shahat based on morphology (Shahat 2018a). In his field notes, Reisner called this specimen "small fruits/date seeds" (Reisner 1900: D-2, 137).
[22] Nubian scratched-ware sherds were found in seven tombs in the same area of the cemetery and were also found in numerous houses at the site. While such cooking-ware pots are known from Pan-Grave and Kerman burials, they are usually intact when purposefully placed in tombs see (Petrie 1901:Pl.XL).
[23](Reisner 1900:D-3, 73).

(Figure 8) datable to the early 18th Dynasty (Erikson 2006), a Nile silt bowl, and a burnished Nile silt beaker containing a food offering of 21 whole parthenocarpic (unpollinated) dates and seven fragments. On some of the parthenocarpic dates the calyx is preserved. They are extremely light in weight compared to pollinated dates: all 21 dates weigh 2.23 grams total, while the average weight of a single pollinated date pit in the assemblage is 1.24 grams.

Figure 8. Two Cypriot base-ring juglets and one fragmentfrom tomb 89 at Deir el-Ballas. Courtesy of the Hearst Museum of Anthropology, UC Berkeley.

3.5.4 Tomb 105

This was a small, shallow shaft, 1 m long and 0.75 m deep, built into the corner of a room of a house and oriented E–W (Reisner 1900:D-3). Human remains were not recorded. The plant remains were recorded by Reisner as “fragments of doum” (Reisner 1900) but the samples catalogued at PAHMA from this tomb include a whole date as well. One doum was intentionally cut and has a circular hole punched in the top (Figure 9). This modification is known from Nubia and Upper Egypt, where it is made into a child's toy, rattle, or necklace (Shahat, ethnographic observation). The only other recorded material in the tomb were bits of wood and plaster, possibly from a child's coffin.

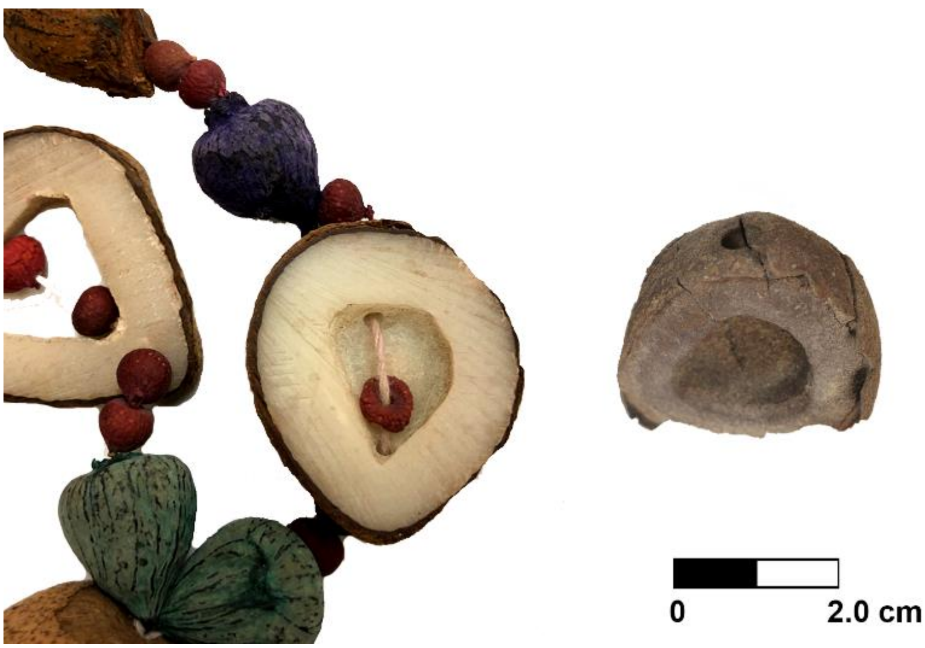

Figure 9. Worked doum fruit with hole on top (right) found in child tomb 105 and modern ethnographic parallel from Aswan as a necklace (left)

- Image credit for ethnographic parallel (left): Shahat 2018.
- Image credit for ancient specimen (right): Image courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California (6-6507).

3.5.5 Tomb 128

Oriented N–S along a house wall, this shaft tomb had a loculus[24] on the western edge (Reisner 1900).[25] No dimensions were recorded by Reisner. Two mostly intact burials were found in the tomb. The burial in the shaft had its head to the south, while the one in the loculus had its head oriented to the north. A white-painted Nile silt jar with a wide, flaring neck[26] contained food offerings of Christ's thorn, juniper berries, dates, pomegranate, and grapes, while a marl beaker contained "grain husks." Two beakers and one doum fruit were underneath a large, broken marl dish near one head. The tomb contained a relatively rich assemblage of two alabaster kohl jars, a small bichrome carinated jar, a wide bronze blade, a bronze needle, part of an offering stand, a tall storage jar, a small bottle with quatrefoil-shaped cup-like mouth, a burnished ring-based bowl, and a total of 13 beakers, many of which had black-painted rims (Bourriau 1982, Seiler 2005). The dating of this tomb is narrowed to the reign of a Thutmoside king (ca. 1504–1425 BCE) by the presence of a scarab inscribed with Ḏḥw.ty-ms (Thutmose).

3.5.6 Tomb 163

This shaft tomb was oriented N–S in the center of what was once a room (Reisner 1900).[27] Partial human remains were found resting on the floor of a wooden coffin. This tomb was one of the very few in the cemetery that held valuable objects: three kohl pots, a bronze razor and tweezers, several scarabs including one with the name and title of Senenmut (Hatshepsut's high steward), a faience necklace, earrings, finger rings, and glass amulets of Taweret, Sekhmet, and Bes. There were 22

[24] A loculus is a cavity carved out from one side of the bottom of the burial shaft.
[25]Reisner 1900:D-3, 76–78, 81–82.
[26] PAHMA 6-6621. This jar is similar to the bottles published in Seiler (2005:Falttafel 8), but the neck on the PAHMA example is shorter and wider.
[27] Reisner 1900:D-3, 171–73.

pottery vessels. Contained in a marl beaker were endocarps of two doum fruits, 34 grape seeds, 13 of which have their testa preserved, one date, and a scarab. Additionally, Reisner noted that a beer jar in the tomb contained roots (Resiner 1900).[28] This might be the result of grains sprouting in the vessel (Holthoer 1977:84).[29]

3.5.7 Tomb 190

Oriented E–W along a house wall, the tomb had a brick curb built around the mouth. At the base of the burial shaft, the tomb had two loculi behind mudbrick partition walls. [30] Human remains were not mentioned in the northern loculus but clustered at its western end were four dishes, a small Nile silt jar painted white, and three beakers. One of the beakers contained "grain husks," and another held two pits that Reisner tentatively identified as "2 fruits olive?",[31] (Reisner 1900), but are actually desert dates (*Balanites aegyptiaca* (L.) Delile). The southern loculus contained a mostly intact skeleton and an abundant amount of mummy cloth. Objects on this side were a black stone kohl jar, one beaker, and a doum fruit found near the head, while another beaker was near the left femur.

3.5.8 Tomb 192

Tomb 192 (Reisner 1900),[32] is oriented E–W in the center of a room. this tomb had one particularly large loculus to the north (100 cm long and 100 cm wide). No mention was made of human remains, but there were two boards remaining from the end of the coffin. The assemblage included

[28] Reisner 1900:D-3, 173.
[29] Holthoer noted that some of the "flower pot" forms from the Scandinavian Joint Expedition to Nubia contained remains of roots that likely originated from accidentally germinating grain seeds or fruits the vessels had contained.
[30] Reisner 1900:D-5, 10–11.
[31] Reisner 1900:D-5, 10.
[32] Reisner 1900:D-4, 66–68.

sherds from a jar that had applied decoration depicting hands holding breasts (Budka 2016, Seiler 2006). The tomb also contained many beakers, most containing “vegetable husks”; small saucers; a bowl with red-painted rim and splashes typical for the reigns of Thutmose III – Amenhotep II, ca. 1479–1400 BCE (Aston 2006); an offering stand; a beer jar; carinated jars; and two mud jar seals. A barley spikelet was embedded in one of the jar seals.

3.5.9 Tomb 205

The Hearst Expedition’s maps show that the tomb was oriented E–W in the center of what used to be a room before reusing the settlement as a cemetery.[33] No sketches were made of the tomb’s architecture and no mention was made of any human remains or funerary pottery. The recorded assemblage consists of a bead in the form of a fish, a blank scarab, and what Reisner termed “1 fruit” (Reisner 1900),[34] identified in this research as a desert date (*Balanites aegyptiaca*.); this example displays the exocarp and mesocarp but not the endocarp.

3.5.10 Tombs 244/255

Two grape seeds, five complete and six fragmented watermelon seeds, one unidentifiable piece of cereal chaff, one doum fruit mesocarp, and one tiger nut rhizome were catalogued at PAHMA as having come from Tomb 244.[35] However, the watermelon sample at least might have originated in Tomb 255 instead: Reisner’s notes for Tomb 244 (Reisner 1900),[36] were uncharacteristically brief and do not mention botanical finds, but his notes for Tomb 255 include “melon and date

[33] Reisner 1900:D-5, 13.
[34] Reisner 1900:D-5, 13.
[35] Shahat 2018a. Thanks to C. Newton, C. Hastorf, and M. van der Veen for confirming the identification of the watermelon (Newton, Hastorf, and van der Veen, pers. comm. September 2018) and Rim Hamdy, Cairo University, for confirming the tiger nut species identification (Hamdy, pers. comm. February 2019).
[36] Reisner 1900:D-5, 98.

seeds" (Reisner 1900).[37] This is the only mention of melon seeds in all of the field notes. Because of this ambiguity, both tomb contexts are described here together. Black-painted rims on pottery in both tombs indicate that they can both be dated from the late 17th Dynasty through the reign of Thutmose III (ca. 1560–1425 BCE) (Bourriau 1982:78, Seiler 2005:154). **Tomb 244**: Oriented E–W, the shaft descends to a loculus that was closed off by a brick partition wall. No dimensions were given. There is no mention of human remains in the field notes, but bones are visible in tomb photos along with 14 beakers and a large dish.[38] Moreover, PAHMA has other pottery (small saucers, a small carinated jar with neck) that have original field marks giving Tomb 244 as the findspot. **Tomb 255:** No dimensions were given, and the tomb is not identified on the map. It is described as a pit with its mouth bricked up, covered with a 1 m deep layer of *tafla* chips. It contained 15 pottery vessels as well as a coffin decorated with red, black, yellow, and dull white. In addition to the presence of melon and date seeds, Reisner noted that one beaker contained "grain husks."

3.5.11 Tomb 257

No architectural information or record of human remains were noted for this context; the only objects listed under this number are one pottery beaker and botanical remains.[39] Paradoxically, this was one of the most archaeobotanically diverse assemblages, consisting of 14 whole and 15 fragments of persea nuts, and one Nile silt beaker that contained two emmer wheat spikelets, one of which is the apical spikelet; one barley spikelet; small fragments of pomegranate rind and mesocarp holding one whole red seed; four Christ's thorn fruits; seven grape seeds; and three date

[37], Reisner 1900:D-12, 7.
[38]Hearst Expedition 1900–1901, photographs B-1054, B-1055, B-1056, B-1057, and B-1058.
[39] Reisner 1900:D-12, 9.

pits (Reisner 1900).[40] The beaker was burnished and decorated with a black-painted rim, thus dating the assemblage between the late 17th Dynasty through the reign of Thutmose III (ca. 1560–1425 BCE) (Bourriau 1982:78, Seiler 2005:145).

Uncertain contexts:

In addition to the tombs mentioned above, there are numerous references in the field notes to other tombs that contained "grain husks," "nuts", doum, dates, fig, pomegranate, and honeycomb, but these have not been linked with specific artifacts at PAHMA (Jensen 2019).[41] On the other hand, there are botanical materials at PAHMA whose specific proveniences at the site are lost. The latter are listed in Table 1 but they did not include any additional species. All materials are desiccated except for #6-8276, which was a mineralized macrofossil of doum fruit (Figure 10).

[40] Reisner described the persea as various seeds not date and doum, and the contents of the beaker as "small fruits, grain, etc." (Reisner 1900:D-12, 9).
[41] Jensen 2019. Further details of the contexts of all food offerings recorded in Hearst Expedition archival records—whether extant or not—will be presented in Jensen's dissertation.

Figure 10. A doum macrofossil in which the organic elements of the doum fruit were replaced with mineral composition in the soil that still takes the shape of the fruit. Photo by Amr Shahat (courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California (6-8276)).

3.6 Discussion

The funerary food offerings at Deir el-Ballas reveal a diverse assemblage of edible plants including a combination of both wild (e.g., desert dates, tiger nut rhizome, Christ's thorn, persea, and Phoenician juniper) and domesticated taxa (e.g., watermelon, pomegranate, emmer wheat, and barley) (Murray 2000b:511–13) (Figure 11).

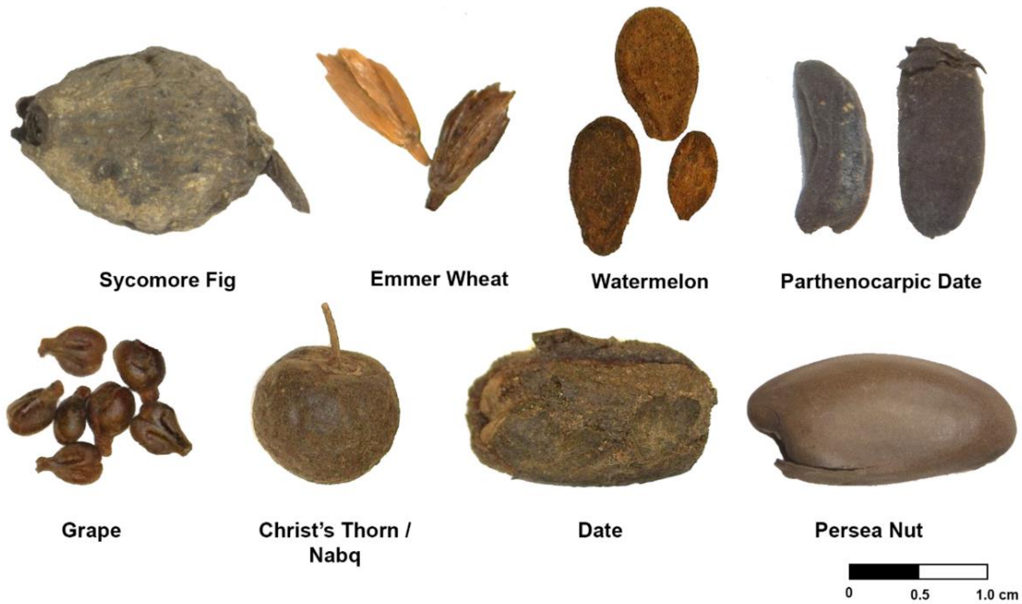

Figure 11. Plant species from different tombs show preservation by desiccation. Image credit: Amr Shahat, Venicia Slotten,[42] and Leslie Freund.[43]

Some wild taxa have a long history of continued use as funerary offerings, such as desert dates, which were found in the botanical assemblage from the neighboring Predynastic cemetery of Ballas[44] and persea nuts (Murray 2000a:610–12),[45] which are included in the offering formula in the 4th Dynasty stela of Wepemnofret (PAHMA 6-19825). Doum palm fruits are prolific, especially in Upper Egypt, with the earliest evidence dating to the Late Palaeolithic, while dates are attested sporadically, with the earliest evidence in the Predynastic (Murray 2000a:619, 621). At Deir el-Ballas, in addition to pollinated dates, 21 specimens of parthenocarpic dates were placed

[42] Many thanks for the help of Venicia Slotten during my academic year in the University of California Berkeley and particularly for her help with preparing these microscopic photographs for publication using Photoshop in archaeobotany to reflect the real size of the botanical samples.
[43] I express my thanks to Leslie Freund for her incessant help and coordination and her curatorial skills, which facilitated my analysis of the botanical remains at the Hearst Museum of Anthropology, University of California Berkeley.
[44] PAHMA 6-5755.
[45] Murray 2000:610–12 provides tables summarizing attestations of these species and more.

among the food offerings in one tomb. The discovery of parthenocarpic dates in the tomb of Tutankhamun (Terral et al. 2012:939)[46] shows that these non-sweet dates were acceptable as food offerings not only for the non-elite but for the elite as well. The continued presence of wild plants from the Predynastic into the Dynastic period in particular regional patterns indicates that these species continued to be valued alongside domesticated and imported taxa.

The doum endosperm in Tomb 105 invites us to be careful while analysing each plant part because not every edible plant buried in the tomb is meant as food; in this case, the doum was intentionally cut in half and punched with a hole, showing that this fruit was used to make an object like jewelry or a toy, as is still done today in Upper Egypt and Nubia (Shahat ethnographic observation). By considering the context of Tomb 105, which had remnants of wood that may have been a child's coffin, the worked doum endosperm may have been a necklace or an object embodying a sentiment toward a deceased child.

Although chaff is not a readily edible commodity, the grain "husks" found in many beakers may have been indeed a foodstuff. Coarsely processed grains in their husks, known as *srmt*, were an intermediate product in the production of beer that was consumed as well as included in tombs as a food offering, as demonstrated by Samuel (2000:543–55). However, it may also have been simply packing material, as seen in the findings in KV63 (Hamdy and Fahmy 2018)[47] and in Saqqara tombs (M. El Dorry, pers. comm. January 4, 2019) and also noted and analyzed by the author among the collection of Kha and Merit from Deir el-Medina in Luxor.

[46] Terral et al. 2012:939 reported an ethnographic observation that parthenocarpic dates are undesirable for human consumption and are only used as fodder.

[47] Hamdy and Fahmy 2018:45. However, the chaff found in this embalming cache (KV63) is hypothesized to have been used to pack the body during mummification, which does not pertain to the non-mummified remains at Deir el-Ballas.

Our data contribute to the understanding of these plant-based food offerings as being available to and valued by the non-elites, as well as the elites. What is lacking from the tombs at Deir el-Ballas are written offering formulae, iconographic representations, and physical offerings of meat and fowl that are common in elite burials (Ikram 2015:132–33). In elite tombs, offering formulae give a list of the elite's idealized choices of foods that were deemed important for their afterlife. They also contained a larger quantity and diversity of actual food offerings than what has been identified in Cemetery 1-200.[48] For example, the burials at Deir el-Ballas that included doum contained from one to at most five fruits. In contrast, a more elite burial dating to the 2nd–3rd Dynasty at Nag ed-Deir, also found by Reisner, contained 40 doum fruits, weighing 1615g (PAHMA 6-1737 from Tomb 3753). At Deir el-Ballas, the small quantities of food may have been caused to an extent by taphonomy, but it is also possible to be indicative of common people having less expendable food stuffs for their dead that they could afford to leave in the tombs.

The food offerings include cultivars that have historical origins from different regions. An African cultivar, domesticated watermelon (*C. lanatus*) was found in one burial. According to Wasylikowa and Van der Veen, the earliest reliable published identification of *C. lanatus* in Egypt (as of 2004) comes from the tomb of King Tutankhamun (Egyptian Museum, Cairo catalogued under SR 1/4500), although other, earlier samples might belong to this species (Wasylikowa and Van der Veen 2004:214). More recently, domestic *C. lanatus* was published among the botanical discoveries from Amarna (ca. 1345–1336 BCE) (Stevens, C. and Clapham, A., 2014, p. 157). The history of watermelon is a subject of debate because *C. lanatus* is polymorphic, with some forms

[48] A statistical analysis of food offerings published from elite tomb contexts would make for an interesting quantitative study to compare with our non-elite material but is beyond the scope of this dissertation.

confused in older archaeobotanical reports with the native wild *C. colocynth* known in Egypt since the Predynastic (Wasylikowa and Van der Veen 2004:213).

From the Eastern Mediterranean, juniper berries, grapes, and pomegranate were imported to Egypt, where they underwent a process of cultural absorption and indigenization (Pearsall and Hastorf 2011:182, Dietler and López Ruiz 2009:30–31). Grapes were indigenized into Egyptian culture in the Predynastic Period as wine presses are depicted on 1st Dynasty seal impressions (Murray 2000c:577). From the Juniperus family, *J. phoenicea* berries are attested in the mid-18th Dynasty Tomb of Kha at Deir el-Medina (Mattirolo 1926:551–54), as well as the tomb of Tutankhamun (ca. 1332–1223 BCE, Cairo Museum sp. 2803 & 2789, catalogued under SR 1/4500; Lucas 1942:145).

Pomegranate was reported from Dra Abu el-Naga in what may have been a 12th Dynasty context (Schweinfurth 1884:314), but is known more securely from Tell ed-Dabʿa in the Second Intermediate Period (Thanheiser 2004:378) and became indigenized in the 18th Dynasty (Murray 2000a:625, Ward 2003:533, table 1). Tomb 128 held pomegranate and the only confirmed evidence of juniper in our assemblage as well as a scarab naming Thutmose. While pomegranate had already been introduced to Egypt, the fruit's absorption into Egyptian culture seems to have increased in the Thutmoside period, as witnessed by the botanical depictions of pomegranate in Thutmose III's Akh-Menu at Karnak Temple and in tombs of the 18th Dynasty (Murray 2000a:625). Increased contacts with Cyprus and the Levant are also shown in the material culture evidence, as Cypriot base-ring ware and Eastern Mediterranean red lustrous wheel-made ware appear in Egyptian tombs beginning in the early 18th Dynasty (Erikson 1993:97–98, 149–53, Hein 2018:137), including the non-elite Deir el-Ballas cemeteries (Jensen 2019).

Whether the Deir el-Ballas plants were cultivated locally or brought in as imports is discussed in Chapter 4. Regardless of when the indigenization of these plants happened, finding them inside tombs indicates that these plant species carried funerary/afterlife meaning and value in the Egyptian cultural setting.

From an anthropological perspective, a contextualized analysis of the archaeobotanical funerary assemblage at Deir el-Ballas provides an illuminating lens with which to view different social meanings of plant use. As food offerings, they hint at the sensory experience of taste associated with these plants to the living (Pearsall and Hastorf 2011:128). However, certain plants were valued funerary offerings not only because they were a delicious food but because they also embodied religious symbolism, such as the sycomore fig's association with Hathor and Nut (Sheikholeslami 2015:83) or the doum fruit's with Thoth (Santolini 1984).[49] Pomegranate, as an exotic fruit, was depicted in the Karnak Botanical Garden by Thutmose III among the exotic flora and fauna brought into Egypt by the king. However, this finding of pomegranate in Deir el Ballas is an early example of this fruit from a non-elite context.

