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The Elite Meroitic Experience on Sai Island, Sudan: Using Stable Isotope Analysis to Identify Patterns related to Sex and Age for the Interpretation of Social Identity

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THE ELITE MEROITIC EXPERIENCE ON SAI ISLAND, SUDAN: USING STABLE ISOTOPE ANALYSIS TO IDENTIFY PATTERNS RELATED TO SEX AND AGE FOR THE INTERPRETATION OF SOCIAL IDENTITY

by

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ABSTRACT

The research conducted for this thesis utilized stable isotope analysis to reconstruct the diet of 35 individuals from an elite Meroitic (350 BC – 300 AD) cemetery (site 8.B.5A) located on Sai Island, Sudan, with a focus on adult age categories and biological sex, to understand intra-class variation in diet. Stable carbon and nitrogen values from human bone collagen were used to understand elite social organization, social practice, and gender roles in the Meroitic period through the lens of social identity and post-processual theories. The samples were grouped based on biological sex, median age, and assigned age categories (young, middle, and old adult). The isotopic values of each group were compared to determine if any differences could be identified to create social identity profiles. Carbon-13 and nitrogen-15 stable isotope values indicate that the elite class was relatively homogenous in their diet, but there were some statistically significant differences. The percentage of C_4 plants in the diet showed that the majority of females had a diet of approximately 25% C_4 plants, while the majority of the males had a diet of 25-50% C_4 plants. These values suggest females were eating a more homogeneous diet possibly based on lower status foods, which are primarily in the C_3 plant category. The different ranges of nitrogen and carbon isotope values in the male (-18.05‰ to -12.66‰ $\delta^{13}C$ and 8.62‰ to 11.94‰ $\delta^{15}N$) and female (-17.92‰ to -16.43‰ $\delta^{13}C$ and 11.05‰ to 14.59‰ $\delta^{15}N$) samples may indicate a much broader diet in males and/or differential geographic origins and residency patterns between males and females. The isotopic values may indicate particular Meroitic and Nubian cultural practices such as the production and consumption of a C_4 plant based beer. Lastly, this research demonstrates the ability to ascertain intra-class differences from isotope values derived from human bone collagen.

ACKNOWLEDGMENTS

I would like to thank my family for their contributions to my education and constant support throughout this journey. A special thank you to my mother for teaching me the value of hard work and perseverance and for always pushing me to heights I never thought I could reach. To my Grandmother and Papaw, thank you for always supporting me and going to whatever lengths necessary to make sure that I succeed. Without you, I could not have achieved half of what I have today. I would also like to thank my better half, Adrian, for staying by my side over the past two years and constantly giving me a reason to push forward. This thesis is ultimately dedicated to my co-advisors, Dr. Tosha Dupras and Dr. John Schultz for their unending patience, support, and guidance, and Dr. Emily Zavodny for her assistance as a committee member. Without their assistance, this research would not be possible. I would also like to acknowledge Dr. Vincent Francigny for allowing us to do this research, and Dr. Alex de Voogt and the American Museum of Natural History for the funding to allow for the collection of these samples. Rachel Gregoire, Ariana Gugora, and Kaylee Biegler are also recognized for their assistance in processing the samples used in this project.

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CHAPTER ONE: INTRODUCTION

The use of stable isotopes in bioarchaeology has become ubiquitous due to the wide range of information that can be obtained through isotopic methods, including, but not limited to, diet, mobility, and weaning patterns (Makarewicz and Sealy, 2015; Katzenberg et al., 2011; Britton, 2017; Sehrehwat and Kaur, 2017). However, the evaluation of intra-class variation has not been previously assessed isotopically with a high degree of success.

The purpose of this thesis is to utilize carbon and nitrogen stable isotope analysis of bone collagen to reconstruct life experiences for individuals recovered from an elite Meroitic (350 BC - AD 300) cemetery (site number 8.B.5A) located on Sai Island, Sudan (Figures 1 and 2), with a focus on adult age categories and biological sex to help identify and understand any intra-class differences. The theoretical approach taken combines isotopic methods with post-processual and social identity theories to provide a more detailed assessment of how life was experienced differently by each of the biological sexes and age categories in the Meroitic period and provide insight to any differences within the elite class. This topic is significant because the relationship between age and sex categories and stable isotopes has not been widely explored in an intra-class context, and because there is a large gap in the literature as it pertains to Nubian and Meroitic intra-class differences. Therefore, this research contributes additional information to the scarce pool of extant literature on the relationship between isotopic values and life experience based on age categories, biological sex, and intra-class variation.