3.7 Conclusion

The non-elite burials of the early 18th Dynasty in Cemetery 1-200 at Deir el-Ballas were excavated in 1900 but were never published. Our archival research has revealed that Reisner documented evidence of food offerings in one-third of the excavated tombs. In those tombs that contained botanical remains, quantities were small, which may be due to limited access of the deceased's family to large quantities of food offerings. The primary botanical remains were what Reisner

[49] In a hymn to Thoth, the doum is said to contain water that refreshes the deceased (Gardiner 1937:85–86; thanks to Emily Cole for her translation).

termed “grain husks” (which were discarded) and doum fruits. Additional species were deposited in a small number of tombs: date, sycomore fig, desert date, pomegranate, grape, watermelon, Christ’s thorn, tiger nut, persea, and juniper berries.

Archaeobotanical analysis—particularly in the case of non-elite populations such as those of Deir el-Ballas, which had almost no written offering formulas or funerary iconography within the tombs—is an invaluable source of information to understand the complete composition of food offerings. Throughout Egyptian history, cultural interactions are echoed in the diversity of plant materials as new taxa were introduced into the traditional group of food offerings. Thus, as part of Egyptian beliefs about the afterlife, the concept of what constitutes a proper food offering was reshaped over time, reflecting both continuity and change. The data from Deir el-Ballas shows that the indigenization process of including originally foreign plants such as watermelon, pomegranate, and juniper as funerary food offerings applies in this non-elite community of the early 18th Dynasty, as it did in elite and even in royal contexts. The fact that these non-traditional food offerings are in a non-elite context are an even stronger argument for their acceptance as part of the “proper” offerings. Although the samples presented here came from funerary contexts, they offer a baseline with significant implications for further applications of stable isotope in archaeobotany and the bioarchaeology of diet in ancient Egypt. We recognize the caveat that the species found in funerary food offerings might not be representative of the diet of individuals. However, we argue that the mortuary offerings represent food items that were available to at least some members of the community during life. Furthermore, all of these fruit species except for pomegranate have been identified in non-elite settlement contexts, either in a recent archaeobotanical analysis by A. Shahat in Deir el-Ballas or in the Amarna Workmen’s Village (Stevens and Clapham 2014).

CHAPTER 4

4. Stable isotopic values of ancient Egyptian food offerings: A case study from a non-elite cemetery of Deir el-Ballas.[50]

4.1 Introduction

In this chapter I present baseline ^{13}C stable isotope data and AMS ^{14}C dates for five botanical species excavated from Cemetery 1-200 at Deir el-Ballas, Upper Egypt (Figure 12). A workers' village consisting of tightly-spaced mudbrick houses was subsequently reused as a cemetery when the floors of many rooms and alleyways were cut through to insert the graves of Cemetery 1-200. Based on the material culture, these graves date between the early 18th Dynasty and the early 19th Dynasty, with only a few tombs containing material that could possibly date as early as the late 17th Dynasty. While there was variability in the quantity and variety of grave goods, as well as the subterranean tomb architecture indicating a range of socioeconomic hierarchy in the local population, none of the tombs was decorated or provided evidence of elite titles.

[50] An abridged version of this chapter will appear as a book chapter in press with the following citation: Shahat, **Amr and Victoria Jensen, 2021, Biomolecular Stable Isotope and ^{14}C Dates of Ancient Egyptian Food Offerings: A Case Study from a Provincial Cemetery of Deir el-Ballas, in S. Ikram, J. Kaiser, and S. Porcier (eds),** ***The Ancient Egyptians and the Natural World: Flora, Fauna, and Science*****, Leiden: Sidestone Press**. Thanks to my co-author, Victoria Jensen who contributed with archaeological contexts and ceramic data. I contributed with the stable isotope lab research and carbon dating on the paleoethnobotanical materials, and interpretation of archaebotanical materials.

Figure 12. Map of Cemetery 1-200 indicating the graves from which isotopic study on plant remains was conducted. Hearst Expedition maps (Sheets I, II, and III) courtesy of the Museum of Fine Arts, Boston. Edited and annotated by Victoria Jensen.[51]

Archaeobotanical analysis of remains from Cemetery 1-200 yielded a total of 243 specimens of 13 species (see Chapter 3). This chapter focuses on five graves from this cemetery, reporting on AMS ^{14}C values on botanical findings from the tombs to help determine the date of the burials, ascertain that these species are not intrusive, and relate the archaeobotanical offerings to the material culture assemblages. Additionally, the carbon stable isotope measurements help identify local species grown with Nile water versus imported non-local species based on water-use efficiency reflected by the ^{13}C. The botanical species of focus here include doum fruit from Tomb 105, juniper berries from Tomb 128, grapes from Tomb 163, the special finding of domesticated watermelon from Tomb 244 or 255, and pomegranate from Tomb 257. This chapter aims to communicate the results

[51] Tombs 255 and 257 are not identified on this map because the Hearst expedition did not record their locations.

of stable isotope analysis in plants to bioarcheologists that can serve as a baseline on the diversity of plant sources contributing to isotopic input observed in bioarchaeological remains.

The population buried in the cemetery is designated as "non-elite" as distinguished from royal or high-level courtiers and priests, whose decorated tombs at Thebes and Saqqara have been a prominent source of Egyptological information on funerary food offerings.[52] The population that inhabited the area after the abandonment of the palace shows a lack of access to texts, with only a handful of individual's names recorded and almost no titles, which are a key component of elite self-presentation used to display their proximity to the king (Frood 2010:476–77).[53] However, the community exhibits a range of socioeconomic hierarchy as reflected in the graves, which show differential access to material culture, indicating that some individuals may have been better off than others (Jensen 2019:431–43). For instance, both Tomb 128 and Tomb 163 discussed in this chapter exhibited a higher than average diversity and quantity of material culture, including stone cosmetic jars, bronze razors, and royal name scarabs, as well as rarely-attested fruits including imported juniper. Archaeobotany may contribute to the discernment of social status by showing who had access to imported fruits versus who did not.

The botanical samples from Cemetery 1-200 have not been published since they were stored in the university museum over 100 years ago. A visual analysis using a stereomicroscope was conducted on all botanical remains known from the site by Shahat at 20x magnification at the UC Berkeley McCown Archaeobotany Laboratory. Two hundred and forty-five specimens were

[52] For the New Kingdom, the term "elite" in Egyptology is often mainly defined with a bias toward what burials look like in the Theban region; there is less discussion of what a provincial elite or non-elite burial may have looked like in other regions (Kara Cooney, pers. comm.2019)

[53] Cemetery 1-200 features simple tomb architecture that primarily consisted of undecorated shafts or shafts with loculi (Jensen, 2019). In Cemetery 1-200, of approximately 200 tombs there were only two stelae discovered: one dating to the early 18th Dynasty in which the deceased is given no title, and one dating to the late 18th to early 19th Dynasty that mentions a *nb.t pr* offering to a *w'b*-priest, which is the lowest level in the priestly hierarchy.

identified based on morphology, including 13 different species belonging to 11 different families. This analysis showed regular use of native wild fruits such as doum, date, sycomore fig, desert date (*Balanites aegyptiaca* L.), persea (*Mimusops laurifolia* Forssk.), and Christ's thorn (*Ziziphus spina-christi* (L.) Willd), along with domesticated wheat and barley. Moreover, funerary food offerings also included foreign species such as domesticated watermelon, which was originally a East African, plant but could have been grown locally by this time (Chomicki and Renner 2015), and pomegranate and juniper berries from the eastern Mediterranean (Asouti et al. 2018:1–38). Although these plant species were found in a funerary context, their presence at the site indicates that they were available to the population living at Deir el-Ballas in the early 18th Dynasty. Moreover, except for pomegranate, as we discuss below, all these species have also been encountered in the settlement excavations at Deir el-Ballas and/or the workers' village at Amarna, and thus almost certainly were not reserved for exclusive use as grave goods but were consumed by the living. However, these samples from Deir el-Ballas are the earliest attestation of pomegranate, domesticated watermelon, and juniper in the Egyptian paleoethnobotanical evidence.

4.2 Aims and objectives

Since the site of the cemetery was originally a settlement associated with the palace at Deir el-Ballas before its reuse as a necropolis, it was necessary to conduct ^{14}C AMS dating on the archaeobotanical materials to ensure that the items investigated are not intrusive or a result of post-depositional processes and to determine the date of tombs lacking material culture. Carbon dating was further helpful in verifying the ancient dates of the plants that have been rarely reported to have been found prior to this cemetery's investigation. In particular, the earliest encounter of domesticated watermelon in Egypt continues to be much debated in Egyptian archaeobotany, with the earliest securely dated samples coming from the Amarna workers' village (Stevens and Clapham 2014), so one specific objective was to discover the date ranges of the samples buried as food offerings at Deir el-Ballas to contribute to the discussion of *C. lanatus* seeds. One alert for us regarding post-depositional concerns in these reused contexts comes from archaeobotanical materials excavated by Reisner at another site, the Predynastic cemetery of Nag ed-Deir. In one case there, the carbon dating of the botanical remains was at odds with the material culture.

The species I investigated were chosen as part of a long-term project to create a baseline dataset of ^{13}C values to serve the community of researchers in Egyptian archaeobotany and bioarchaeology. The question for us is to understand the ancient food ecology and how much imported fruits arrived into these communities, identified by different paleoecological conditions compared to those grown along the Nile. The species measured here are the commonly-encountered wild local doum fruit, found in the cemetery in Deir el-Ballas, and cultivated species such as grape, as well as the rarer findings of what were originally non-indigenous plants such as pomegranate, watermelon, and juniper. Measuring the traditional carbon stable isotope traditionally helps determine the photosynthesis pathway of the plant, whether it is C_3 such as cereals, fruits, and nuts in Egypt or C_4 (e.g., sorghum, millet), which were more common in sub-Saharan Africa than in Egypt during the pharaonic period (Thompson et al. 2008). The value of the stable isotopes to archaeobotany is thus helpful to bioarchaeologists in differentiating between the Egyptian plant-dietary input, which was predominantly C_3, versus the Nubian diet that was higher in C_4 (Thompson et al. 2008).

In this study, a further step is taken to provide additional archaeobotanical data. The ^{13}C isotope values provide information not only regarding whether each species is a C_3 or C_4 plant but also about the ecophysiological conditions that affected the plant and the paleoenvironmental history of the sample. For example, in this study, the ^{13}C of the juniper berries had a carbon value of –19.5, showing that the plant grew in ecological conditions of limited water, which differs from local Egyptian plants that grew along the Nile river, which were also found in the same cemetery. Thus, the use of ^{13}C isotope analysis captures important information on the paleoecology of the plant, particularly on the efficiency of water use by plants and the climate conditions under which the plant grew, helping to determine whether it is locally grown or imported.

Therefore, this project contributes a dataset that serves bioarchaeologists and zooarchaeologists by adding to a baseline of stable isotope data on specific plant species that were part of ancient Egyptian flora and were part of the food culture and funerary food offerings. To communicate the stable isotope results of these plant species to bioarchaeologists, the key argument here is that bioarchaeological literature to date has focused on C_3 domesticates such as wheat and barley as dietary staples in ancient Egypt, but stable isotope tests on many archaeobotanical remains provide more fine-grained information of the detailed "menu" that contributed to such isotopic values we gain from human bodies. Local wild plants found among the funerary food offerings as well as the settlement of Deir el-Ballas, such as doum and sycomore fig, are infrequently discussed by bioarchaeologists dealing with past diet and isotopic data, even though these were a wide range of C_3 plants contributing to the isotopic input of the Egyptian diet.[54] As such, these plants I have analyzed contributed to the ^{13}C isotope values observed in the analysis of ancient Egyptian human bones and teeth and should be included in future interpretations of their dietary interpretation.[55]

[54] The ^{13}C isotope value for doum coming from the cemetery is presented below in this chapter, while the value of wild sycomore fig from a modern type collection is –26.76 ‰ (Shahat unpublished lab report 2019).

[55] One major caveat here is our inability to study the human skeletal remains from Deir el-Ballas to correlate the stable isotope results between food remains and human bones. Reisner did not record where he stored the human remains and they were not sent to Berkeley.

4.3 Materials and methods

All archaeobotanical materials were found during Reisner's excavations in 1900 and sent to the University of California, Berkeley in the early 1900s. The botanical samples are preserved at PAHMA in a desiccated condition. AMS dating was conducted on the five botanical samples noted in Table 7, following the pretreatment protocol steps of chemical cleaning, combustion, and graphitization. The samples were treated by an acid-base-acid chemical cleaning process to remove calcareous contamination and humic and fulvic acids (Olsson 1986:273–312). Humic and fulvic acids can remain in botanical samples coming from residing in a dry desert, in which case they do not require chemical cleaning with a base; however, if the humic and fulvic acids come from soil the resulting dates will be biased toward a more recent age.

4.3.1 Sample preparation sequence

1. **Chemical cleaning**: Since all samples were preserved by desiccation and not charred, the protocol commonly applied on charred botanicals was modified to a less rigorous pre-treatment process to allow for the fragility of the desiccated botanical materials from a desert environment. The samples were thus treated with less severe base solutions and heat, as noted in Table 7: 1N HCl was applied for 30 minutes at an elevated temperature of 70–80° C.

   The next step of the cleaning process was conducted with a single rinse of 0.25N NaOH at room temperature for 10–30 minutes. 1N HCl was applied again for 30 minutes at room temperature or elevated temperature according to the integrity of the samples. Neutralization of the samples was conducted by rinsing several times using ultrapure milliQ water. When the samples were treated with an acid solution, they turned yellow, which indicates contamination with fulvic acid, and when treated with base solution they turned yellow or brown. In either case, they were completely cleaned by the end of the application of the final acid solution (Table 7).

<table>
<tr><td colspan="2">Progression of pretreatment steps →</td><td>HCl(1)</td><td>NaOH(2)</td><td>HCl(3)</td><td>milliQ (4)</td></tr>
<tr><td>PAHMA #</td><td>Context</td><td colspan="4">Sample</td></tr>
<tr><td>6-6509</td><td>Tomb 105</td><td colspan="4">doum fruit fragment</td></tr>
<tr><td>6-6626</td><td>Tomb 128</td><td colspan="4">juniper berry seed fragment</td></tr>
<tr><td>6-6895</td><td>Tomb 163</td><td colspan="4">grape seed fragment</td></tr>
<tr><td>6-7482</td><td>Tomb 244 or 255</td><td colspan="4">watermelon seed fragment</td></tr>
<tr><td>6-7517</td><td>Tomb 257</td><td colspan="4">pomegranate rind fragment</td></tr>
</table>

(1) 5 mL 1N HCl for >30 min. @ 70–80° C
(2) 5 mL 0.2N NaOH for 5–10 min. @ room temperature
(3) 5 mL 1N HCl for 10 min. @ 70–80° C
(4) 2 or 3 rinses of 5 mL ultrapure milliQ water for 10 min. @ 70–80° C

Table 7. Chemical treatment summary

Sample combustion:

For the combustion process, 2 mg were taken from each dried sample mixed with cupric oxide as an oxygen source and put in a quartz tube. The tube was sealed under vacuum with a gas torch. Then it was exposed to combustion for 3 hours at 900º C. The samples were then cryogenically cleaned and placed in vials with an iron-powder catalyst in them and measured in the W.M. Keck Carbon Cycle Accelerator Mass Spectrometer Lab.

Graphitization:

After the combustion process, the samples were graphitized under gaseous state using a hydrogen-reduction method by which the samples were heated for 3 hours at 525º C. The graphites were then placed in an aluminum sample pellet to be analyzed in an accelerator mass spectrometer (AMS) at UC Irvine (Table 7). Results of carbon dates and $\delta^{13}C$ ‰ are presented in Table 8.

Duplicates of the samples were taken to another laboratory for cross-testing at the University of California Berkeley, School of Life Sciences. This second run of the samples included drying the samples under 60 degrees Celsius in the oven for two days then crushing them into powder and weighing them in silver capsules for the oxygen isotope measure of the carbonyle group. The measure of the oxygen-18 is very sensitive to weight error and should be an exact weight of 0.35mg for each sample. Results are summarized in Table 9.[56]

Sample ID	UCI AMS #	Yield % C	$\delta^{13}C$ ‰	Modern fraction	$D^{14}C$‰	^{14}C age (^{14}C yr BP)	Calibrated date (cal BCE)
Hyphaene thebaica 6-6509	219088	47	–25.0 ± 0.1	0.6830 ± 0.0012	–317.0 ± 1.2	3060 ± 15	1395 – 1334 (51.9%) 1326 – 1265 (43.5%)
Juniperus phoenicea 6-6626	219089	50	– 19.5±0.1	06726 ± 0.0012	–327.4 ± 1.2	3185 ± 15	1498 – 1428 (95.4%)
Vitis vinifera 6-6895	219090	54	–24.93	0.6715 ± 0.0011	–328.5 ± 1.1	3200 ± 15	1501 – 1435 (95.4%)
Citrullus lanatus 6-7482	219091	56	–23.5 ± 0.1	0.6740 ± 0.0011	–326.0 ± 1.1	3170 ± 15	1496 – 1471 (22.1%) 1465 – 1413 (73.3%)
Punica granatum 6-7517	219092	53	–22.3 ± 0.1	0.6695 ± 0.0011	–330.5 ± 1.1	3225 ± 15	1526 – 1447 (95.4%)

Table 8. AMS carbon dating and $\delta^{13}C$ stable isotope results

[56] The watermelon sample had a weight error and therefore the result was not reliable and not reported here

Sample	δ18O ‰V-PDB	δ13C ‰ V-PDB
Doum fruit	23.8	–25.4
Pomegranate	30.85	–22.3
watermelon	-----	–23.5
Juniper	27.9	–19.5

Table 9. Summary of the results of the oxygen and carbon stable isotope on the samples.

4.3.2 Stable isotope analysis

^{13}C stable isotope analysis was conducted on botanical fragments from the cleaned and graphitized gaseous samples. An aliquot of the gaseous sample was collected from the vacuum line and placed in a Fisons NA-1500NC elemental analyzer connected with a Delta-Plus stable isotope mass spectrometer (IRMS). I confirm that these are the ^{13}C values reported here in Table 12, not to be confused with the conventional ^{13}C measures taken by the AMS spectrometer to correct for fractionation factors during the ^{14}C dating process. The latter are usually less precise and give drifted values as much as 3‰ (T. Dawson, pers. comm. 2018) and are therefore not reported here. Carbon isotope results are reported in parts per thousand (permil values) $\delta^{13}C$ ‰, relevant to the international standard VPDB (Vienna Pee Dee Belemnite). The isotopic composition of carbon in the plant specimens is expressed following the standard equation (Faure and Mensing 2005:753).

- $$\delta^{13}C = \left(\frac{(^{13}C/^{12}C)\ \text{sample} - (^{13}C/^{12}C)\ \text{standard}}{(^{13}C/^{12}C)\ \text{standard}} \right) X1000$$

Equation 1

4.4 Results:

4.4.1 Tomb 105: context for doum sample

This was a small, shallow shaft 75 cm deep that was dug into the corner of a room of a house, oriented E–W. A several-courses-high mudbrick wall was built at the bottom of the shaft along the east and north sides, with only a few centimeters of space that were cleared behind these walls. The width at the mouth of the shaft was 80 cm but the bottom of the shaft was just 37 cm wide. The depth of the shaft was 103 cm, and the northern mudbrick wall reduced the usable space to 95 cm. Human remains were not recorded, and the only objects found included fragments of doum fruit and bits of wood and plaster; a fragment of wood was found clinging to the bricks on the north side. Given the size of the shaft, the wood may have been from a child's coffin. No pottery or other material culture was recorded, but the ^{14}C dates obtained from these doum fragments have a range of 1395 – 1265 BCE (Figure 13), the period from Amenhotep III into the early reign of Ramesses II. Only a few other tombs in the cemetery can be dated to this same late 18th to early 19th Dynasty timeframe, based on their material culture, so this ^{14}C data is useful in identifying another tomb of that period that otherwise would have remained a mystery in terms of its dating.

The doum fruit's ^{13}C stable isotope value was -25.4 ± 0.1, identifying it as a C_3 plant growing in good water conditions. Since doum palms grow in Egypt along the Nile Valley in Upper Egypt, this sample may serve as a baseline for non-water stressed C_3 plants locally grown in the region at this time. Meanwhile the measure of the non-exchangeable $\delta^{18}O$ in the organic matter of the doum fruit is 23.80 ‰. This shows the higher humidity environmental conditions of local irrigated plants along the Nile in the past, in contrast to the results of the experiment in Chapter 2 in which the oxygen isotope on modern similar species face extremely high evaporative conditions driven primarily by decreased relative humidity, temperature increase, and higher aridity conditions of the soil consistent with all data that post-dates the construction of the high dam.

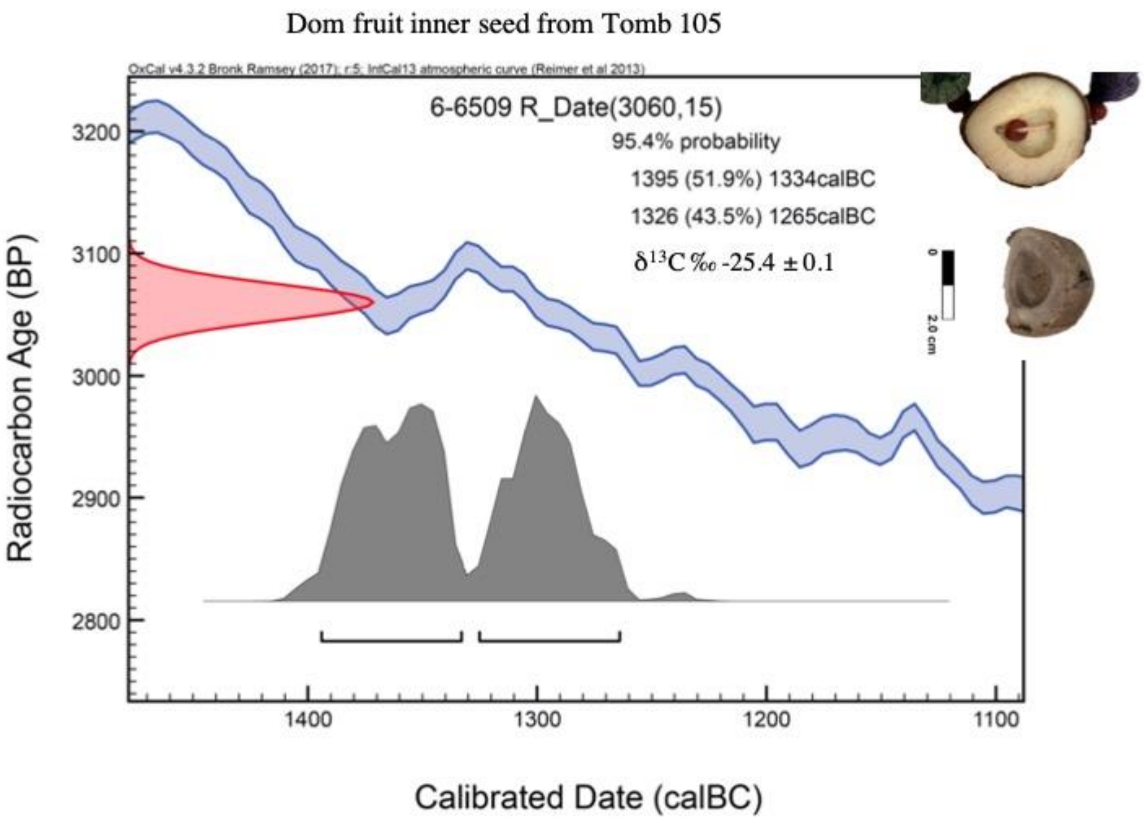

Figure 13. Sample #6-6509 *Hyphaene thebaica* doum fruit.

As shown in figure 13, sample #6-6509 *Hyphaene thebaica* doum fruit shows the inner seed, punched probably as a child's piece, coming from child grave 105 in Deir el-Ballas. The figure also presents calibrated radiocarbon results using OxCal 4.3.2. Double lines denote the IntCal13 terrestrial calibration curve with 1-σ envelope (Reimer et al. 2013). Inset denotes the results of Bayesian statistical analysis. (Amr Shahat and Brian Damiata, Cotsen Institute of Archaeology, UCLA).

4.4.2 Tomb 128: context for juniper berry sample

This tomb was oriented N–S along a house wall of the abandoned workers' village. No dimensions were recorded, but the field note sketch indicates that it had one loculus carved out along the western edge of the bottom of the shaft. Two seemingly intact burials were found in the tomb (Figures 14 and 15). The burial along the eastern side at the base of the shaft was supine and had its head to the south; a biconical necked jar with pendant line decoration, alabaster kohl jar, bronze needle, and bronze blade as well as a beaker containing grain husks were found near the head, while two large dishes and part of an offering stand were near the feet. The burial in the loculus had its head to the north, with the head turned to the side.

Figure 14. Tomb 128, south end, showing head end of burial in shaft, legs of burial in loculus (Hearst Expedition Photograph B-1042). Courtesy of the Phoebe A. Hearst Museum of Anthropology.

Figure 15. Tomb 128 tomb assemblage (Hearst Expedition Photograph C-1739). Courtesy of the Phoebe A. Hearst Museum of Anthropology.

Eight beakers and a jar were clustered near the head of this burial, while a stone kohl jar, biconical ceramic jar, white-painted Nile silt jar containing fruit, two beakers, a bowl, and a doum fruit *Hyphaene thebaica* were placed near the feet. A scarab inscribed "Ḏḥw.ty-ms" (6-8767) was found in the tomb, but its precise findspot was not recorded (Figure 16). However, it provides *terminus post quem* evidence that this tomb dated as early as the 18th Dynasty, but to which Thutmosid king's reign is uncertain. Some of the beakers had black-painted rims, a decoration that is not attested after the reign of Thutmose III (Bourriau 1982:78), indicating that the scarab may be inscribed for Thutmose I, II, or III, but not Thutmose IV.

A  B

Figure 16. A and B: Scarab (6-8767) from the Hearst Museum found in tomb 128 inscribed with the name of King Thutmose (Jensen 2019:726–27, 1225).

The white-painted Nile silt jar (6-6621, Figure 17) contained a variety of fruit species including Christ’s thorn, juniper berries, dates, pomegranate rind fragments, and grapes. Notably, we see a combination of wild local plants as well as imported juniper berries that do not grow in Egypt. Although juniper berries are now sometimes reported growing in the North Sinai region, they are nonetheless recorded as an endangered species according to the Egyptian government (El-Bana et al. 2010).

Figure 17. Jar (6-6621) found in tomb 128 in Deir el-Ballas. It is a white-painted Nile silt jar, which contained local and imported plant species (Courtesy of the Hearst Museum).

The association of edible organic material with a Thutmoside scarab provides an interesting dating opportunity. AMS carbon dating was run on a fragment of *Juniperus phoenicea* (6-6626) at UC Irvine using the ^{14}C pre-treatment chemical protocol yielding 50% of carbon with a calibrated date range between 1498 and 1428 BCE and 95.4% certainty (Figure 18). Aston's study of archaeological, astronomical, textual, and radiocarbon results, and their implications for New Kingdom regnal lengths, concludes that the most likely accession date for Thutmose III should be 1493 BCE (Aston 2012:309–10, Ramsey et al. 2010); this king is known to have died in his Year 54 (Aston 2012:293), which would be 1440 BCE according to this chronology. Thus the radiocarbon dates for the tomb's juniper berries align well with the reign of Thutmose III, as does the ceramic evidence based on the presence of black-painted rims that disappear from use after this reign. The scarab could have been an heirloom inscribed for one of his Thutmosid predecessors (Thutmose I or II), or it may have been inscribed for Thutmose III, making it contemporary with the tomb's organic contents. Thus this circumstantial archaeobotanical data can be added to that already amassed for 18th dynasty historical dating inquiries.

The ^{13}C stable isotope analysis on the juniper berries gave a significantly higher value ($\delta^{13}C$ = –19.5 ± 0.1‰) than all other C3 plants in the cemetery food offerings. A duplicate sample of the juniper berry was run by the author without AMS ^{14}C acid-base-acid chemical pre-treatment in the Dawson Stable isotope facility in UC Berkeley for cross-checking of lab precisions. The atomic carbon percent yield of the untreated duplicate sample is 45.38 % C and the $\delta^{13}C$ carbon value is –19.11 ‰. The implications of these consistently high values in the juniper sample duplicates for understanding the ecological environment in which the plant grew are explored in the discussion section below.

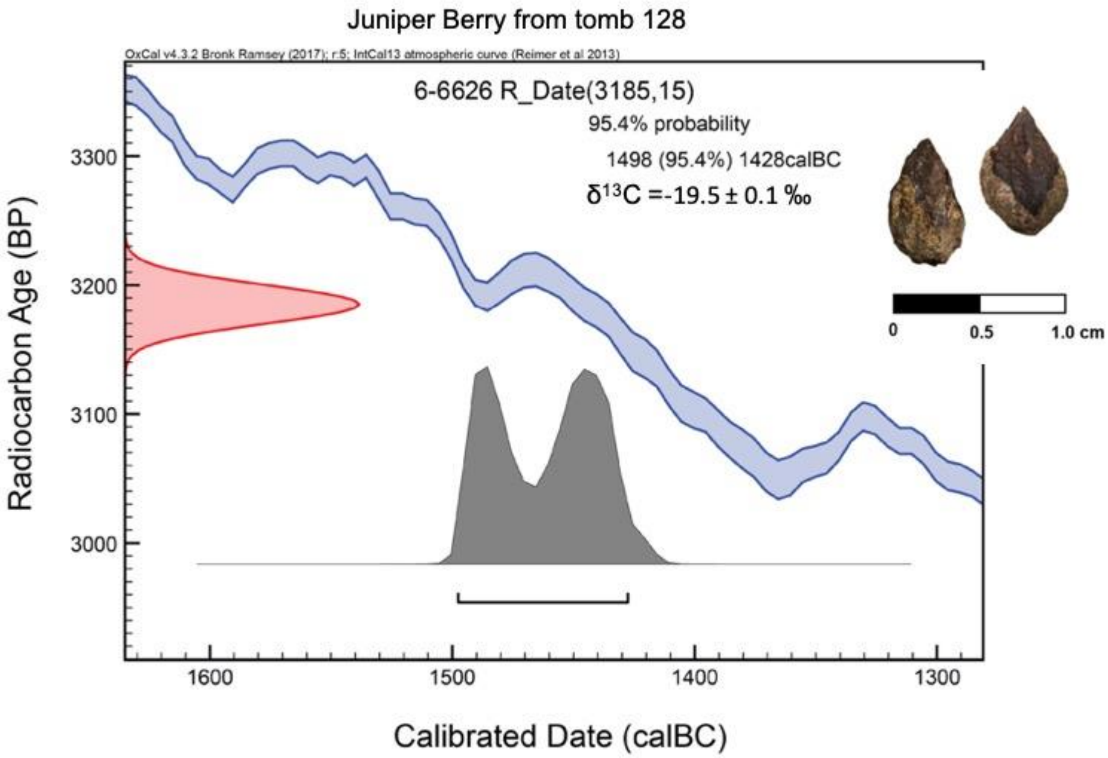

Figure 18. Carbon date chart for sample #6-6626 *Juniperus phoenicea* juniper berry

Figure 18 presents the carbon dates chart of sample #6-6626 *Juniperus phoenicea* juniper berry, from Tomb 128, Cemetery 1-200, Deir el-Ballas, illustrating the calibrated radiocarbon results using OxCal 4.3.2. Double lines, which denote the IntCal13 terrestrial calibration curve with 1-σ envelope (Reimer et al. 2013). The inset denotes the results of the Bayesian statistical analysis. (Source: Amr Shahat and Brian Damiata, Cotsen Institute of Archaeology, UCLA).

4.4.3 Tomb 163: context for the grape sample

This was a shaft tomb that was oriented North–South and was located in the center of a room in the worker's village. The shaft was 210 cm deep, 70 cm wide, and 230 cm long. Reisner recorded finding the lower legs of a human skeleton on a "rotten board," presumably the floor of a wooden coffin, the rest of which had decayed completely. There were 22 pottery vessels found in this tomb.

Reisner noted the presence of roots inside a beer jar (6-8101, Holthoer's BB-3 type) (Reisner 1900:173, Holthoer 1977:86–88, Pl.18). However, at some point the contents of this jar were emptied and the vessel as it is currently preserved at PAHMA does not contain any visible residue. Two doum fruit endocarps, one whole date and 34 grape pips (6-6895), along with a scarab inscribed with a spiral design (6-8798) were found within one of the beakers (Figure 20). At least 13 of these grape pips have part of the fruit skin preserved (see Figure 19).

Figure 19. Grape pips (sample #6-6895); some pips have part of the fruit skin preserved. (Courtesy of the Phoebe A. Hearst Museum).

Figure 20. A scarab inscribed with a spiral design (6-8798). (Courtesy of the Phoebe A. Hearst Museum)

A sample weighing 30 mgC was taken from grape pip 6-6895 for carbon dating. The sample yielded 54% of organic carbon. The AMS-^{14}C calibrated results fall in the range between 1501 – 1435 BCE with 95.4% certainty (Figure 21). The sample size was too small to obtain δ^{13}C results from the treated sample. However, the measure of a powdered yet chemically untreated duplicate sample of grape pip was measured in UC Berkeley, yielding +28.11 %C, which is almost half of the yield from the treated sample. The δ^{13}C value of this sample is –24.93‰ which falls in the range of regular C_3 plants in non-water stress conditions or irrigated. The nitrogen isotopic composition in this grape pip sample is $\delta^{15}N = +14.84$ ‰, with C:N % ratio of 9.699%, a high value that reflects either the use of fertilizer or richer soil fertility for where this grape was grown (Szpak and Chou 2019, Araus et al. 2014:4), as opposed to modern depleted soil fertility reflected in modern type collections of similar species grown in the same region, due to the use of fossil-fuel-based fertilizers that are depleted (close to or below 0‰) in their ^{15}N isotopic composition (Sharp 2017: 9–17).[57]

[57] For example, nitric acid emission from farming using modern industrialized fertilizer and fossil fuel emission causes lower values of ^{15}N (Schulze et al. 1994:765). This is extremely important in the case of Egypt, especially after the increased use of industrial fertilizer after losing the naturally fertile soil deposited by the annual floods due to the construction of the High Dam at Aswan.

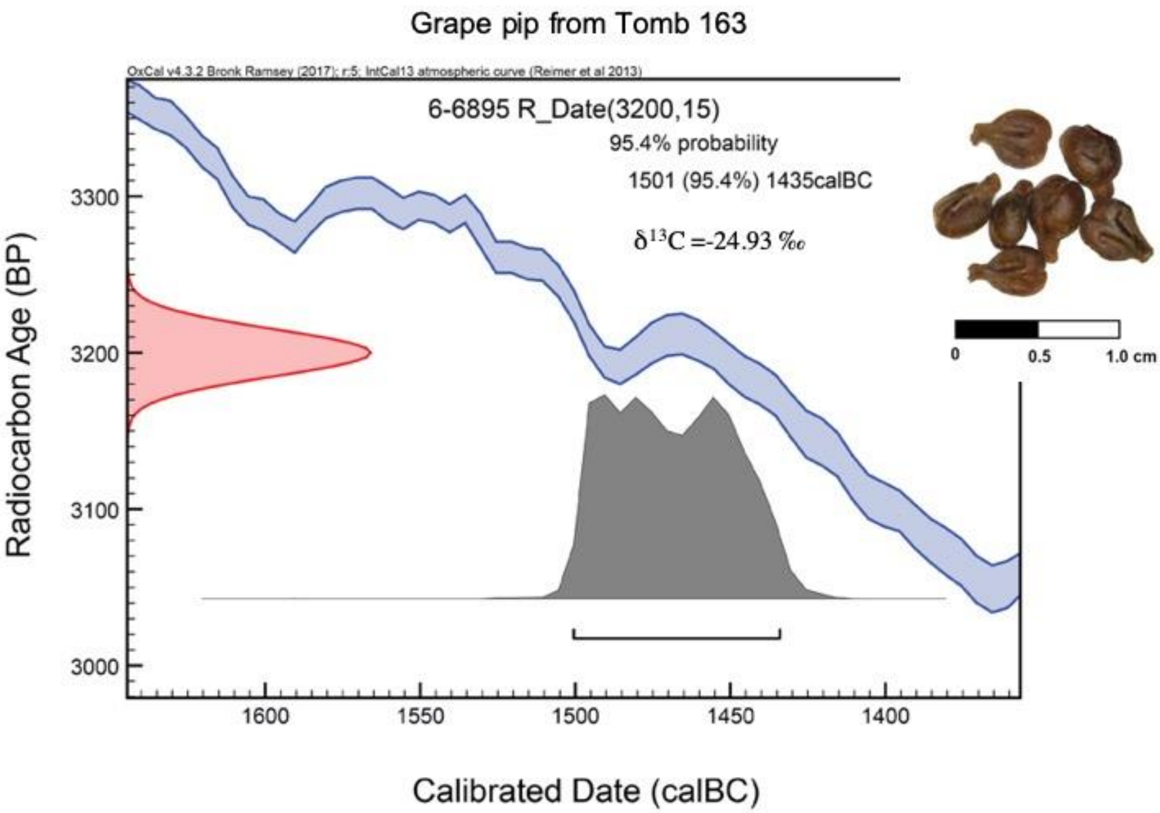

Figure 21. Sample #6-6895, *Vitis vinifera* grape pip fragments.

Figure 21 presents sample #6-6895, *Vitis vinifera* grape pip fragments, from Tomb 163, Cemetery 1-200, Deir el-Ballas. The chart presents the calibrated radiocarbon results using OxCal 4.3.2. Double lines denote the IntCal13 terrestrial calibration curve with 1-σ envelope (Reimer et al. 2013). Inset denotes the results of Bayesian statistical analysis. (Source: Amr Shahat and Brian Damiata, Cotsen Institute of Archaeology, UCLA).

The objects in Tomb 163 revealed an assemblage that was relatively more numerous and diverse than most tombs in the cemetery, despite the simple architectural style of the tomb. Small finds from the tomb whose exact findspot is uncertain include bronze tweezers, a necklace made of thin faience discs, penannular earrings, an ear stud, finger rings, a bone needle, as well as amulets made of glass and faience that include the deities Taweret, Sekhmet and Bes (Jensen 2019:115–19, Fig. 31) (see Figure 22)

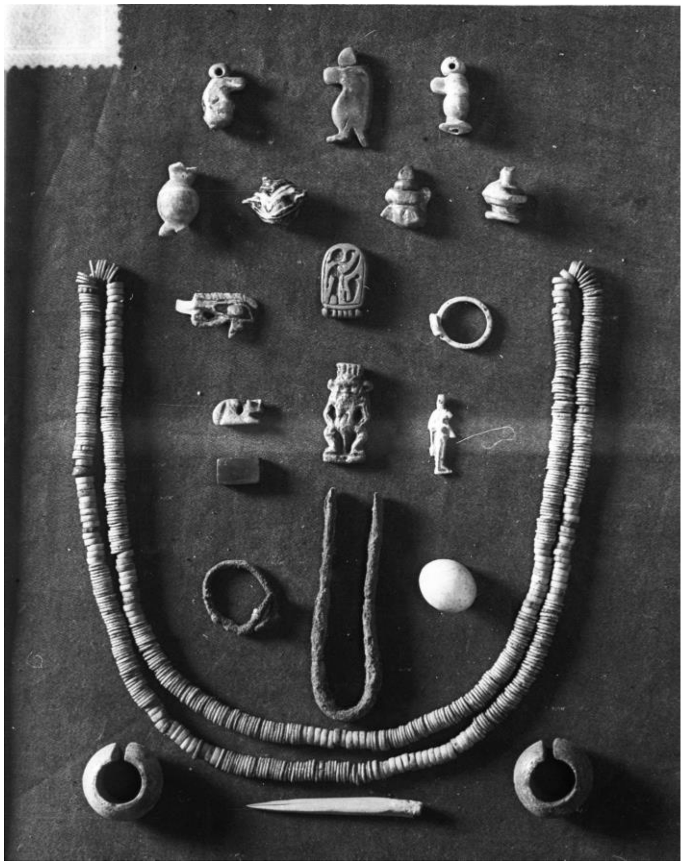

Figure 22. Objects from Tomb 163, including amulets, necklace, and finger rings. (Courtesy of the Hearst Museum)

As shown in an expedition photograph (Figures 23 and 24), clustered around the lower legs at the foot end of the shaft were three stone kohl pots, two small biconical ceramic jars with painted decoration, offering dishes, and numerous small beaker jars, including the one mentioned above that contained the fruit and scarab.

Figure 23. Tomb 163, south end (Hearst Expedition photo). Courtesy of the Phoebe A. Hearst Museum.

Figure 24. Tomb 163 pottery assemblage (Hearst Expedition Photo C-1744). Courtesy of the Phoebe A. Hearst Museum.

Near this beaker, beside the right leg, a bronze razor and two scarabs were found, one of which was inscribed with the name of Hatshepsut's high official Senenmut (6-8795) (Figure 25), giving his title as Steward of Amun (Jensen 2019:102, 104, 468–69, appendix 3).[58] The complete

[58] Photos of the scarab can be found on the Hearst Museum website at https://portal.hearstmuseum.berkeley.edu/catalog/3525bed0-5cd7-4d4c-ac90-8eeb00584777.

inscription reads *imy-ra pr Imn 4nnmwt ms n jAt-nfr* (Overseer of the House of Amun, Senenmut, born of Hatnofer) (Jensen 2019:104) (Figure 25). This helps to narrow down the carbon dating results for the grape seeds (1501 – 1435 BCE), as Senenmut is thought to have been given this title around the time of Hatshepsut's coronation in Year 7 of Thutmose III's reign (Dorman 1988:119–20, Eichler 2000:11ff, 17ff, 217, Shirley 2014:191), i.e., 1486 BCE.[59] Senenmut's last known date in the office is Year 16 (1477 BCE), although he may have lived a few more years (Dorman 1988:176–77, Hayes 1960:42–43, Shirley 2014:192). This date range for Senenmut's tenure as Steward of Amun helps to pinpoint the production date of the scarab to no earlier than c. 1486 BCE and thus indicates the earliest possible date of the botanical sample, but of course, the tomb owner might have been buried with this object after Senenmut's career had ended, therefore the AMS dating of the grapes is important to pinpoint the *terminus ante quem* date of burial as 1435 BCE, some 40 years after Senenmut disappears from the historical record.

[59] Following Aston's dating of the coronation of Thutmose III in 1493 BCE, this would place Hatshepsut's coronation seven years later in 1486 BCE and Year 16 of the joint reign would equate to 1477 BCE (Aston 2012:309–10).

Figure 25. Scarab (6-8795) with the botanical samples in a jar in Tomb 163 inscribed with the title of Senenmut. (Courtesy of the Phoebe A. Hearst Museum).

4.4.4 Tomb 244/255: context for watermelon sample

A collection of diverse botanical remains in the Hearst Museum, registered under number 6-7482, were attributed to Tomb 244 as their provenience. These included cereal chaff, a doum fruit mesocarp fragment, and the intriguing discovery of seven seeds of domesticated watermelon (*Citrullus lanatus*). Also, one rhizome of tiger nut (*Cyperus esculentus*) was found desiccated inside a vile of a soil sample. However, there is a point of confusion, in that Reisner's field notebook did not include any notes on botanical findings from Tomb 244. Normally, he carefully numbered and described the material from each tomb (including plant remains) but in this case he only sketched the tomb elevation and wrote "19 pots." However, he did record finding "melon and date seeds" in another tomb, Tomb 255. Since this was the only mention of melon seeds in all the excavation notes by Reisner, it is not certain whether the watermelon seeds held at PAHMA belong to Tomb 244 or 255. Nonetheless, both contexts can be dated to the early 18th Dynasty based on their similar style of pottery assemblages.

Tomb 244: The tomb consisted of a vertical shaft with a loculus carved out at the bottom. No dimensions were recorded, but the sketch indicates that the loculus was separated from the shaft by a mudbrick partition wall that was intact. Human remains were not listed in the field notes, but Reisner took five photographs of the tomb, in some of which disarticulated human bones can be seen.[60] Although the contents of Tomb 244 were not described in Reisner's notes in detail, ten ceramic vessels at PAHMA have been associated with this tomb, thanks to the original field numbers preserved on the pottery. These include a biconical necked jar (6-7480) decorated with concentric red- and black-painted lines; such bichrome ware came into vogue in the reign of Thutmose III (Hope 1987:109).

Tomb 255: This tomb was described as a pit with the mouth bricked up and was covered with a 1 m layer of rock chips (*tafla*). Human remains were not mentioned, but Reisner recorded the presence of a coffin that was painted red, black, yellow, and white. No information about the pattern or designs of the coffin were noted. Like Tomb 244, Tomb 255 contained pottery of the early to mid 18th Dynasty such as beakers with black-painted rims, one of which contained grain husks (6-7499). Tomb 255 also held a tall ovoid storage jar (6-7498) that was red-slipped and decorated with concentric black bands. This type of decorated jar finds parallels in Aston's New

[60] The photographs are B-1054, B-1055, B-1056, B-1057, and B-1058.

Kingdom Phase I, from the reigns of Ahmose through Thutmose II (Aston 2003:141, Fig. 1b) but also continues into the reign of Hatshepsut/Thutmose III, particularly in the Theban region (e.g., Galán 2014:254).

The carbon dates on the Deir el-Ballas watermelon seed:

AMS carbon dating of *C. lanatus* had a 56 % carbon yield. Calibrated dates fall between 1465 and 1413 calBCE with 73.3% certainty and 1496–1471 with 22.1% certainty (Figure 26). If we compare 1465–1413 calBCE dates with the higher probability to Aston's suggested high chronology of 18th Dynasty reigns, this 52-year time period begins about 30 years into the reign of Thutmose III (1493–1440 BCE) and extends into the reign of his successor, Amenhotep II (1440–1409 BCE) (Aston 2012:309). This date range aligns well with the Tomb 244 pottery, given the bichrome ware that appears in the reign of Thutmose III and continues into Aston's Phase 2B (Amenhotep II – Thutmose IV), but it also could match Tomb 255 if the actual date of the watermelon falls in the earlier half of the range suggested by the carbon dating, i.e., the reign of Thutmose III.

As for the carbon isotope ratio $\delta^{13}C$ of the domesticated watermelon, an aliquot of the remaining sample of carbon dating was taken in gas form and run in IRMS in UC Irvine. The $\delta^{13}C$ value is –23.5 ± 0.1 ‰, which is in the range of C_3 plants (Figure 26).

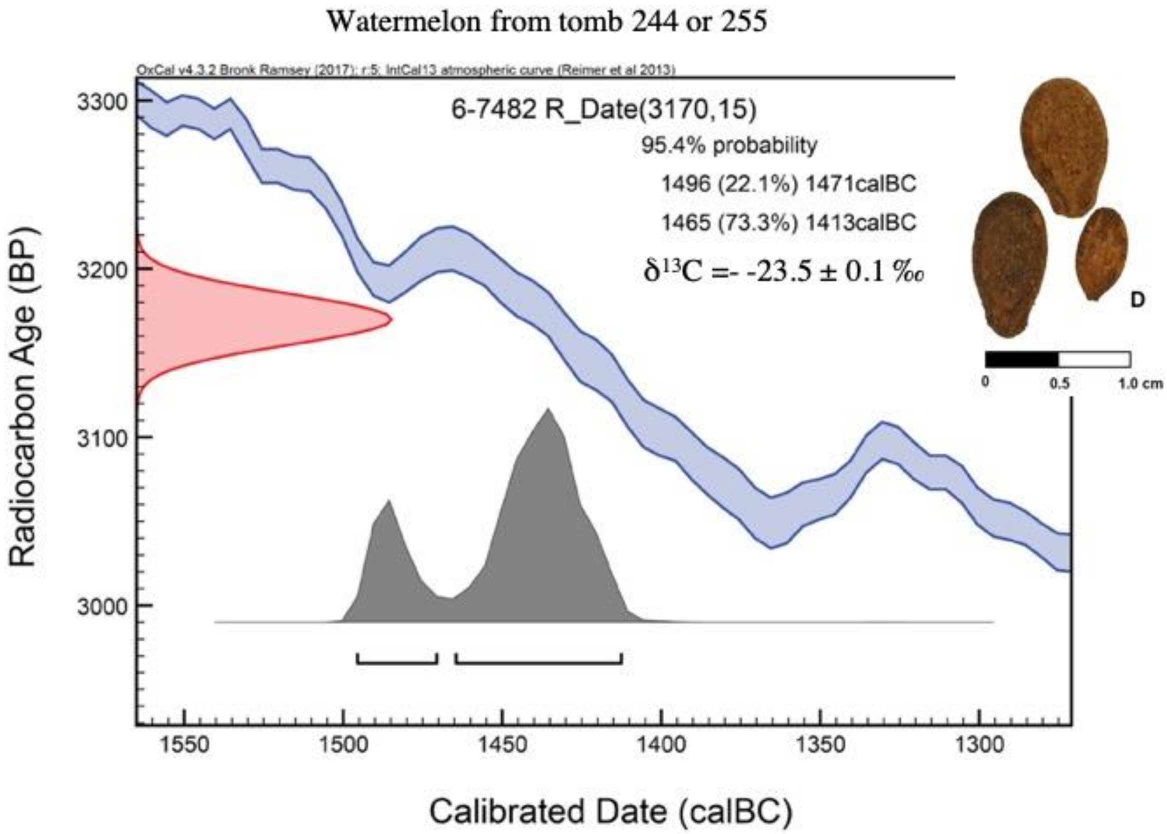

Figure 26. Carbon dates for sample #6-7482 *Citrullus lanatus* domesticated watermelon

In figure 26, the carbon date of the domesticated water melon is presented. It was found in Tomb 244 or 255, Cemetery 1-200, Deir el-Ballas. Figure presents the calibrated radiocarbon results using OxCal 4.3.2. Double lines denote the IntCal13 terrestrial calibration curve with 1-σ envelope (Reimer et al. 2013). Inset denotes the results of Bayesian statistical analysis. (Source: Amr Shahat and Brian Damiata, Cotsen Institute of Archaeology, UCLA).

4.4.5 Tomb 257: pomegranate sample

This tomb revealed the most diversity of food offerings, but unfortunately it has the least archaeological information that can be associated with the botanical remains. Under the number 257 in Reisner's field notebook, there is no description or sketch of a tomb. The only artifacts he recorded under this number were the botanical remains and one Nile silt beaker that was burnished vertically and had a black-painted rim (6-7520). There were 14 whole seeds and 15 fragments of persea (*Mimusops laurifolia*)[61] found in this context, while the beaker contained two emmer wheat spikelets (*Triticum dicoccum*), four Christ's thorn fruits, seven grape pips, three date pits, as well as a large number of pomegranate rind and mesocarp fragments (*P. granatum*), one of which still held one red seed of pomegranate, with the color preserved. A fragment of pomegranate rind (6-7517) was sampled for carbon dating, revealing dates between 1526 and 1447 calBC with 95.4% certainty (Figure 27) The relative dating suggested by the ceramic vessel with its black-painted rim would place this context from the late 17th Dynasty through the reign of Thutmose III (Bourriau 1982:78). The carbon date range obtained from the pomegranate sample helps narrow this window to the early 18th Dynasty, excluding the late 17th Dynasty and the reign of Ahmose.

The carbon isotope ratio $\delta^{13}C$ was –22.3 ± 0.1 ‰, indicating that the pomegranate is a C_3 plant (Figure 27). There was no sign of drought or water-stress conditions, so it was most likely grown in irrigated conditions. However, it is not straightforward to say whether it was grown locally in Egypt or imported without conducting further isotope analysis of oxygen and strontium. As for the other fruits such as persea and Christ's thorn, they are currently known within Egypt with a regionally specific pattern from the south. Archaeologically, they are found in large quantities in assemblages that come almost exclusively from Upper Egyptian contexts. Based on the ^{13}C isotopic measure done on a modern reference collection collected from Cairo University Herbarium, the $\delta^{13}C$ of persea is –27.57‰. A modern sample of Christ's thorn fruit was also collected from a tree on the west bank of Luxor and has the $\delta^{13}C$ value of –26.02‰, which means that the local wild fruits of persea and Christ's thorn are also C3 plants.

[61] Persea fruits found in the tombs were mainly the inner seed parts and the actual fruits were not found.

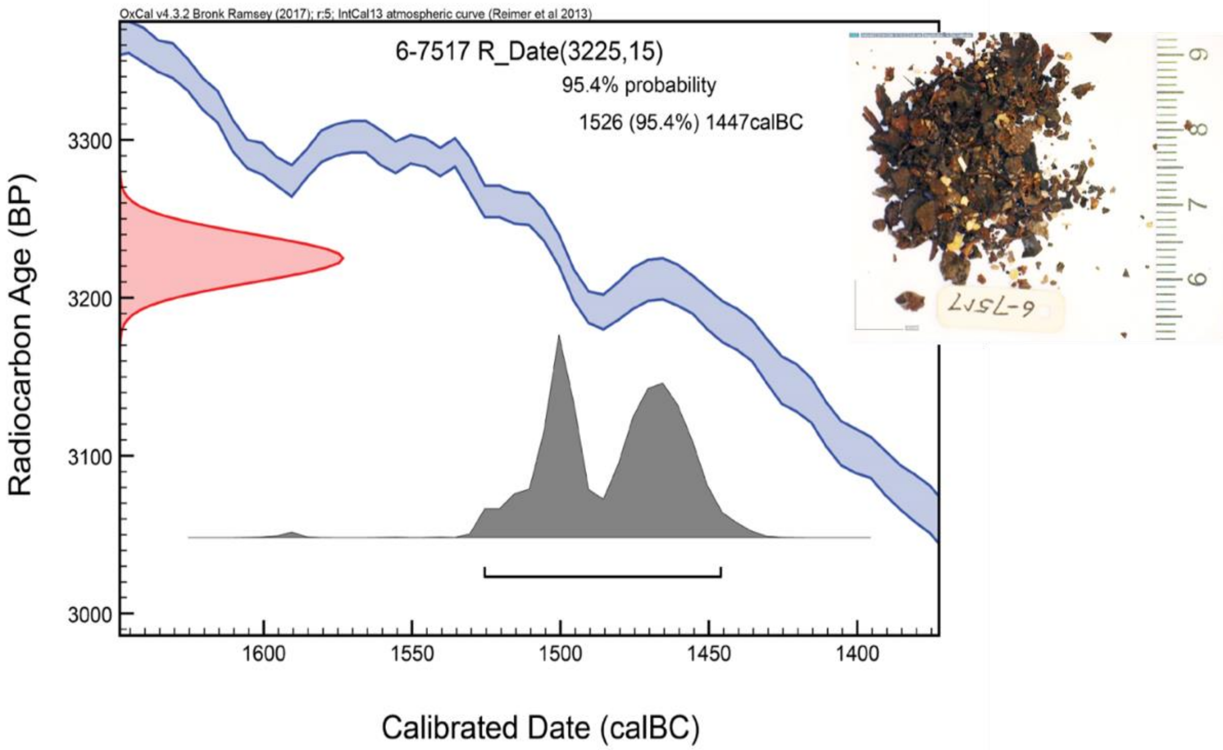

Figure 27. Sample #6-7517 *Punica granatum* pomegranate rind fragment, Tomb 257

In figure 27, sample #6-7517 *Punica granatum* pomegranate rind fragment, Tomb 257, Cemetery 1-200, Deir el-Ballas. Figure presents calibrated radiocarbon results using OxCal 4.3.2. Double lines denote the IntCal13 terrestrial calibration curve with 1-σ envelope (Reimer et al. 2013). Inset denotes the results of Bayesian statistical analysis. Bayesian calibration by Brian Damiata, Cotsen Institute of Archaeology, UCLA.

4.5 Discussion

The composition of food offerings in the cemetery shows the significance of wild Upper Egyptian fruits such as doum, persea, Christ's thorn, desert dates, palm dates, and sycomore figs, in addition to domesticated cereal grains (barley, wheat) as well as local and imported fruits (juniper berries) in ancient Egyptian foodways and food offering composition. While it can be argued that finding these plant species in a burial context is not evidence that they were consumed or were a standard part of ancient Egyptian diet, the recent discovery of several of these fruit species (doum, date, sycomore fig, and grape) in the Deir el-Ballas settlement as well refutes the idea that such plants were reserved exclusively for funerary use (Shahat field notes 2020).[62] However, specific foods may have had different meanings in the funerary context. For instance, doum fruit, which was the most common grave offering in Cemetery 1-200 after cereal grains, can rather be interpreted through the hymn to Thoth, in which the doum is mentioned to contain water as a blessing from Thoth to refresh the deceased (Gardiner 1937:85–86).

Meanwhile, the concept of offerings for the afterlife was not limited to traditional plants that were locally available. Imported or newly introduced species were also added to the food offerings across Egyptian history, and we see this introduction of novel species echoed in several tombs at Deir el-Ballas. It is beyond the scope of this paper to delve into an analysis of the socioeconomic hierarchy at Deir el-Ballas and a thorough comparison of this provincial site with Thebes. However, we assert that while imported fruits may have been largely restricted to people of relatively high status, they were not entirely unreachable (albeit in small quantities) to people of lower social status as they became indigenized.[63] Indeed, all of the species observed in the graves of Cemetery 1-200, except pomegranate, have been encountered and published from the workers' village in Amarna (Stevens and Clapham 2014). The non-native species—watermelon, pomegranate, and juniper berries—will now be discussed in turn.

[62] Additional species identified from House E that are not known from the cemetery are acacia (*Acacia nilotica* (L.) Del.) and beans (*Vicia faba* L.) (Shahat research notes 2020). The recent fieldwork also revealed more samples of the species identified by Wetterstrom in the 1980s: wheat, barley, and flax seeds (Wetterstrom 1990:25).

[63] Although the example of the juniper berries in Tomb 128 co-occurred with a scarab inscribed with the name Thutmose, indicating that the individual may have been of a higher social status compared to other individuals in the cemetery by having access to imported fruit and material culture often associated with elites, the quantity (n=21) and quality of the fruits (small cones) are much less than those found in elite Theban tombs (e.g., Kha and Merit). Additionally, the Deir el-Ballas graves lack any meat and fowl among the food offering assemblages, items that are often found in elite Theban tombs and even the tombs of the craftsmen of Deir el-Medina.

4.5.1 Watermelon

The earliest finding of domesticated watermelon in Egypt is an area of debate in Egyptian archaeobotany. In 2004, Wasylikowa and Van der Veen noted that the earliest reliable published identification of domesticated watermelon in Egypt came from the tomb of King Tutankhamun (Cairo Museum # sp. 2792) (Wasylikowa and Van der Veen 2004:215), although other early samples might belong to this species such as examples of *C. vulgaris* found in the gut of a mummy from the Predynastic site of Nag ed-Deir that were published by Netolitsky in 1943 (Netolitzky 1943).[64]

More recently, the domesticated watermelon species along with *C. colocynth* (sour melon) was published among the botanical discoveries from the vicinity of the workers' village at Amarna (Stevens and Clapham 2014:157), suggesting that this species was not reserved for elite usage. To contribute new evidence to the debate on the appearance of watermelon in Egypt, we conducted AMS carbon dating on one of the Deir el-Ballas watermelon seed fragments, revealing a date between 1465 and 1413 calBCE with 73.3% certainty. Identification of the seeds in our study as being the domesticated watermelon was confirmed by Claire Newton, Christine Hastorf, and Marijke van der Veen. Thus, while we cannot assert that the Deir el-Ballas sample is the earliest domesticated watermelon known in Egypt because of the disputed Predynastic sample mentioned above, it is between 60 and 100 years older than the confirmed *C. lanatus* specimens identified from the Amarna settlement.

Unlike the example from Tutankhamun's tomb or Amarna, this Deir el-Ballas example comes from a non-elite context, adding more information to the kinds of people who would have had

[64] Netolitzky was given the samples by Elliott Smith, who had received them from George Reisner. Netolitzky had some of the samples in his laboratory at Czernowitz which was destroyed in World War I, while others were sent to a colleague at Wageningen who died before publishing any results (Netolitzky 1943:5–7).

access to this fruit in ancient Egypt. In addition, while the cemetery is generally speaking a non-elite burial context, this dataset has shown differential presence/absence of different fruits within these graves with some graves having richer assemblage of fruit variety than others, suggesting differences in status, among the individuals. It may also suggest variation in the identity among the individuals in the burials.

The carbon isotope ratio $\delta^{13}C$ of the domesticated watermelon sample is -23.5 ± 0.1 ‰, which is that of a C_3 plant. At present, we cannot determine whether the Deir el-Ballas samples were grown locally or were imported but this study provides baseline stable isotope measures that we hope will be useful in clarifying this question as more samples from other regions are tested and published.

4.5.2 Pomegranate

Pomegranate was another non-native species that became integrated into Egyptian food culture as well as being used as a funerary offering. The earliest report of pomegranate in Egypt was a specimen from Dra Abu el-Naga (Western Thebes) in what may have been a 12th Dynasty context (Schweinfurth 1884:314),[65] but which is known securely from Tell ed-Dabʿa in the Second Intermediate Period (Thanheiser 2004:378). The fruit became indigenized, absorbed into Egyptian cultural foodways in the 18th Dynasty (Murray 2000a:625; see Pearsall and Hastorf 2011:181–83 on indigenization of food). The fruit's acceptance into Egyptian culture seems to have been

[65] Schweinfurth refers to seeing pomegranate displayed in a case in the Boulaq Museum (the forerunner of the Egyptian Museum at Tahrir Square). These offerings were said to be from a 12th Dynasty vault from Dra Abu el-Naga. However, there is no way to verify this date. If the ceramics were the basis for this date, it should be remembered that 19th century Egyptologists did not have as firm a grasp on the relative dating of pottery as is currently available and any dating assertions should be reviewed before they are accepted (Victoria Jensen and C. Redmount, pers. comm. May 2019).

complete by the Thutmosid period, as witnessed by the botanical depictions of pomegranate trees and fruit in Thutmose III's Akh-Menu at Karnak Temple and elite tombs of the 18th Dynasty (Murray 2000a:625). Several models of pomegranate-shaped faience were excavated by Loret in 1898 in KV 35, the tomb of Amenhotep II in the Valley of the Kings, currently in the Egyptian Museum in Cairo (#JE 32452) (Loret 1898). The discovery of pomegranates in both Tomb 128 and Tomb 257 at Deir el-Ballas indicates that this non-native fruit had become available (at least to a limited extent) to provincial members of Egyptian society by the early 18th Dynasty. In addition to these two tombs, according to Reisner's field notes, Tomb 102 contained a small, intact pomegranate but it has not been identified at PAHMA. However, one of the differences between elite and non-elite grave goods is that non-elite graves contained fewer of these non-local food items than elite graves.

The carbon isotope ratio $\delta^{13}C$ was –22.3 ± 0.1 ‰ indicating that the pomegranate is a C_3 plant. There was no sign of significant drought, but water conditions on this specimen were not optimal compared to those doum and other fruits growing along and irrigated by the Nile River. However, it is not straightforward to say whether it was grown locally in Egypt or imported without considering further isotope proxies such as oxygen and strontium. The oxygen isotope results of the pomegranate sample $\delta^{18}O$ = 30.85 ‰, which is a much higher value driven by more arid conditions than local fruits growing along the Nile and reflecting higher humidity, such as the doum fruit in this assemblage having a value of 23.80 ‰. One caveat however is that $\delta^{18}O$ may vary among plant spices. One way to avoid this caveat is to interpret the oxygen value using another proxy for water availability conditions in the past, for which the carbon isotope is of relevance. Considering both carbon and oxygen as dual proxy, the higher oxygen and carbon values of the pomegranate show evidence of the plant growing under relatively more arid conditions than the local plant species irrigated by Nile water and found in the same archaeological assemblage. Thus, the pomegranate could have also been an import.

4.5.3 Juniper berries

The juniper berries from Tomb 128 had a significantly higher $\delta^{13}C$ value than the rest of the assemblage of local fruits. The $\delta^{13}C$ of juniper is –19.5 ± 0.1‰ which is very enriched for a C_3 plant and indicates that the berries grew in a water-limited condition in which the plant leaves closed the stomata longer to avoid water loss (Escudero et al. 2008:705–13, Hartman and Danin 2010:837–52). In good water conditions, C_3 plant leaves open their stomata more and discriminate against ^{13}C, thus resulting in lower values for the carbon-13 isotope. The results of the carbon-13 isotope of the Deir el-Ballas juniper berries thus show clear evidence of water stress and ecological differences in contrast to the plants that grew along the Nile found in the same cemetery. For example, doum fruit from Tomb 105 had a $\delta^{13}C$ value of –25.4 ± 0.1‰ (Shahat lab report 2019). Thus, the carbon isotope not only speaks to the type of plant photosynthesis as a C_3 or C_4 crop but also reveals information about a plant's water-use efficiency and hence provides valuable ecological information on the ancient environment in which the plants grew.

As for the ecological distribution of juniper *Juniperus phoenicea*, it grows along the coastal areas of the Aegean including Crete, the Peloponnese, and the Cyclades, and is attested in mainland Greece since the Paleolithic (Asouti 2018:1–38, Asouti et al. 2015:1569, Maria Ntinou pers. comm. November 2018).[66] The species also flourishes in mountainous and woodland steppes in

[66] Thanks to Sarah Morris and John Papadopoulos for coordination with Asouti and the Methone project archaeobotanical team, Greece to provide data on juniper distribution. Comparison of archaeobotanical remains across the Mediterranean is a challenge, as the archaeobotanists working on wood or charred materials outside Egypt face the challenge of identitying the archaeobotanical materials beyond the genus level.

the northern Levant; in modern times the closest location to the Nile Valley where it grows is in north Sinai, where it is reported as an endangered species (El-Bana et. al 2010:171).

If the assumption that the sample comes from the northern Levant is correct, and by putting this high ^{13}C isotope value of the juniper berries as a conifer species in the historical context of the sample, which is carbon-14 dated to 1498–1428 calBCE with 95.4% certainty, the juniper berry sample imported to Deir el-Ballas correlates very well with published data of the same time period on an aridity event in the Levant showing high ^{13}C in C3 conifers *Pistacia sp*. charcoal excavated from woodland steppes (Araus et al. 2014:2). The isotopic values indicated drought stress in contrast to charcoal of similar species growing along riverine forests in northern parts of Syria and Lebanon (Araus et al. 2014:2). Araus has also reported an increased aridity reflected in the carbon-13 isotopic values on archaeobotanical materials dated to the Bronze Age in the Near East (Araus et al. 2014:3). A similar observation is discussed by Steven and Black (2011:95) in the Levant based on ^{18}O in carbonates (e.g., land snails from the Negev desert).

However, it is noteworthy that the $\delta^{15}N$ of the ancient juniper berry is extremely high with a value of +28.58‰, which is the opposite of the extremely depleted $\delta\ ^{15}N$ in the modern type collection imported and purchased by the author from the Al-Harraz historical spice market in Cairo. The nitrogen isotopic composition of this modern sample is $\delta\ ^{15}N = -14.87$‰, which is highly depleted relative to the standard (atmospheric air). While the study by Fraser et al. (2013) showed little alteration of $\delta^{13}C$ and $\delta\ ^{15}N$ isotopic composition of archaeobotanical samples exposed to short-term burials based on their charred cereals experiment, the $\delta\ ^{15}N$ in the desiccated rather than charred archaeological materials from Egypt showed that they were consistently highly enriched, almost twice the $\delta\ ^{15}N$ value in the archeological samples compared to modern type collections of the same species. One interpretation is that charred materials are more resistant or almost sealed from microbial action and contamination, which are known to elevate the nitrogen isotopic compositions. For Fraser and colleagues, the ABA pre-treatment as well as measuring the C:N atomic percentage ratio in archaeobotanical samples is an important step in estimating the post-depositional impact on the archaeobotanical samples' isotopic compositions in charred remains (Fraser et al. 2013:4765). However, the enriched ^{13}C value, which is indicative of photosynthetic rate and water use efficiency, can be corroborated to give the most relevant interpretation to the very high $\delta\,^{15}N$ value of the juniper sample of +28.58 ‰ in this dataset compared to the average of all other species found in the same cemetery of 13.50 ‰ std 2.7 (n=5). While the enriched carbon isotopic value indicated stomatal closure and hence drought condition, $\delta\,^{15}N$ provided additional evidence for the drought conditions as the $\delta\,^{15}N$ values in plants increase with decreasing mean annual precipitation (Niespolo et al. 2020:4).

An additional proxy used in this study is the measure of ^{18}O in organic matter (which is influenced by factors including source water, relative humidity, and temperature). The ^{18}O in the juniper fruit has shown high evaporative enrichment, ^{18}O of +27.90‰, which may have also been driven due in part to increased aridity, not excluding other ecological factors related to relative humidity and water source (Dawson and Siegwolf 2011). However, since the region in the northern Levant relies on rain-fed agriculture, presumably a much more depleted source than Nile water, the $\delta^{18}O$ of source water may not have played a significant role in this enrichment value. The interpretation of this highly enriched value of $\delta^{18}O$ in organic matter in this sample from Deir el-Ballas can be interpreted in the light of other paleoenvironmental data from the Levant, which consistently show increased values of $\delta^{18}O$ carbonates associated with arid conditions in the early Holocene,[67] and lower $\delta^{18}O$ together with lower ^{13}C values driven by abundant rainfall in

[67] Which fluctuated afterwards between arid and humid intermittent phases.

intermittent periods based on measures conducted on land snails from Jordan dated to 3200 BP in Jordan (Mithen and Black 2011:95–96). Transferring this interpretation in our study, which conducts $\delta^{18}O$ on plant organic matter of the juniper rather than on carbonates, as in other studies (Niespolog et al. 2020:106–42, Mithen and Black 2011), explains different considerations of the driving factors of the fractionation processes in these different substrates. For plant organic matter, the driving factors of $\delta^{18}O$ evaporative enrichment can be determined by source water, relative humidity, and temperature, varying among species based on plant physiology.

The foundation of the argument for juniper berries at Deir el-Ballas as an indicator of paleo-environmental arid conditions in the source region where they came from is rather based on the multiproxy isotopic method, measuring carbon, nitrogen, and oxygen in organic matter in the sample rather using one isotopic proxy to reach this conclusion. This way the stable isotope interpretation takes into account the different biological processes of plant life biography to situate ancient food ecology in its larger social context.

4.5.4 Implications for the bioarchaeology of diet in ancient Egypt

The data-rich and informative study on human mummies by Touzeau et al. (2014) shows that the ancient Egyptian diet has as its major component C_3 plants with a minor (<10%) contribution of C_4-derived foods, coming from sub-Sahara (Touzeau et al. 2013:122). Touzeau and colleagues interpreted the consistency of the C_3 carbon isotope levels by stating that "ancient Egyptians had a relatively basic diet with a restricted number of food items" (Touzeau et al. 2014:119). However, they also acknowledge that "the C_3 plant group is by far the most diverse and comprises the majority of vegetables, cereals, and fruits, while C_4-plants are rare, and limited to millet and sorghum in Africa" (Touzeau et al. 2014:115). They briefly consider other food sources beyond cereals that contribute to the C_3 isotope values, noting that "only indirect inferences can be made by considering the salaries paid in kind to pyramid workers and craftsmen from the King's Valley" about vegetables and legumes (Touzeau et al. 2014:115). Notably absent from this list, however, are the wild, native fruits that are encountered archaeologically as funerary food offerings at Deir el-Ballas as well as at many other sites. Although the better preservation conditions in tombs have preferentially preserved these foods in the archaeological record, these foods were not restricted to funerary use and are now being recovered and identified from settlement areas at Deir el-Ballas (sycomore fig,[68] doum, and dates, as well as the domesticated grape) (Shahat and Jensen in press).

Ethnographic evidence notes that wild fruits are still enjoyed by modern Egyptians. For instance, Christ's thorn, doum, and dates are collected and eaten by families regularly; these fruits are also sold in local markets in Qurna and Luxor, Upper Egypt (Jensen and Shahat ethnographic observation 2019). Moreover, these species and many more (including domestic watermelon, grape, persea, desert date, and juniper) are attested in the workers' village at Amarna, in its refuse dump and animal pens, as well as in the gardens of its private chapels (Stevens and Clapham 2014:158–61). In all, Stevens and Clapham present 60 plant species identified from Amarna, greatly enhancing our understanding of the breadth of plant use in popular contexts. Combined with the present study, we propose a more nuanced interpretation of the C_3 stable isotope signature by considering the archaeobotanical records, which give a detailed view of what species contributed to the C_3 signature. The archaeobotanical analysis gives a contextualized understanding of the continuity and changes of the diet of C_3 taxa, which goes beyond domesticated wheat and barley to include a range of wild, local C_3 plants plus imported or newly

[68] Sycomore fig, in Arabic *gimmeiz,* is not to be confused with California sycamore.

introduced fruits such as pomegranate, watermelon, or juniper berries at this time in Egyptian history.

For the sources of C_4 isotopes in the Egyptian human evidence, a suggested origin is the consumption of animals fed with C_4 plants (Touzeau et al. 2014:120), as the C_4 cereals (millet and sorghum) were only found regularly during the Roman Period as a contributor to the human diet in Egypt (Touzeau et al. 2014:120). This archaeobotanical study from Deir el-Ballas invites us to think beyond domesticated cereals and the animals that consumed them to include wild plants and rhizomes that are regularly encountered in the archaeobotanical records when studied in detail. For example, a *Cyperus esculentus* (tiger nut) rhizome from the *Cyperaceae* family was found in Deir el-Ballas in Tomb 244/255 with the watermelon (Chapter 3, table 6). Based on the isotopic analysis result in this research, tiger nut is a C_4, and bioarchaeologists should give it more consideration as a contributor to the ancient Egyptian diet. Archaeobotanically, tiger nut has been found in large quantities in the Predynastic Period (e.g., at Nag ed-Deir) and, albeit less frequent, in the New Kingdom in Upper Egypt, as is the example from the tombs of Kha and Merit[69] and the refuse pit beside the workers' village at Amarna (Stevens and Clapham 2014:159). Thus, we respectfully would like to modify the statement made by Touzeau and colleagues, regarding sorghum and millet being the only C_4 plant sources encountered in Africa (Touzeau et al. 2014:115), to include wild species such as tubers and rhizomes (e.g., tiger nut).

[69] Among funerary contexts, *Cyperus esculentus* (n=8) is attested in the tomb of Kha, where it was found in a box along with 5 almonds (Shahat, personal observation, Museo Egizio, Turin, 2019); it seems that it was also important in Predynastic Egypt, as baskets full of tiger nut rhizomes were excavated at Nag ed-Deir by Reisner and Lythgoe (Shahat lab report 2019).

4.6 Conclusion

This study has confirmed that the carbon dates obtained for the botanical samples support the relative dating provided by the ceramics and other material culture artifacts such as scarabs found in the tombs at Deir el-Ballas. Despite significant plundering of the cemetery over the years, the AMS carbon dates obtained from the plant remains align with the early to mid 18th Dynasty dates suggested by the material culture, thus authenticating that the archaeobotanical samples were part of the original grave goods. While the plant remains that were found within ceramic containers in the tombs were not likely to be intrusive, it was particularly important to conduct independent testing in the case of the watermelon seeds from Tomb 244 or 255 that were not associated with any particular vessel, to demonstrate whether or not they dated to the same time period as the rest of the tomb assemblage. Additionally, the dates obtained for the doum sample from Tomb 105 informed us that this tomb dated to the late 18th to early 19th Dynasty; the absence of material culture from this context had made dating the tomb impossible without this archaeobotanical data.

The juniper sample produced ^{13}C results that point to the plant having grown in water-stressed conditions, presumably outside of Egypt, and especially outside of the Nile Valley. However, understanding whether the pomegranate and watermelon grew locally in a process of indigenization or were imported to the site (either from within or outside of Egypt) is the subject of further rigorous stable isotopic analysis of oxygen and strontium to identify their water source and the region in which they grew.

Describing the identified species of archaeobotanical remains found in archaeological contexts is important, but it does not substitute for the importance of conducting stable isotope analysis on both the archaeobotanical materials and on the human remains as well. Each analysis contributes to a different set of information that complements the others. When added to evidence from human remains, stable isotope analysis can provide a broader picture regarding the extent these foods contributed to the diets of different individuals in the cemetery and whether the individual buried was a local person or an immigrant. However, we did not have the opportunity to conduct stable isotope on the human bodies, as we lack information on where Reisner stored the human remains that he excavated at Deir el-Ballas.

In summary, this variety of food offerings combining local wild and domesticated plants as well as imported fruits, most of which are isotopically C_3 plants, invite bioarchaeologists to be more broad-minded about their interpretations of carbon stable isotope values from human teeth and bones (e.g., Touzeau et al. 2014:122). The archaeobotanical analysis is thus of great importance to better understand the extent of the repertoire of C_3 plants that contributed to the diet that resulted in these isotopic values.

This study of the food offerings from the non-elite Cemetery 1-200 at Deir el-Ballas provides evidence of the complexity of Egyptian plant use in the diet of the residents that we can conclude combined native wild plants, domesticates, as well as the rare imported species. While stable isotope analysis on human teeth, bones, and hair confirms the continuity of a generally C_3-based diet, archaeobotanical materials provide a more refined view of the "menu" of plant taxa that constituted the basis of these isotope results. This menu was not fixed but rather shows both continuity and changes over Egyptian history. Moreover, even though C_4 plants were a minor contributor to the diet, the identification of their archaeobotanical remains gives us an idea of what contribution C_4 plants may have made to this, such as the tiger nut rhizome. Further research on additional native and imported species to determine whether they were C_3 or C_4 plants may help to clarify the picture of the ancient Egyptian diet even further.

CHAPTER 5

5. Botanical remains from Nag ed-Deir: Predynastic non-elite cemetery

5.1 Introduction[70]

Nag ed-Deir is located in the Sohag Governorate on the east bank of the Nile. The archaeobotanical materials were excavated by Reisner and Lythgoe's excavations in 1900–1903 (Podzorski 2013). The dataset derives mainly from cemetery N7000, dated to the Predynastic and with a later period of reuse during the early Dynastic Period (ca. 3607–2494 BCE), based on AMS C14 carbon dating of fruits in the burial (Table 10). In this chapter, I continue the application of paleoethnobotanical visual analysis of species identification, and carbon stable isotope analysis on the plant-food remains from the non-elite cemetery of Nag ed-Deir. The cemetery is also located in Upper Egypt but farther north from Deir el-Ballas, and dated to the Predynastic Period. The sample preparation was conducted in the Ancient Agriculture and Paleoethnobotany lab at UCLA, and radiocarbon dating of the botanical materials was conducted at the University of California Irvine laboratory. Further isotopic analysis measuring the stable carbon isotope was conducted at University of California Berkeley. The goal of this study is to identify the regional pattern of food recipes as revealed from a beer mash and other food offerings, and the early dynamics of cross-cultural interactions in early Dynastic Egypt as implied from imported species. The stable isotope values of the botanical materials were also used to estimate the ancient food ecology and the climate conditions under which the plant-foods grew in the past. This dataset is of relevance to

[70] This Chapter is part of a book chapter in press, single-authored by Amr Shahat. It will be published under the title **Shahat, Amr. New Methods to Reconstruct the Social History of Food in Ancient Egypt: Case Studies from Nag ed Deir and Deir el Ballas, in Kathlyn M. Cooney, Nadia Ben-Marzouk, and Danielle Candelora (eds.), (*Re)Constructing Ancient Egyptian Society: Challenging Assumptions, Exploring Approaches*. London: Routledge, 2021**.

archaeologists interested in identifying the provenance of imported versus local food and the environmental conditions in Egypt at the time.

5.2 The archaeological context

The site of Nag ed-Deir was excavated by Reisner and Lythgoe in early 1900s. Focus in this study is on the Predynastic cemetery N7000, which represents the largest group of burials in the form of grave pits. The grave pits served as a burial place for over 850 individuals buried in flexed positions. Elliot Smith, an expert on anatomy at Cairo University during the time of Reisner, examined the human remains from these graves and recorded information regarding age, sex, physical abnormalities, and cranial metrology (Podzorski 1982, Podzorski et al. 1990). Paleoethnobotanical remains were sent by Reisner to the Hearst Museum at the University of California Berkeley and remained unpublished. In this chapter, I describe the archaeobotanical materials in their tomb contexts.

5.3 Materials and methods

The methods followed in this study are similar to those mentioned in Chapter 4. Paleoethnobotanical materials were analyzed first by non-destructive visual analysis using a stereo-microscope. Since some of the plant remains were discovered during Reisner's excavations, before the development of dry-sieving or flotation techniques, it was important to radiocarbon date them, to provide stronger contextualization and confirm that they were not intrusive or deposited through bioturbation (Pearsall 2015:35–37). For the beer sample recipe, a new method of non-destructive analysis was developed. Instead of using SEM, I used a more advanced digital microscope (Microscope Keyence VHX-7000) at UCLA nano-archaeology laboratory, and at the Conservation laboratory in the Getty Villa. This method allowed visual investigation of anatomical parts of the plant fragments in the beer mash, and measurements in the nano-level that enabled me to identify the botanical fragments from the beer mash. This nano-archaeology method was an advanced non-destructive visual technique that allowed me to recognize changes in grain and fruit morphological characteristics, which appeared slightly different than charred and desiccated botanical materials due to the beer fermentation process. This beer mash was found preserved in a wavy-handled ceramic jar (#6-3588) in tomb 7402.

Sample ID	UCI AMS # & site	Yield % C	$\delta^{13}C$ (in ‰)	Modern fraction	$D^{14}C$‰	^{14}C age (^{14}Cyr BP)	Calibrated date (calBCE)
Cyperus esculentus 6-12080	219095 Nag ed-Deir	60	–10.70 ± 0.1‰	0.5577 ± 0.0010	–442.3 ± 1.0	4690 ± 15	3466–3374 (70.5%)
Beer mash Fruit frag 6-3588.2	219128 Nag ed-Deir	73	–24.8 ± 0.1‰	0.5525 ± 0.0010	–447.5 ± 1.0	4765 ± 15	3607–3522 (83.5%) 3635–3621 (11.9%)
Pistacia lentiscus 6-12139	219096	64	----	0.6108 ± 0.0011	–389.2 ± 1.1	3960 ± 15	2563–2534 (20.1%) 2494–2460 (75.3%)

Table 10. Results of radiocarbon dating and $\delta^{13}C$values in parts per thousand (‰) of archaeobotanical remains from Cemetery N7000 of Nag ed-Deir.

5.4 Results

5.4.1 Tiger nut from Grave N 7459

The grave pit (140x100–115 cm) contained one adult male, probably 50 years or older, buried in flexed position on his left side (Lythgoe 1965:286). According to Lythgoe’s notes, the grave was plundered, as the head and lower jaw were found in the filling of the burial. Grave goods, however, were found in situ, and included plant-matting covering the burial floor, as well as ceramic vessels and basketry (Lythgoe 1965:286). The matting found on the tomb floor is seen in Figure 28, while the basketry and plant samples were taken to the Hearst Museum and analyzed by the author for species identification.[71] The most common plant species found in this grave and other burials in cemetery N7000 in general is tiger nut rhizomes (*Cyperus esculentus*, Figure 29 a and b). From tomb N7459, approximately 485 tiger nut rhizomes were found in a basket, carbon-dated in this study to 3466–3374 calBCE. All rhizomes were found desiccated and tied together in threads, perhaps as way to dry it, as seen in ethnographic parallel today (Shahat, ethnographic observation). The finding provides evidence of exploitation of not only wild and domesticated grains and fruits but also wild tubers and rhizomes such as tiger nut from the papyrus family (*Papyraceae*) integrated in Egyptian foodways and funerary food offerings (Crawford 2007).[72]

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[71] Photo is taken from the online digital copy of Lythgoe's note by the University of Heidelberg. Source: https://digi.ub.uni-heidelberg.de/diglit/naga_ed_der1965bd4/0433/scroll
Accessed May 20, 2021.

[72] The edible tiger nut rhizome (*Cyperus esculentus*) should not be confused with papyrus (*Cyperus papyrus*), used for papers, oil/perfumery, and medicinal uses. Meanwhile both come from the sedge family, Cyperaceae.

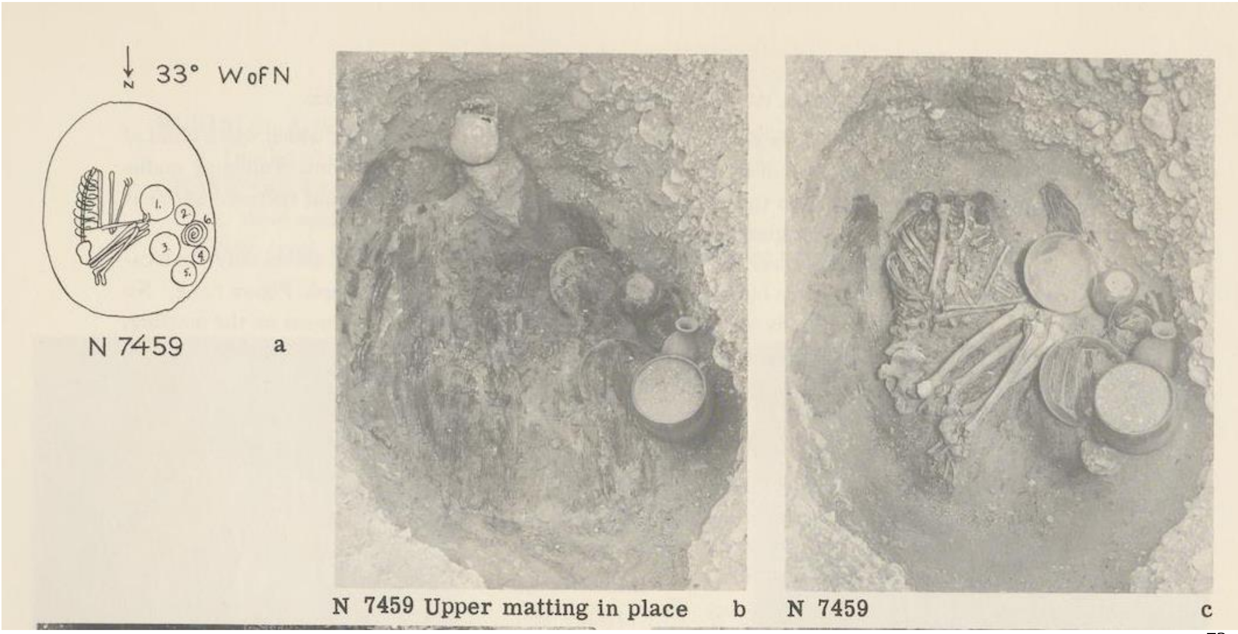

Figure 28. Grave N 7459 dated to Predynastic where tiger nut was found (Lythgoe 1965:286).[73]

Beside the paleoethnobotanical analysis of tiger nut, conducting carbon stable isotopic analysis on the rhizome challenges the assumption stated by Touzou et al. (2014) and discussed in detail in Chapter 4 that the Egyptian diet was devoid of C4 plants until the introduction of sorghum and millet during the Roman Period (Touzou et al. 2014:115). The carbon isotope of tiger nut measured from this grave has a $\delta^{13}C$ value of –10.70 ± 0.1 ‰), which means that the tuber is a C4 plant. These results indicate that while uncommonly found in the archaeological record, local C4 plants were part of the ancient Egyptian diet. The abundance of C4 in the Predynastic Period may indicate different ecological conditions in Upper Egypt, perhaps wetter conditions than at the present time in Upper Egypt.

[73] Source: https://digi.ub.uni-heidelberg.de/diglit/naga_ed_der1965bd4/0433/scroll. Accessed May 20, 2021

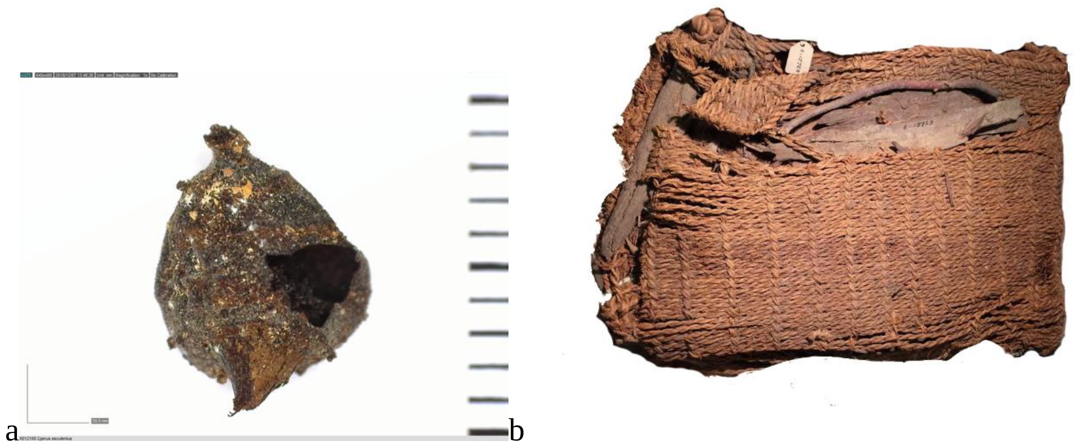

Figure 29. a : sample of tiger nut taken under digital Microscope Keyence VHX-7000 (UCLA nano-archaeology laboratory); b: basket #6-1529 from tomb 7459 (photo by Amr Shahat).

5.4.2 Beer mash from Tomb N 7402:

Another special finding derives from grave pit N7402 (165x105–75 cm), of presumably an adult male, in which 213 g of a well-preserved beer mash was found in situ inside a wavy-handled jar (35.0 cm high, 28.5 cm in diameter, Hearst Museum# 6-3588.1; Figures 30 and 31). The beer mash was found in the bottom of the jar and described by Lythgoe as “soft oily sediment” (Lythgoe 1965:242). A new method of non-destructive analysis was developed to identify the mash’s ingredients using digital Microscope Keyence VHX-7000 at the UCLA nano-archaeology laboratory (see Materials and methods, this chapter). The microscope image helped identify barley and fruit fragments preserved by fermentation even after distortion of morphology due to fermentation of beer process. The sample dated to the Predynastic Period was found in jar in Tomb N7402, at Cemetery N 7000 in Nag ed-Deir (see Figure 31)

The result of the nanoarchaeological analysis of the beer mash revealed a regional recipe of beer, consisting of barley (*Hordeum vulgare* L.) and local upper wild fruit fragments, used as sweetener.[74] Moreover, even after the fermentation of the barley in the beer-making process, radiocarbon dates measured by accelerator mass spectrometer (AMS) of the fruit used as sweetener still yielded reliable carbon dates of 3607–3522 calBCE (83.5% certainty), making it one of the earliest instances of beer mash[75] found in Egypt found in situ. The stable isotope conducted on the carob fragment resulted in a value of $\delta^{13}C = -24.8 \pm 0.1‰$ indicating that it is a C3 plant. This gives us a clue to the paleoclimate under which the fruits were grown, indicating good water availability and relative humidity conditions (as opposed to the water-stressed conditions seen in the juniper in Chapter 4). Important conclusions can be drawn from this sample on regional recipes. While barley was used as a major component of beer, this recipe carried a regional signature by containing a sweetener of local wild fruit that grows in the south, confirming that the recipe is Upper Egyptian. This example also offers a nuanced understanding of the use of domesticates such as barley in combination with local wild fruits, to make a regionally distinct recipe.[76]

[74] The identification is not fully certain as the morphology is partially distorted by the fermentation process of the beer. Many thanks to Vanessa Muros for helping with developing this method, and to Glenn Wharton for the permission to use the digital Microscope at the UCLA/Getty conservation lab; and to Hans Barnard for his help in creating a molecular chemical of different plant species as baseline for further verifications.

[75] Note that this is a beer mash and not a residue. The difference is that the physical plant compositions of the ingredients are preserved, albeit fragmented and distorted in their plant morphology due in part to the fermentation process.

[76] Beer mash from Tomb N7402 was investigated with the digital Microscope Keyence VHX-7000 microscope at the UCLA nanoarchaeology laboratory to ensure identification via a non-destructive method. The microscope image helped identify barley and barley fragments preserved by fermentation even after distortion of morphology due to fermentation of beer process. The sample dated to the Predynastic Period found in a jar in Tomb N7402, at cemetery N 7000 in Nag ed-Deir [image credit given in caption].

Figure 30. Grave N7402 dated to the Predynastic Period, with wavy handled beer jar with beer mash preserved (Lythgoe 1965:241)

(source: https://digi.ub.uni-heidelberg.de/diglit/naga_ed_der1965bd4/0433/scroll).

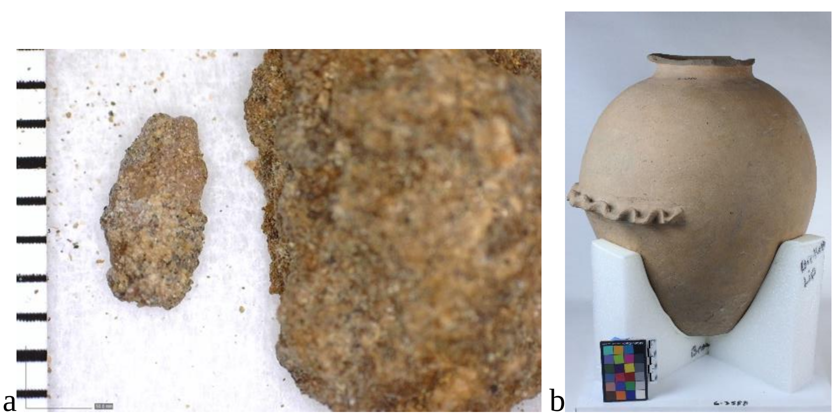

Figure 31. a and b: Beer mash from Tomb N7402 and the jar (# 6-3588.1) in which it was found (photo a. by Amr Shahat, photo b. Courtesy of the Hearst Museum).

5.4.3 Mastic fruits: *Pistacia lentiscus* L. from Grave N 7626

The grave pit 7626 (90x120, depth not given) had four individuals buried in flexed position, a position commonly used in the Predynastic Period and until the 4th Dynasty (Podzorski pers. comm. 2020). Samples of *Pistacia lentiscus* (n=24 fruits) are registered at PAHMA as coming from Tomb 7626 at Nag ed-Deir (Figure 32), which contained bodies of four individuals (A, B, C, and D) as indicated by Lythgoe (Lythgoe 1965:409). The three figures next to each other (A, B, and C) are an adult male, an adult female (around 30 years old with perfect teeth), and a young child (1.5 to 2 years old), all buried on their left side and covered with matting of four layers (Lythgoe 1965:411). Both the adult male and female (A and B) were found intact, but the young child burial was noted as plundered by Lythgoe. Material cultures including a Predynastic ivory comb, lozenge-shaped carnelian beads, and an ivory bracelet were found associated with individual B, the adult female (Lythgoe 1965:411). One more person was found in this burial, individual D, another adult female buried on her left side in flexed position, with the pelvis and legs found in situ, arms found on top of them, and head not found. Lythgoe notes that the body of the adult woman D was found lying around 20 cm higher than A, B, and C, on the west side of the grave, and suggested that this was an intrusive or a later burial (Lythgoe 1965:411). The material culture found in this grave included a cross-line ware vessel, a rhomboidal slate palette, and an ivory comb dating to the early Predynastic (Lythgoe 1902–04, Naga ed-Deir Tomb Cards, PAHMA archives; Lythgoe 1965:411). Based on these objects, the entire assemblage including the botanical remains is attributed to Nagada Ic in the museum records. However, the carbon dating on these *Pistacia* fruits in this study reveals that they date between 2494 and 2460 calBCE with 75.3% certainty (Shahat 2019) suggesting a reuse of the burial pit for a later interment approximately 1000 years after the Predynastic interments. Even though Lythgoe states that the seeds were found near the elbow of the adult woman B, the carbon date indicates that they must have entered the tomb approximately 1000 years later, and most likely during the placement or the disturbance of the other adult woman D (Shahat and Jensen in press).

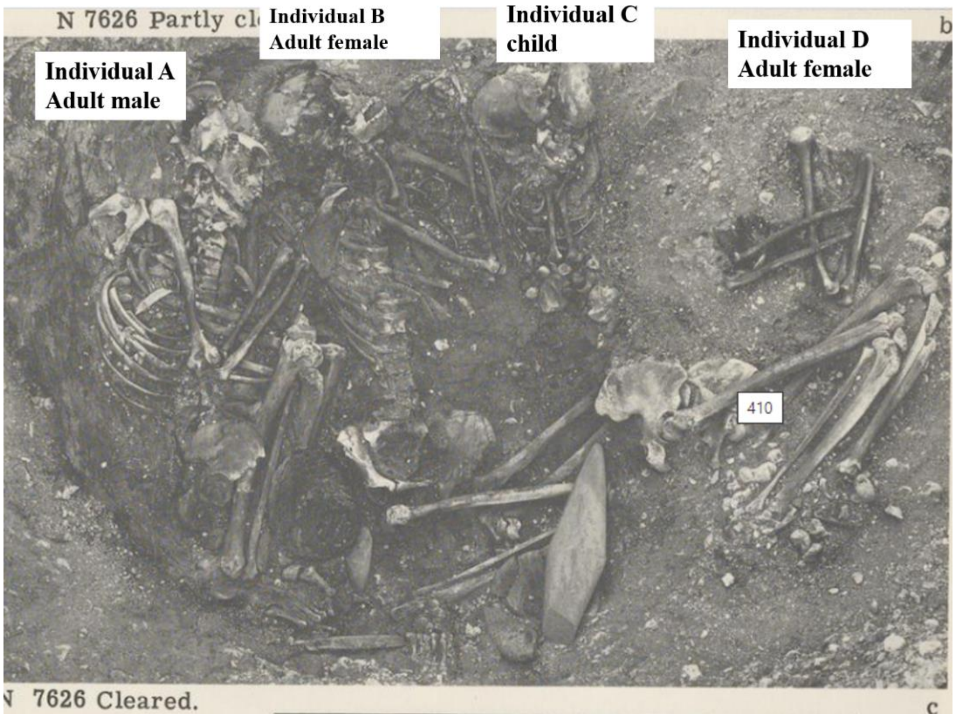

Figure 32. a: grave N7626 in Cemetery 7000 at Nag ed-Deir; b: specimens of *Pistacia lentiscus* (L.) fruits found in it. Photo a. (Lythgoe, 1965, p. 411); b. by Amr Shahat 2020.

5.5 Discussion

There are several key archaeobotanical specimens from the burial site of Nag ed-Deir that inform us about past foodways and the use of plants in the Predynastic Period in Upper Egypt. I will only discuss a few of these key plants that are particularly informative: first, the wild fruits, where they grew and where they were used, and how they formed regional recipes (i.e., the case of tiger nut and beer mash); then the wild imported fruits of *Pistacia* and how they indicate early evidence of cross-cultural interaction, and contribute to our understanding of the social history of reuse of Predynastic grave pits.

5.5.1 Tiger nut

The presence of tiger nut in the tombs represents a complex story of environmental change, cuisine, and exchange in ancient Egypt. Tiger nut is a wild plant, the edible part of which grows under the ground. It is very high in starch (295g/kg) and fibers (4.30%) and low in moisture content (3.75%) (Arafat et al. 2009:151), which makes it highly nutritional but harder to find in the archaeological record unless preserved as whole charred remains or desiccated, as was the case in Nag ed-Deir. This finding of tiger nut in Nag ed-Deir and other Predynastic cemeteries in Upper Egypt indicates that the plant grew in this environment. Today, tiger nut is used in the regional food recipes and culture of the Delta in Lower Egypt; Tanta governorate in the Delta is one of its major distributors to other regions in Egypt (Shahat ethnographic observation). While tiger nut was present in the past in Upper Egypt, today it is almost entirely absent from the southern regions, due to environmental and climatic changes. Over time, tiger nut became a marker of Lower Egyptian food recipes and regional cultural identity.

In contrast, wild upper Egyptian fruits known from other cemeteries dated to the early Dynastic Period at Nag ed-Deir (Cemetery 1500), such as the doum fruit (*Hyphaene thebaica* L. (Mart.)), desert date (*Balanites aegytiaca* (Linn.) Del.), and Christ's thorn (*Ziziphus spina-christi* (L.) Desf.), all are part of the food culture of Upper Egypt and less commonly known in Lower Egypt. When they occur in the Delta, they are assumed to be imports from Upper Egypt, or an indicator of the presence of Upper Egyptians. An ancient example comes from the presence of the Upper Egyptian wild fruit *Balanites* dated to the Second Intermediate Period at Umm Mawagir, Kharga Oasis (Neef and Cappers 2012:661), which can be interpreted as an indicator of Upper Egyptian presence in this Western Desert oasis, as wild fruit consumption is an intimate marker of regional identity. This interpretation is supported by the Yale University Project at Kharga's findings of ceramic made of local oasis fabric but influenced by Upper Egyptian traditions. Cross-regional interaction with Upper Egyptians is also supported by the presence of an administrative and economic complex with a large number of bread molds, and a road from Thebes to Kharga, implying economic and military activities by 17th Dynasty Thebans in Kharga Oasis.[77] This contextualized understanding of plant-food species, their regional distribution in Upper and Lower Egypt, and whether they are local or imported provides us with a lens into regional variation in Egyptian foodways, and cross-regional interactions.

The tiger nut rhizomes found in Nag ed-Deir are another important case that helps shift our understanding of the ancient Egyptian diet, while providing evidence of the contribution of C4

[77] See Umm Mawagir project by Yale University (https://egyptology.yale.edu/expeditions/past-and-joint-projects/theban-desert-road-survey-yale-toshka-desert-survey/umm-mawagir).

plants in the ancient diet, in contrast to previous studies that suggest C4 primarily came to the Egyptian diet through cereals such as millet and sorghum during the Roman Period (Touzeau et al. 2014:115). This case study from Nag ed-Deir demonstrates that tiger nut tubers are a C4 plant, as evident from its carbon stable isotope ($\delta 13C$ ‰ = –10.70) and have been part of Egyptian foodways since the Predynastic and were incorporated into regional recipes. Ethnographic and ecological analysis of the species show that it grows more in marshy regions and is today primarily part of the Lower Egyptian foodways that appear in Upper Egypt as an import from the north (Shahat unpublished ethnographic report). In the Tomb of Kha tiger nut was found along with almonds inside a wooden box made of imported conifer wood possibly as an export from the Delta. In other words, studying the wild plant-food remains helps reconstruct the regional history of foodways and the cultural identities food can inform.

The finding of tiger nut in abundance in Upper Egypt in the Predynastic Period and its limited finding in later periods opens up a discussion on changes of climate and ecological conditions between the past and the present. In modern times, tiger nut primarily grows in moist ecological zones of Lower Egypt and is imported from the Delta region, as seen in modern ethnographic evidence of the regional distribution of tiger nut. If the hypothesis that tiger nut was grown locally in the Predynastic based on its frequent finding in Predynastic cemeteries in Upper Egypt, this may indicate that the ecological conditions in Upper Egypt were much wetter than today's arid conditions, under which the plant only grows in the Delta. The proposition that Upper Egypt had wetter ecological conditions during the Predynastic Period as opposed to the increased aridity conditions in modern times was also suggested by El-Hadidi (1996) based on his finding of different wild species of tiger nut from Hierakonpolis, also in the south. By the New Kingdom, tiger nut was less commonly found in Upper Egyptian archaeobotanical assemblages, and only one tuber was found from the whole assemblage of Deir el-Ballas (Shahat and Jensen in press); and only nine pieces of tiger nut were identified by the author along with five pits of sweet almond (*Prunus dulcis* (Mill.) D. A. Webb) in a wooden box from the Tomb of Kha and Merit. These examples may imply that, by the later Dynastic Period, with increased arid conditions in Upper Egypt, tiger nut might have arrived as an import from the northern Delta to Upper Egypt in the south.

5.5.2 Beer mash

The beer mash from Tomb N7402 reveals a nuanced understanding of the use of domesticates such as barley in the Egyptian diet, and the variation in the ways by which it is incorporated into the foodways and beverages in different regions. In this beer example, fermented barley was mixed with local wild fruits, suggesting that domesticates did not substitute the use of wild fruits, but that these were integrated with domesticates in regional recipes to create unique flavor. Domesticates of wheat and barley were not a replacement but an addition to the complex use of a variety of wild fruits, nuts, and tubers available locally or imported. This example of a regional beer recipe complicates our understanding of variation in regional food culture, revealing regional diversity in Egyptian foodways.

5.5.3 Mastic: *Pistacia lenticus* L.

These samples of imported mastic fruits, which do not grow in Egypt, provide important evidence of cross-cultural interactions and exchange with communities in southwestern Asia during the early Dynastic Period. Furthermore, carbon dating of these fruit specimens tells us that this burial pit was reused in later periods. In Lythgoe's field notes for this tomb (Naga ed-

Deir Tomb Cards, PAHMA archives, 1902–04), he recorded three Predynastic burials (A–C) and one later, intrusive burial (D) that was placed at the edge of the pit. He did not attempt to date burial D, only noting that it was placed 20 cm above the other three burials and had partially disturbed the closest skeleton, burial C. Burial D also was later disturbed. Lythgoe states that the seeds were found near the elbow of burial B, but their carbon date indicates that they must have entered the tomb approximately 1000 years later, most likely during the placement of burial D of the adult female, which can now be suggested to date to the 5th Dynasty (Shahat and Jensen in press).

5.6 Conclusion

This contextualized study of paleoethnobotanical materials along with carbon dates enables researchers to track the (re)use of burial contexts and to pinpoint regional variation in food offerings recipe, as seen in the beer mash example. This investigation also provides evidence of imported foods in non-elite contexts and how they were introduced into the Egyptian diet in early times, reflecting the multi-directional cultural interactions between Egypt and other cultures. This case study and the one from Deir el-Ballas in the previous chapter are not intended to be a holistic way of studying food in ancient Egypt but rather to expand our theoretical and methodological apparatus, especially in non-elite contexts where conventional Egyptological sources of texts and iconography are often unavailable.

CHAPTER 6

6. Kha and Merit: A case study of New Kingdom food offering from an elite context in the Theban Region, Upper Egypt.

6.1 Introduction

This chapter presents a paleoethnobotanical analysis of the food offerings from the Tomb of Kha and Merit at Luxor. This dataset comes from an elite context and is included here to serve as a contrastive example with the dataset from the non-elite contexts in Deir el-Ballas dating to the same time period. The tomb was found completely intact and unplundered during the excavations of Arthur Weigall and Ernesto Schiaparelli in 1906. The materials were then moved to the Museo Egizio in Turin. Kha was the overseer of the workers who built the tombs in the Valley of the Kings and lived in the settlement of Deir el-Medina, Luxor (Meskell 1998). He was a high official under the reigns of Amenhotep II, Thutmose IV, and Amenhotep III in New Kingdom Egypt. He was buried with his wife Merit in the Theban Tomb TT 8. The botanical materials from this tomb can be compared to those from non-elite cemeteries in the previous chapters in order to reveal aspects of variation in social structure and individual status in Upper Egypt, through the value and access of foods fit for the afterlife.

6.2 Materials and methods

The archaeobotanical materials from the Tomb of Kha and Merit were analyzed visually with a stereo microscope and photographed for further archaeobotanical identification in Turin in 2019 (Shahat 2019). The level of preservation, while excellent, as they are desiccated, poses challenges to quantifying the materials without disturbing the assortments of the fruits merged together in dishes and baskets. It was also important to abide by curatorial standards, such as requirements not to unwrap bowls or baskets. This limited the quantification of the materials to counting, weighing, or measuring subsamples. In this chapter the archaeobotanical materials will be discussed along with their associated containers, specifying the measurements of the container and the sizes of the subsamples reported in terms of metric dimensions and weight. Careful description of what species co-occurred together in a bowl are also reported to expand our understanding of the social meaning of taste. For example, safflower seeds almost always co-occurring with barley invites further speculation. The chapter will present the Tomb of Kha and his wife Merit TT 8 in order to demonstrate variation in status between elite and non-elite contexts that come from the same region of Upper Egypt.

6.3 Results

Results will include a list of plant species identified and contextualized by container (e.g., basket, box, or ceramic bowl) with its content of food offerings.

Ceramic bowl S. 08344: dates, grapes, fig (Figure 33)

The ceramic bowl is made of Nile silt and is 20.5 cm in diameter and 6.5 cm high. The bowl contains 5 different plant species. Most of the food offerings in this bowl are dates with skin preserved. Surface count of the dates amounts to 140 specimens, which is estimated to be over 200 specimens of dates with skin and calyx preserved. No parthenocarpic dates are visible, and all dates appear to have been pollinated. Average weight of a date is 1.819g (Figure 33). Other fruits include a large fig (*Ficus carica*) n=1, grapes (V*itis vinifera*) n=29, Christ's thorn (*Ziziphus spina-christi*) n=2; and one rhizome of *Cyperus sp c.f esculentus*. This reported count is based on subsamples of 7cm x 7 cm from the bowl surface vertically. In other words, I am treating each bowl as an excavation unit, which I subsampled not to disturb the assortment arrangement following the museum's permission and curatorial instructions.

Figure 33. Ceramic bowl S. 08344 containing dates, grape fruits and pips, and figs. The diameter is 20.5 cm (courtesy of the Museo Egizio in Turin, Italy).

Bowl S. 08253 with *Citrullus colocynth* (Figure 34)

Ceramic bowl 3.5 x 10 cm; contains fried or roasted seeds of the sour melon *Citrullus colocynth* L. Seeds are on average 6 mm x 4mm in size. The weight of one seed is 0.012g; 10 whole seeds weigh 0.097g (Figure 34).

Figure 34. Ceramic bowl S. 08253, containing sour melon seeds, *Citrullus colocynthis* (L.) Schrad (Courtesy of the Museo Egizio in Torino, Italy).

Ceramic bowl S. 08346 with persea fruits (Figure 35)

This ceramic round bowl is 17.2 cm in diameter and 4.3 cm in depth. The bowl includes 66 whole fruits of persea; they are of a light brown color near the top, and at the bottom are darker in color. Persea (*Mimusops laurifolia*) belongs to the Sapotaceae family (Figure 35). This is a special finding of whole fruits, because in excavations often the persea seeds inside the fruits are the only preserved parts. Bouquets of persea leaves were common in ancient Egyptian funerary assemblages and were encountered by the author in TT 16 as part of funerary bouquets over the mummies, and have been found in elite tombs such as KV 63, analyzed by Rim Hamdy (Hamdy and Fahmy 2018).

Only one fruit of sycomore fig *Ficus sycomorus* was found in this bowl, weighing 4.771g. Persea fruits had religious significance, as we see in the temple of Ramesses II (the Ramesseum) on the west bank of Luxor. On the temple walls, the deities Seshat, Thoth, and Atum carve the name of Ramesses II on the persea fruits to eternalize his name on the sacred *ished* tree, or persea (Shahat, Jensen, and El-Tayeb-Khaled, personal observation).

Figure 35. Bowl S. 08346 with persea fruits and one sycomore fig. The bowl is 17.2 cm in diameter (courtesy of the Museo Egizio in Torino, Italy).

Bowl S. 8627: cattle dung cakes

The collection also includes cattle dung molded into cakes. Five pieces of dried cattle dung were identified within this bowl among the food offerings. An interpretation is challenging, but these were probably there as cooking fuel for food preparation in the afterlife or as food for the beetle god Kheper, a form of the rising sun indicating resurrection in Egyptian mythology (Podzorski, pers. comm. 2020) (Figure 36).

Figure 36. Bowl S. 8627: cattle dung, in a ceramic bowl (courtesy of the Museo Egizio in Torino, Italy).

Wooden box S.08378 with almonds and tiger nut rhizomes

Eight rhizomes of tiger nut (*Cyperus esculentus*) were found along with five almonds fruits (*Prunus dulcis*) in a wooden box. One fruit of juniper berry (*Juniperus phoenicea*) was also identified (Figure 37). At least three kinds of wood were used in this box (11 x 14.5 x 22 cm), which is made with the sides of the box connected by dovetail joints; long, thin pieces of wood were then added on top along three sides, and attached at the corners with miter joints, and held in place with wooden dowels. These pieces created a lip around three sides, into which the flat lid was able to slide. Another piece was added to the lid, which supported a wooden handle, to help hold the lid as it was opened and closed. A second handle was added to the short side of the box, mostly for decoration, though it would allow a user to keep the box stable while moving the lid. Interestingly, softwood is used to make the lid of the box (Carrie Arbuckle pers. comm. 2019); softwood from conifer trees is not local to Egypt and is usually imported. The top edges are of a different wood than the body of the box, and the wooden dowels are made of a third wood species. Besides the botanical remains, the box also held small pebbles of basalt: one of steatite weighing

8.250g, one of serpentinite of 8.224g, one of quartz of 13.387g, and one of aglomarite of 8.111g (Figure 38). Three reed kohl jars were also found inside this box. The lid of the box is inscribed in hieratic: “For the ka [soul] of the overseer of work, Kha, namely the shining one.”

Figure 37. Box from the Tomb of Kha and his wife Merit containing almonds and tiger nuts (photo by Amr Shahat).

Figure 38. Stones are included in the box with almonds and rhizomes of tiger nuts (courtesy of the Museo Egizio in Turin, Italy).

The main findings in this study include plant species that indicate cross-cultural interactions. One is a basket of juniper fruit. The most abundant imported fruits were species of juniper berries (Figure 39). The first species, *Juniperus phoenicea,* was found in many ceramic bowls. The second species, *Juniperus drupacea*, identified by its larger cones, was found fully preserved in desiccated conditions in a large basket with its cover.

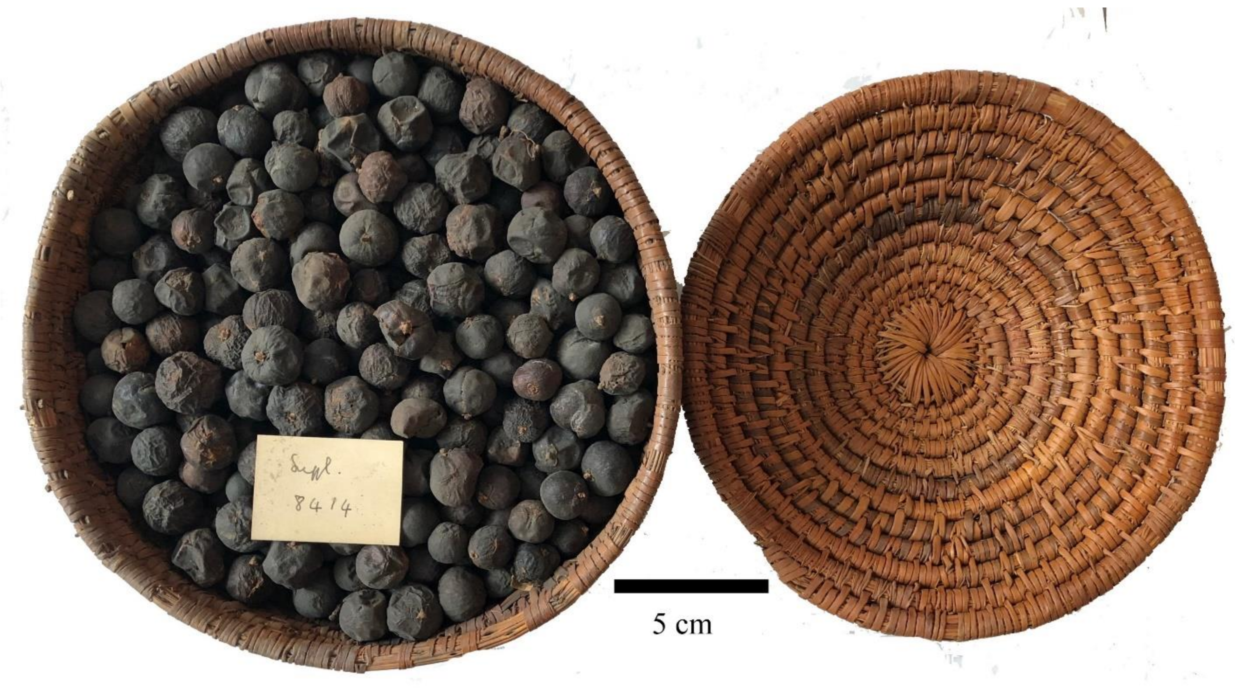

Figure 39. Basket of juniper fruits (*Juniperus drupacea* L.) (photo by Amr Khalaf Shahat, with thanks to Museo Egizio in Turin for research permission).

The archaeobotanical materials from the Tomb of Kha and Merit are known for their exceptional level of preservation. Archaeobotanical materials were found desiccated and kept in ceramic bowls or baskets. The most special finding in this collection is a basket (S. 08415) of what I identified as cumin (*Cuminum cyminum* L.), which preserves its smell after thousands of years (Figure 40). The basket contained cumin leaves, which was not a native species at the time. The container is relatively large, 11 x 20 cm in diameter.

Figure 40. Basket of cumin from the Tomb of Kha and Merit (photo by Amr khalaf Shahat 2019).

6.4 Discussion

An earlier archaeobotanical study was undertaken on these items by the Italian botanist Mattirolo, who published the materials 100 years ago (Mattirolo 1926). This study presents a more extensive identification of the archaeobotanical remains from the Tomb of Kha, reviewing some identifications by Mattirolo and presenting newly identified data. Botanical remains were preserved in bowls and baskets and demonstrate how elite members of the same region would have consumed the same wild species as non-elites but in larger quantities and of better qualities of selected imported species. These botanical materials, combined the local plants, are similar to non-elite tomb offerings, with the imported wild fruit such as the two different species of juniper berries. Cumin and almonds were further additions to burial offering plants when compared to the non-elite burials, making them markers of the high status of Kha. In addition, these samples indicate multi-directional cross-cultural interaction, as evident from the ecology of the plant samples that did not grow in Egypt at the time: cumin might have come through trade with India, and almonds from southwest Asia. However, further isotopic investigations are required.

The botanical materials comprised local plants similar to the non-elite range, in addition to imported wild fruits such as two different species of juniper berries. The author has analyzed the paleoethnobotanical assemblage and their containers. Important results include the identification of some species uncommonly known in the ancient Egyptian archaeobotanical record such as the finding of imported almonds along with rhizomes of tiger nut kept in a closed wooden box made of imported conifer wood inscribed with Kha's title in Hieratic in black ink. The inscription, "For the ka [soul] of the overseer of work, Kha, namely the shining one" emphasizes the importance of these plants as food offerings to the deceased in the afterlife.

Another important find is the palm-leaf basket full of cumin seeds and cumin leaves that astonishingly still preserve their fragrance. Cattle dung cakes were presented in bowls among the offerings, which can arguably be interpreted as fuel or as a food for the sacred beetle Kheper (a form of the sun god). Medicinal plants such as cumin may have been interpreted as condiments but could also be associated with well-being in the afterlife.

Although the plants from the Tomb of Kha and Merit come from a context associated with the preparation for their afterlife, the combination of this particular assortment of fruits informs us about what species can co-occur in the same dish, giving us access to the recipes as well as sensory experiences of taste in that society. The high quality of selected fruit and the large quantities as compared to the assemblages from Deir el-Ballas indicates the high status of Kha and Merit. They clearly had access to valued food, as borne out by the variety and large quantities of imported food species (Hastorf 2016). The social and religious meanings of the plant offerings are complex and go beyond the notion that these offerings merely represent food for the deceased, also representing regional identity in life and in the afterlife.

Finding imported species in large quantities and the high quality selection of fruits and herbs indicate both long distance trade/cultural interaction as well as the value of those foodstuffs that served as status markers. While the basket of juniper berries suggest integration with the eastern Mediterranean and southwest Asia, cumin might have been imported through a network of even longer distance trade with the Indian subcontinent (McLaughlin 2010). This case study shows the role of imported species among the food offerings and how they reveal the marking and negotiation of social status during the 18th Dynasty in Upper Egypt.

6.5 Conclusion

The botanical materials from the Tomb of Kha and Merit show both variation and similarities in burial foodways among the different social statuses of the time in New Kingdom Upper Egypt. On the one hand, local species of Upper Egypt such as persea, dates, and sycomore figs were found in both elite and non-elite cemeteries in Upper Egypt, as an indicator of regional identity and the value of these local products. On the other hand, Kha and Merit, as members of the elite, enjoyed larger quantities and better qualities of selections of local and an imported variety of fruits. Elite status was especially reflected through the large quantity of imported taxa such as juniper berries and cumin, in addition to almond nuts, preserved in a non-local wooden box.

CHAPTER 7

7. Climate change and damming of the Nile River impact on foodways and social structure

In the previous chapters I have outlined the methods for and the potential of stable isotope analysis on botanical materials in archaeological investigation. The case studies presented in Chapters 3, 4, and 5 have shown the value of integrating interdisciplinary approaches that combine humanities, and life sciences (i.e., ethnoarchaeology, archaeobotany, and stable isotope sciences) to provide deep time data on ancient food and water sustainability in Egypt and the Nile Valley. The goal of this chapter is to take the results of the archaebotanical and stable isotope studies of ancient plant-food remains to create an advocacy to ensure peace among communities along the Nile by building resilience against climate change on the Nile river and their native foodways. This resilience is based on and informed by their culture heritage, including their traditional knowledge of managing the Nile river and their past sustainable agricultural system.

Results of oxygen isotope experiments in Chapter 2 and comparing them to the isotopic composition of ancient plants in later chapters shows the huge impacts of climate change and damming of the river on altering the oxygen isotope of the Nile water and the plants that were irrigated with that water. The average $\delta^{18}O$ of ancient plant remains (= +29.53‰) record better water availability and relative humidity conditions than do the modern botanical samples, which have average $\delta^{18}O$ of +40.29‰, indicating increased aridity and evaporative enrichment of ^{18}O

as a consequence of climate change and the increased dams along the river (Shahat laboratory report 2019).

Furthermore, the example of some plant species such as tiger nut found in abundance in different Predynastic sites such as Nag ed-Deir (Chapter 6) and its decline in later times (New Kingdom) indicates climatic and ecological changes in the past and their impact on adaptations in foodways. Today this species is only found in the Delta. This means that climate changes or habitat formation have also impacted plant biodiversity, causing changes in food access and their circulation in society. The impact of climate change on plant biodiversity comes with a public health crisis as decline of plant biodiversity comes hands on hand with decline of gut microbiota biodiversity, that builds populations immune system. While ancient populations had around thirteen thousand families of bacteria in their gut microbiota, modern humans consuming western diet have around five thousand families in their gut microbiota (McCarthy, pers.com. 2020). This huge decline of biodiversity of plants in our diet and consequently, decline of gut microbiota is associated with increase in gut dysbiosis, diabetes, cancer and cardiovascular diseases.

While this research mainly measured carbon and oxygen isotopes for ecological evidence, preliminary results of nitrogen stable isotope are included, because some experiments have shown that this provides an estimation of past soil fertility. Meanwhile, consideration should be given to the post-depositional impact on desiccated plant materials (see DeNiro and Hastorf 1985 on the effect of diagenesis on δ^{13}C and δ^{15}N isotopic composition of archaeobotanical materials). A recent publication by Sharp also indicates that the global-scale model of nitrogen isotope levels in soil varies depending on multiple factors including temperature, soil pH, and mean annual precipitation, driving variations from region to region (Sharp 2017:7–9) These results require further experimentation in arid environments such as Egypt and Eastern Africa.

The case study from Deir el-Ballas shows that the juniper trees were exposed to environmental stress, based on their carbon stable isotope result. The interpretation of $\delta^{15}N$ in these samples is also complicated but helpful as they suggest climatic conditions and soil fertility in antiquity different than the present. While the archaeological juniper sample was highly enriched (+28.58‰), the opposite value of nitrogen was discerned using a modern reference collection of imported *Juniper phoenicea*. The sample, collected in 2019 from a specialized spice store in Cairo, measured a $\delta^{15}N$ value of –14.87‰, a value that is highly depleted relative to the standard, i.e., the atmospheric nitrogen in the air. Meanwhile, its $\delta^{13}C$ is –24.30 ‰, showing a value of a C3 plant growing in regular non-drought conditions.

Furthermore, preliminary results of the nitrogen isotopic values on the ancient botanical samples show that the average ^{15}N values in the archaeological samples are extremely higher in the ancient plants compared to the present ones indicating higher soil fertility in the past and severe decline in modern soil fertility. The ancient plants nitrogen isotopic composition average is $\delta^{15}N$= +16.01‰ among six different species, including a C4 rhizome of *Cyperus esculentus*. The opposite is observed in modern type collections of the similar species growing in modern Egypt. For these, the average shows much depleted values of $\delta^{15}N$ of +3.90‰. The results of the nitrogen isotope evidence support the oxygen isotope experiment in Chapter 2 and suggest a severe impact from both climate change as well as the damming of the river, which has created the subsequent loss of natural fertilizers leading to decreased soil fertility; all reflected through the nitrogen isotope, and increased aridity as seen in the oxygen isotope in the fruits and grains. However, it should be noted that interpretations of the nitrogen isotope in archaeological plant samples require multiple considerations. For this reason, a review of different possible interpretations from the literature on the subject is discussed below.

The difficulty of interpreting nitrogen values in archaeological samples and interpreting the high values in the archaeological samples as opposed to modern samples may be due to multiple factors that may intersect in a given ecosystem. The high nitrogen values of $\delta\ ^{15}N$ and its interpretation have been discussed by Bogaard and colleagues as indicating the use of organic fertilizers (Bogaard et al. 2007). One possible interpretation of enrichment is the use of manure, which leads to the increased value of ^{15}N (Szpak and Chiou 2019). Another study that has created a breakthrough in our understanding of the useful application of stable isotope analysis in archaeobotany of the ancient Near East was conducted by Araus et al. (2014). This publication compared the increased ^{15}N values in the ancient samples to modern samples of cereals from Syria, which were also interpreted as an indicator of the "decrease of soil fertility" starting in the Holocene, due to agricultural intensification and deforestation. For Araus and colleagues (Araus et al. 2014:4) the intensification of agriculture marked the start of the decrease of soil fertility, thus indicating the first human-induced impact on the environment. In addition, Niespolo and colleagues (2020), working on materials (ostrich eggshells) from Eastern Africa, have shown that there was a correlation between the increased aridity associated with lower mean precipitation and increased $^{15}N/^{14}N$ isotope ratio (Niespolo et al. 2020). Overall, this evidence suggests that the high nitrogen value in ancient fruits and grains, reflects higher soil fertility, and the variation in modern samples reflects increased aridity conditions and decreased soil fertility based on a combination of carbon and nitrogen isotope results.

Meanwhile, further experiments are needed to consider species-specific ^{15}N intake, the nitrogen cycle in dry environments, and the post-depositional alteration of desiccated botanical materials in arid environments with low mean annual precipitation in the soil, as well as the anthropogenic impact on the soil nitrogen cycle over time. These nitrogen isotope archaeological experiments should be informed by current concerns addressed in nitrogen biogeochemistry and its application in plant sciences. The $\delta^{15}N$ in plants is dependent on the ^{15}N in the soil, as most plants cannot incorporate nitrogen N2 from the atmosphere into their plant tissues (Sharp 2017:9–7). The $\delta^{15}N$ of natural soils and plants range between –10 and 15 ‰ (Sharp 2017). Some plants have nodules with nitrogen-fixing bacteria living in their roots in symbiosis. An example can be found in beans (Fabaceae family), which have $\delta^{15}N$ values close to zero (Sharp 2017:7–9). The nitrogen stable isotopes studies report the $^{14}N/^{15}N$ ratio relative to the nitrogen in the air as the standard. Nitrogen isotope biogeochemistry studies have shown the extreme complexity of understanding the underlying process that determines $\delta^{15}N$ in terrestrial plants based on natural abundance only. The task of interpretation is even harder for ancient archaeobotanical materials. Even within the same soil, where the nitrogen cycle is expected to be the same, plant species differ in their nitrogen uptake, and their cell membrane may favor particular forms of nitrogen, such as negative or positive ions such as nitrate NO_3^-, nitrite NO_2^-, or ammonium NH_4^+. Some plants prefer ammonium, which requires more ATP energy from plants than nitrate to be assimilated into the plant tissues; this is also an important component of fertilizer (Sharp 2017). Seasonal shifts in nitrogen due to atmospheric deposition inputs must also be considered. For example, dust matters alter the ^{15}N cycle on the Hawaiian Islands due to dust rains that comes from the Gobi Desert in northern China, influencing the nitrogen and strontium signature in the soil (Todd Dawson pers. comm. UC Berkeley spring 2019). Similar considerations should be kept in mind in Egypt where

Khamasin winds carrying dust from desert areas to the Nile alluvial region could possibly have an impact on the ^{15}N and ^{87}Sr isotopic ratio in the soil and hence on the plants growing in these soils (cf. El-Asrag 2005:52, Frumkin 2004:451, Prendergast et al. 2015:88, 90). All of this needs to be accounted for in any paleoenvironmental or anthropological studies that rely on nitrogen isotopic results.

This case study comparing ancient and modern plant samples from Egypt provides deep-time data on the increased anthropogenic impact on foodways over the centuries. For example, nitric acid emission from farming using modern industrialized fertilizer and fossil fuel emission produce lower values of ^{15}N (Durka et al. 1994:765). This is extremely important in the case of Egypt. The dramatic change after the construction of the Aswan Dam under the British colonialism, and then the High Dam- built before the modern environmental and climate change sciences were coined- halted the natural fertile soil deposits that have characterized the Nile Valley since ancient times. As a result, the use of industrial fertilizers increased. More recently, other large-scale dam projects along the Nile in Sudan (the Meroe Dam) and Ethiopia (the Renaissance Dam) will make this effect of decreased soil fertility along the Nile more pronounced.

One interpretation of the high nitrogen values in the ancient archaeobotanical samples (δ^{15}N= +16.01‰) and the depleted values in the modern plant samples (δ ^{15}N of +3.90‰) mentioned above can be associated with the lack of the flood fertile soil deposits due to damming and the increased use of industrial fertilizers. Industrial fertilizers using the Haber-Bosch process, which have replaced the natural fertile soil deposits of the flood, are extremely depleted in ^{15}N isotope (composition close to or below 0‰ [Sharp 2017], compared to the standard), unlike the rich ^{15}N in ancient Egyptian natural fertilizers. This means that dam constructions and the useo f industrial fertilizers have caused irreversible impact on the agriculture cycle and the nutrition values of the crops grown along the Nile in the present compared to the past.

The results of these preliminary nitrogen isotopic values on ancient and modern plant remains support the oxygen isotope experiment in Chapter 2 and suggest a severe impact of human-induced climate change, particularly due to the damming along the Nile River. While the nitrogen isotopic values reflect the impact of damming on decreased soil fertility, the oxygen isotopic values of the Nile water and of the carbonyl group in the fruits and grains organic matter reflect increased aridity due to the increased evaporative conditions the dam creates. More recently, other large-scale dam projects along the Nile in Sudan (Meroe Dam) and Ethiopia (the Renaissance Dam), in addition to having a damaging sociocultural and political impact by relocating native communities and destroying cultural heritage sites (Kleinitz and Näser 2011), have an ecological impact on the isotopic composition of the Nile water and on the agriculture cycle and soil fertility that is expected to be even more pronounced.

The increased evaporative conditions seen in the oxygen stable isotope composition of the Nile River in this study (Chapter 2), compared to the results that Nada reported (2013) for the samples collected in the 1990s, are most likely driven by the increased dam projects along the river altering the oxygen cycle of the Nile. Evidence to support this conclusion comes from measuring surface water samples from the Nile in Nuri, Sudan (January 2020), which shows more depleted values of $\delta^{18}O$ = +0.8 ‰ than in Egypt; while the $\delta^{18}O$ of Tekeze, a tributary to the Nile in Ethiopia is even more depleted, with a value of –0.66 ‰. This means that the high evaporative conditions starting in Aswan with $\delta^{18}O$ = +2.8 are not due to the hot conditions of the summer flood season alone, but most likely driven by the High Dam and even more aggravated by the current increased dam projects along the river including the Renaissance dam. The exceptionally high value of $\delta^{18}O$ the

Fayum lake seen in Figure 1 of +8 to 9 ‰ is even more concerning, as it indicates a rapidly drying lake.

The altering of the oxygen ratio of the Nile and the decreased soil fertility due to multiple dam projects along the river will increasingly aggravate the anthropogenic damaging consequences on the river system, plant ecology, and the entire food web beyond Egypt, and extend the problem into all countries within the Nile basin. Beside the deep-time data presented in this dissertation, published literatures in life sciences have increasingly warned of the impact of dams on altering riverine systems, and the debouchment area of the sea as well. For, example, the seminal article by Humborg et al. (1997) has provided striking evidence of the impact of the dam in the Danube on the nitrogen: silicon: phosphorus ratio (Humborg et al. 1997). According to this study, the increase of nitrogen has altered the river and the Mediterranean Sea into which it pours its water. Altering the nitrogen cycle is argued to have caused damage to the riverine environment food web, the river water isotope biogeochemistry, and the entire river and sea ecosystem of these waters (Humborg et al. 1997:385). Dams around the world are thus affecting the food web structure and the biogeochemical cycling of rivers and the coastal seas in which they pour their waters (Humborg et al. 1997:385).

Furthermore, the high temperature increase due to climate change, the hydrological disruption of the river water flow, and the increased residential time of the water by damming create optimal conditions for toxic algal bloom, including cyanobacteria, endangering other types of life in the river, in addition to the water quality itself (Kim et al. 2021).[78]Such algal bloom may extend thousands of kilometers in the river in downstream locations, due to the flow alteration of the river

[78] Breakthrough studies in the Geum River Basin in South Korea have discussed the amplified impact of dams and in-stream structures and how they cause harmful algal bloom.

water caused by dams (Kim et al. 2021). Thus the current problem of climate change and the construction of dams along rivers aggravates concerns over food and water sustainability.

The study of paleoethnobotanical materials and stable isotopes requires that we keep sound social science theories in mind, as discussed in the introductory chapter. In this case it is important that postcolonial and indigenous archaeologies theories be part of research design, to reflect local voices for many cultures and care about the water and sustainability among all communities along the Nile. Unfortunately, current theorists, economists, and historians from the region celebrate nationalistic viewpoints, which often internalize the previous history of colonialism in Africa, even in the absence of colonialism. For them, the river's wealth is measured not by its life-giving power but rather by its megawatts-giving power. In other words, they have increased dams to maximize the potentials to produce hydropower for industrialization, thus internalizing the concept of "progress" according to the Western–colonial history in the Nile region. It is an internalization of the goals and values of colonialism under a nationalistic veneer, which fails to take into account the cultural meaning and the ecosystem of the Nile River along with the multiple impacts of the alteration of water and food systems on the public health of all the communities along the Nile.

The publication by Seifulaziz Milas (2013), for instance, views the Nile as a gift of Ethiopia. He claims that the Renaissance Dam will benefit the Nile Basin's industrialization: "[The Renaissance] Dam will benefit all of the basin states, . . . The Nile basin and the Horn of Africa are parts of a region where development is severely constrained by lack of access to the reliable and affordable power that is vital to industrialization. . . . To provide a viable basis for industrialization and creation of **non-farm livelihoods** a key need is for energy, particularly energy in the form of abundant, reliable, and **affordable electricity**. That is a key requirement for the transformation of the Ethiopian and other Nile basin economies. In the context of the Nile basin, hydropower is the only energy source likely to fill these requirements” (Milas 2013:4–5, emphasis added in bold). This call for increased industrialization is opposite to what the current literature from the life sciences demands in terms of the ecological impact of dams all over the world and the need to preserve rivers and freshwater resources against climate change (see Montanarella et al. 2015). From the anthropological side, such large projects cause the relocation and cultural annihilation of indigenous groups and the destruction of cultural heritage located in the flooded areas, let alone the environmental devastation, and the impact on the rich plant and animal life of those habitats that rely on the sound river ecosystem that sustains life. A post-colonial perspective, however, urges us to see the Nile as an ecosystem that requires a shared curation for a balanced river environment and to maintain a healthy food web as a responsibility for the entire Nile Basin. This is what science, in the form of isotope analysis on archaeological plant materials and the study of ancient foodways contributes to our view of the Nile. There are so many alternative ways to produce electricity, but there is no alternative to make a river if it dries out, as we see in the case of the Colorado River, which is alarmingly drying up. While some may think this is far-fetched imagination, the isotopic values of the Nile addressed in Chapter 2, and especially Lake Qarun ($\delta^{18}0$ of +8 ‰), which branches off the river, are very concerning, as they represent the highly evaporative conditions of a drying lake.

This overview of stable isotopes application on food ecosystems in the past and the present indicates that creating dams means losing more natural fertile top soil and altering oxygen, carbon, and nitrogen cycles of the Nile river. My answer to studies such as Milas (2013), based on contextualized and comparative archaeobotanical analyses of ancient and modern plants from Egypt, is that industrialization of this precious agricultural zone in such a way internalizes the

Western concept of "progress" (see Adas 2015). Such a concept has been installed by the colonial history of Eastern Africa and will cause irreversible damage to the whole Nile region ecosystem.

In other words, it is not the Nile Basin as a monsoon-dependent agricultural region that should be altered to fit with the colonially defined and currently nationalistically internalized industrial ambitions of Nile Basin states, and the neocolonialism in the form of business-oriented investment that barely cares for environmental sustainability. Instead, we need to learn to adapt to and collaborate as Nile Basin countries around the Nile's natural cycles and what it needs to preserve its ecosystems for the health of plants, animals, and human communities, and the health of the planet itself as freshwater resources in the planet are so limited. These archaeobotanical data and the stable isotope results presented in this dissertation show that the oxygen isotope composition of the Nile River and the plants growing with that water have been significantly altered by anthropogenic activities, and our intensified human agricultural systems that differ from the past. Instead of current political divisions on water shares, the Nile countries should rather unite on what the Nile requires as a natural ecosystem, rather than viewing it only as megawatt hydropower resource, as seen by Milas (2013).

7.1 Suggested solutions: from scientific research to advocacy

One of the key solutions to resolve the problem of damming along the Nile river is to put the issue of into global context by caring for the preservation of all rivers and freshwater sources in the planet. International efforts are needed to protect freshwater resources not only the Nile river in Africa, but all freshwater resources in the world as very limited planetary assets facing dangers of climate change. If all the world coalesced including the UNESCO to protect Abu Simbel temple as a world heritage, reflecting one of the multiple civilizations that grew along the Nile, the Nile itself, and all the world freshwater resources are rather worth that attention as a worldly or planetary asset. In this case the Nile River and all rivers in the world require protection from the impact of climate change, damming and the increased political conflicts. Similar efforts to Paris treaty to combat climate change needs to take place, with intentions to take strong actions to care about all rivers and freshwater lakes in the world and monitor the impact of dams on accelerating the dangers of climate change on rivers, especially in arid regions. In the case of the Nile river, dams along the Nile affect the Nile river life cycle, and the life of animals, plants and human that rely on these water. So, to care about a river is to care about all forms of life it sustains and the cultures that thrive along its shores and tributaries.

Comparative studies of nitrogen and oxygen using archaeobotanical data and modern type collection are further encouraged to serve as a deep-time reliable database to track the damage of damming along the river and to inform political stakeholders, especially that the dams are not designed to increase water availability to communities. Even if this is the goal, current research in California shows that despite the spending of US$10.215 billion on dams, water delivery has increased only by 1.25%.[79] There are several other ways to provide electricity to serve development ambitions, but there is seldom a way to reverse the damaging impact of the dams on the cultural and ecological environment along the Nile.

Another solution is a long term plan of dam removal which is in rise nowadays in the USA due to the dams endangering impact on river ecology, the plant and animal biodiversity, as well as water quality. Dam projects however needs to be planed and observed scientifically to monitor the

[79] Data collected by the non-profit organization in California (Friends of the River in 2018) based on reports from the California Water Commission, and the reports regarding the raising of Shasta Dam, Sites Dam, Centennial Dam, Los Vaqueros Dam, San Luis Dam, and the Temperance Flat Dam projects in California. The author has also filed a petition in May 2021 against the recent proposal of raising the Shasta Dam in California for its destructive impact on the sacred sites of the Native American nation of Winnemem Wintu, in addition to its expected harm to the salmon habitat, and the river's surrounding wildlife.

dynamics of groundwater and stream river water after removing the dams. Any plans for dam removals along the Nile needs to be planned scientifically incorporating hydrologists and stable isotope specialists and environmental scientists. The scientists should work along with political stakeholders and the communities with good intentions to care for the Nile water quality and the plants and animals it sustains to avoid public health and environmental crisis. Any military means needs to be avoided to ensure peace among the Nile communities. Not only military means endanger the peace along Nile basin but it may also endanger the Nile water itself for generations to come. Chemicals in explosives may contains radioactive materials such as ^{137}Cs cesium, which are absorbed by the water and the soil for decades. Plants incorporates this into their tissue and eventually come into the food and water of people and animals, causing damages to body cells due to internal irradiation of beta particles and gamma rays inside the body cells causing cancer (see example on ^{137}Cs Human diet in Chicago by Faure and Mensing [2005:679]). In other words, solutions require peaceful endeavors and international advocacy to foster collaborations between the scientists, international organizations, political leaders and the diverse local communities with the shared goal to care about rivers and freshwater resources as a planetary shared asset and not as a state-owned asset.

While some may consider this anthropological discussion tangential to the paleoethnobotanical and stable isotopic focused study, it is the most important deep-time conclusion from the collected data presented here. It is also important to point out that the current frontier in isotope biogeochemistry focuses on the anthropogenic and urban impact on surface-water and plant-food ecosystems.[80]The main conclusion here is to urge life scientists and archaeologists to benefit from

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[80] See Mayer et. al 2002 on the positive correlation of ^{15}N and land use in a major river basin in northeastern USA; and USGS website on dual isotope ^{18}O and ^{15}N values of nitrate to track changes in rivers; Chang et. al 2002, Kratzer at al 2003, and Mayer et al 2002 on how surface water nitrate in the Mississippi river basin has higher ^{18}O

the archaeobotanical record and its high preservation in Egypt. However, this should be done through sound anthropological theories using, in particular, post-colonial and indigenous archaeology theories to account for the environmental and ecological alterations by putting them into their historical contexts.

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and lower ^{15}N than nitrate in the San Joaquin basin, marking the urban impact on atmospheric nitrate on water and plant catchments. Source USGS (https://www.usgs.gov/mission-areas/water-resources/science/water-quality-nation-s-streams-and-rivers-current-conditions?qt-science_center_objects=0#qt-science_center_objects) accessed in Nov 15, 2019.

8. Discussion and conclusions

8.1 Implications of stable isotope and paleoethnobotanical applications for the bioarcheology of diet in Egypt

As seen in the case studies in Deir el-Ballas and Nag ed-Deir, a variety of food offerings combining local, wild, and domesticated plants, as well as imported fruits, most of which are isotopically C_3 plants, invites bioarchaeologists to be cautious about their interpretations of carbon stable isotope values from human teeth and bones in ancient Egyptian materials. Finding the carbon isotope values in human remains with significant C_3 plants does not necessarily mean that domesticates of wheat and barley are exclusively the main contributors to the Egyptian diet. The archaeobotanical analysis is thus of importance to understand the extent of the repertoire of C_3 plants that have contributed to the diet and resulted in these isotopic values as seen in Chapter 5.

The data-rich and informative study on human mummies by Touzeau and colleagues showed that the ancient Egyptian diet has as its major component C_3 plants with a minor (<10%) contribution of C_4-derived foods (Touzeau et al. 2014:122). They interpreted the constancy of the C_3 carbon isotope levels by stating that "ancient Egyptians had a relatively basic diet with a restricted number of food items" (2014:119). They rarely considered other food sources beyond cereals that contribute to the C_3 isotope values, basing their interpretation mainly on ancient Egyptian textual sources, stating that "only indirect inferences can be made by considering the salaries paid in kind to pyramid workers and craftsmen from the King's valley," pertaining to vegetables and legumes (Touzeau et al. 2014:115). Notably absent from this interpretation is a thorough consideration of archaeobotanical records beyond domesticated cereals. This study shows the complex plant-use by the ancient Egyptians combining the wild native fruits, nuts, and tubers that were funerary food offerings at Deir el-Ballas and Nag ed-Deir and many other sites and that still are enjoyed by modern Egyptians in the region and form their food culture and regional identity.

The present study invites a paradigm shift in the understanding about ancient Egyptian diet and the interpretation of the continuity of the C_3 stable isotope signature on tooth enamel and bone from human remains in Egypt, by considering the archaeobotanical records, which provide a detailed look into what species contributed to the C_3 signature. The stable isotope values of food offerings from Deir el-Ballas suggests that the continuity in the C_3 signature in bone collagen and tooth enamel does not necessarily mean continuity in the same species contributing to those diets, and the composition of the contributing C_3 plants has been shown to change from period to period. The archaeobotanical analysis gives a contextualized understanding of the continuity and changes within the diet and the varied composition of C_3 taxa from one period to another in ancient Egypt in historically contextualized and regionally specific ways. But this is only possible when our thinking about food in Egyptian archaeology goes beyond domesticated wheat and barley to consider wild C_3 plants and imported or newly introduced species.

Another key point gained from this research is that the constant *longue durée* signature of C3 plants in human remains does not necessarily mean linear continuity in the list of C3 plant species in Egypt. The variety of C3 plants in use in ancient Egypt was not fixed but constantly reshaped by Egypt's social and political interactions with other regions. This conclusion challenges the simplistic interpretation by Touzeau and colleagues, who find the continuity of C3 signatures in human bone collagen and tooth enamel carbonates contradictory to the changes in political history, assuming continuity in the C3 plant composition. However, the archaeobotanical materials as indicated in the case studies from Deir el-Ballas, Nag ed-Deir and from the elite Tomb of Kha and

Merit provide evidence reflecting the complex use of plant sources combining both continuity and change in diet by integrating wild, domesticated, and new imported species of fruits within a regionally specific and historically contextualized way. With these caveats, the contributions by Touzeau et al. (2014) in applying stable isotopic analysis on Egyptian mummies are highly valuable.

8.2 C3 and C4 plants in the diet

As discussed in Chapter 5, in the Egyptian situation there is a misconception of the exclusiveness of C3 plants in the diet, as the implications of the presence of C4 plants have not been recognized. Touzou and colleagues (2014) find evidence of a minor contribution of C_4 plants in the Egyptian diet (<10%), and accordingly suggested this originated from the consumption of animals fed with C_4 plants (Touzeau et al. 2014:120). This was based on the assumption that the C_4 cereals (millet and sorghum) only were brought in during the Roman Period as a contributor to the human diet in Egypt (Touzeau et al. 2014:120). The archaeobotanical study in Deir el-Ballas, and Nag ed-Deir invites us to think beyond domesticated cereals and bring to light the C_4 rhizomes that were common in the Egyptian archaeobotanical record (Shahat and Jensen in press). I argue that C4 contributions to Egyptian diet did not necessarily come from cereals, but rather they may have come from the consumption of tubers and rhizomes. Indeed, the archaeobotanical record from Egypt includes multiple findings of tubers, and rhizomes from the Cyperaceae family, specifically from the species *Cyperus esculentus* (tiger nut) and *Cyperus rotondus* (Arnold et al. 2016:5). *Cyperus esculentus* tubers have been identified in archaeological contexts since the Predynastic Period. For example, *Cyperus esculentus* rhizomes were found in Nag ed-Deir (Chapter 5) and at Hierakonpolis Locality 11 C, dated to 3800–3500 calBC (El-Hadidi et al. 1996), and their use continued until at least the New Kingdom. They have been found in tombs of elite and non-elite, as seen at Deir el-Ballas in Tomb 244/255 (non-elite context) and the Tomb of Kha and Merit (elite context) (Shahat and Jensen in press). This was most likely an import from the Delta region, the only region in Egypt where *Cyperus* grows today, if ethnographic evidence through personal observation is transferrable to the past. However, the evidence of tiger nut found in basket at Nag ed-Deir by Reisner and Lythgoe (Chapter 6) suggests that more humid and less arid conditions prevailed in Upper Egypt than later periods and in modern times.

Stable isotopic research on these materials will be published separately, but for the current presentation, it is important to report that tiger nut sample #6-12080 from Nag ed-Deir has a $\delta^{13}C$ value of –10.69‰, which confirms that it is a C4 plant. The ancient samples seem to be more depleted in $\delta^{13}C$ compared to the modern type collection of *Cyperus esculentus* from Egypt, which has a value of $\delta^{13}C$ –13.01‰. This study urges bioarchaeologists to give more consideration to archaeobotanical data and collate them into their interpretations of the stable isotope dietary reconstruction for ancient Egyptians. It also invites us to think beyond domesticated species when we envision diets and meals in the past. Thus, we respectfully would like to modify the statement made in Touzeau et al. regarding sorghum and millet being the only C_4 plant sources in Africa (Touzeau et al. 2014:115), arguing for the presence of C4 from non-domesticated species such as the rhizomes of Cyperaceae in Egypt as early as the Predynastic Period. Meanwhile, we appreciate their significant scientific contribution of stable isotope sciences in Egyptian bioarcheology (Shahat and Jensen in press).

8.3 Implications for Egyptian chronology

Contextualized study of fruits also provides tighter carbon dates than other plant parts such as wood, which makes these absolute dates a significant contribution to the ongoing discussions about Egyptian chronology. This study confirms that the carbon dates obtained for the botanical samples support the relative dating provided by the ceramics and other material culture artifacts such as scarabs found in the tombs in Deir el-Ballas Cemetery 1-200. In the case of Deir el-Ballas, despite significant plundering of the cemetery, the AMS carbon dates obtained from the plant remains align with the early to mid-18th Dynasty dates reflected by the material culture (e.g., ceramic style, scarab, and inscribed seals), thus confirming that the archaeobotanical samples were part of the original grave goods.

While the plant remains that were found within ceramic containers in the tombs were not likely to be intrusive, it was particularly important to conduct independent testing in the case of the watermelon seeds from Tomb 244 or 255, which were not associated with any particular vessel, in order to ascertain whether or not they dated to the same time period as the rest of the tomb assemblage, which they did (Shahat and Jensen in press).

Other cases where the carbon dating of the botanical remains is at odds with the material culture was the sample of *Pistacia lentiscus* L. from Nag ed-Deir, which provide a cautionary example, proving the value of conducting a carbon dating on organic samples whenever possible. While the grave contained early Predynastic artifacts dated to Naqada Ic, the *Pistacia* sp. fruits were carbon-dated to 2494–2460 calBCE with 75.3% certainty, indicating a 5th Dynasty date (Shahat and Jensen in press), approximately 1000 years after the Predynastic interments. So, this reminds researchers to conduct a carbon dating on archaeobotanical materials whenever possible for more accurate contextualization and interpretation, in order to discern whether plant remains are part of an original deposit or were a later reuse or even an intrusion into a context, especially if conclusions are critical to building historical chronology. Carbon dating of this botanical sample thus provides an important example of the reuse of non-elite graves during the Dynastic Period. This example also gives an alert for researchers to conduct ^{14}C dating on archaeobotanical materials whenever dealing with reused, insecure, or mixed contexts for more accurate contextualization and interpretation.

8.4 Implications for social history of food valuation and cultural interactions

The case studies of Nag ed-Deir and the New Kingdom Deir el-Ballas reflect social histories of cultural interaction in non-elite contexts. Botanical samples of mastic dated to the early Dynastic Period tell us about imports of the fruits, most likely from southwest Asia, and how they were incorporated into Egyptian diet and funerary offerings. At the site of Deir el-Ballas, similar wild fruits in food offerings, such as doum fruits and dates, indicate that there was some aspect of continuity in regional foodways. Meanwhile, new species were introduced, such as pomegranate and juniper fruits, which suggest interaction with Eastern Mediterranean cultures, and domesticated watermelon, which indicates interaction with East African cultures. Textual evidence found in Deir el-Ballas, albeit scarce, includes an ostracon (inscribed ceramic sherd) that lists the names of ship crews, among them crew members with Canaanites and Nubian names (Peter Lacovara pers. comm. 2021). Furthermore, evidence of cultural interaction in the site comes from the finding of Kerma pottery and Syrian vessels from both grave and domestic contexts (Peter Lacovara pers. comm. 2021). Recent DNA studies also suggest that watermelon was domesticated in Sudan (Renner, S.et. al, 2021). Thus, these findings support the interpretation of the paleoethnobotanical materials as a window to the social history of cross-cultural interactions.

The Tomb of Kha and Merit informs us that while wild fruits in the region continued to mark the regional identity of the consumers, imported species in large quantities and of high quality indicate cross-cultural relationships. Furthermore, a long-distance trade network was also evident from the basket of cumin, which suggests long-distance trade with the Indian subcontinent (McLaughlin 2010).

8.5 Conclusion

This study of the food offerings from the non-elite Cemetery 1-200 at Deir el-Ballas, Nag ed-Deir and the Tomb of Kha and Merit provides evidence of the complexity of Egyptian plant use in a diet that combined regionally and historically specific patterns in Egyptian culture. Native wild plants, domesticated plants, as well as imported species were introduced into the diet over the course of history. While stable isotope analysis on human teeth, bones, and hair confirms the continuity of a C_3-based diet, archaeobotanical materials give a more focused look at the "menu" of plant taxa that constituted the basis of the isotopic results (see chapters 4 and 5). This menu was not fixed but rather shows both continuity and changes in the composition of Egyptian foodways and food offerings over time (see chapter 3, 5 and 6). Moreover, even though C_4 plants were a minor contributor to the diet, the identification of archaeobotanical remains demonstrates that the tiger nut is a C_4 plant that was a regular part of the diet over time. Further research on additional native and imported species to determine whether they were C_3 or C_4 plants, and what their possible source regions are may help to clarify the picture of the ancient Egyptian diet even further.

Overall, this dissertation studying archaeobotanical remains in combination with isotopic analysis opens up new ways of thinking about the social history of Egyptian foodways and the role of food in Egyptian society more broadly. The agriculture cycle in Egypt benefited from both domesticated and wild species management, forming the basis for regional recipes. Regional diversity in Egyptian foodways goes beyond domesticated plants and should be sought through close analysis of the combination of domesticated plants, wild fruits, and imported species in each context and time period. Conducting radiocarbon dating is necessary to contextualize the materials and insure they are not intrusions. Food remains found in ancient Egyptian settlements and tombs not only embody a list of taxa reflecting ancient plant biodiversity in the diet but also encode the social history of food, as well as the influence on past climate conditions on the society in the past. While the distinct identity of a region may have continued to be reflected in the use of local wild fruits and rhizomes, new social relations and cultural interactions shaped and reshaped Egyptian foodways, in both elite and non-elite contexts.

It has also been shown that (see chapters 1, 2 and 7.1) that paleoethnobotanical and stable isotope applications on Egyptian foodways needs careful synthesis of theories from life sciences and post-colonial and indigenous archaeology theories from the social sciences. This synthesis of theories and scientific methods helps to understand the value of native local knowledge in relation to water and food sustainability while recognizing the regional and temporal diversity. It also demonstrates the importance of foodways as a marker for cultural identity.

This research (chapters 2, 4 and 5) also discusses the importance of integrating paleoethnobotany and stable isotope analysis in ancient plants and the comparison with the modern plant reference collections from Egypt to trace the anthropogenic impact of climate change and how damming along the river accelerates these dangers. The dams on the Nile river, have altered foodways and social structure in Egypt and the larger Nile Basin in Eastern Africa. Contextualized archaeobotanical studies in archaeology thus provide a *longue durée* perspective and possibly even a corrective guiding principle to such human-induced environmental dangers on the Nile valley and its diverse communities. As seen in the discussion section (7.1) the Nile River as a freshwater resource that sustained multiple civilizations and communities in the past and present needs to be reconsidered as World Heritage and a planetary asset that requires shared efforts and curation to reverse the impact of climate change, damming and political conflicts on native communities, their cultural heritage, and foodways.

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