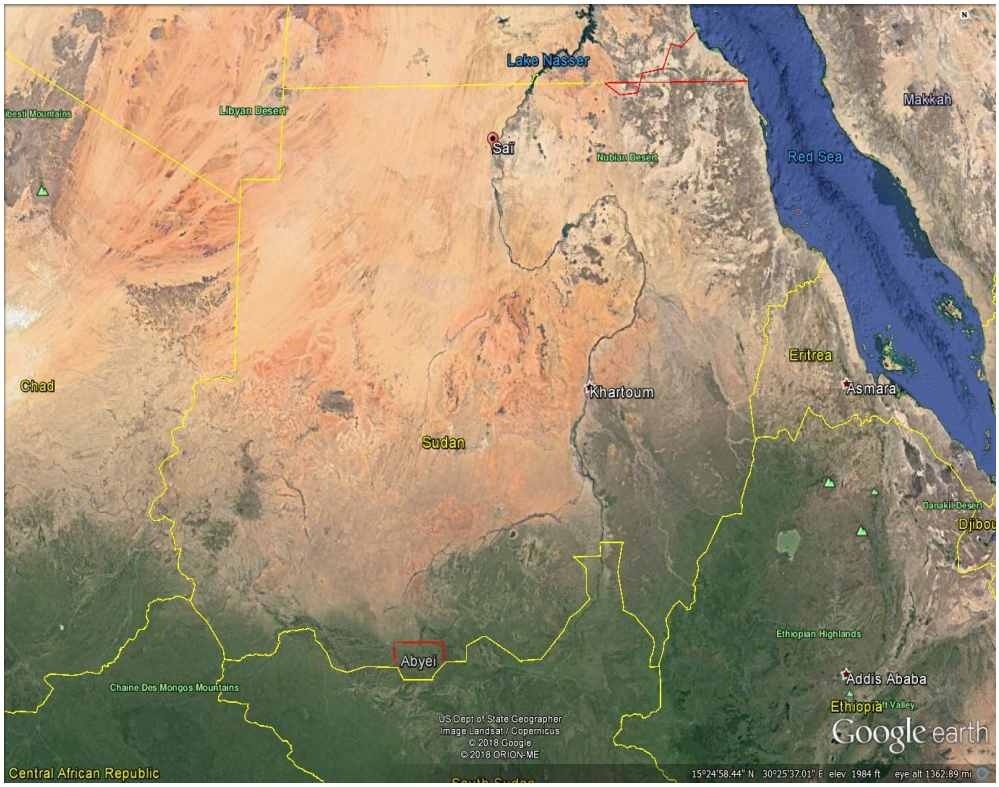

Figure 1: Map showing the location of Sudan with the approximate location of Sai Island, indicated by the red and black marker near the Egyptian border. North is to the top of this image.

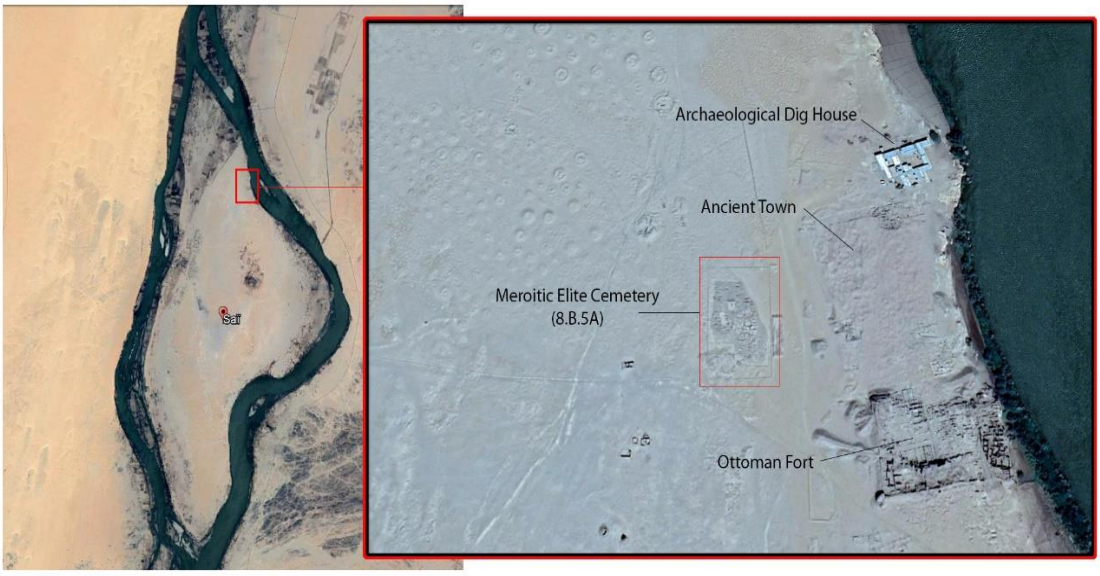

Figure 2: Map showing a more detailed view of Sai Island, Sudan. The site is located in the red box at the center of this image. North is to the top of this image.

The primary research questions of this thesis are, “Can differences in life experiences between adult age categories within the elite class be inferred based on carbon and nitrogen stable isotope values?”; and “Can differences in life experiences between the biological sexes within the elite class be inferred based on carbon and nitrogen stable isotopic values?” These main questions are accompanied by three additional questions.

1. Are the differences in isotopic values between age categories and elite males and females indicative of specific cultural practices?
2. What are the implications of cultural practices on everyday life for elite individuals of different age and biological sex categories in ancient Nubia?
3. Can distinctions between elites be made in order to provide a deeper understanding of elite societal organization?

The hypothesis is that sub-groups within the elite population, including males, females, and groups delineated by age, will have different isotopic values and compositions of C_4 in their diets that will provide the basis for identifying differences between the groups. Additionally, I hypothesize that these differences will provide the basis for identifying cultural practice, interpreting its implications on everyday life and gaining a deeper understanding of elite societal organization.

These questions will be addressed using data from carbon and nitrogen stable isotopic values from bone collagen from 53 male and female adult individuals from the elite Meroitic cemetery (8.B.5A) located on Sai Island in northern Sudan. Of these 53 individuals, 19 are female, 33 are male and 3 were of unknown sex, but some individuals had a known age. The sample was divided into an additional three groups including young adult (5 total), middle

adult (36 total), and old adult (10 total). There was one additional female present, but the age was not available for this individual and there was one individual of unknown sex not included in this count because their age was unknown.

The remainder of this thesis will provide a more detailed discussion of related literature and the research completed to address the aforementioned questions. Chapter two includes a detailed review of the literature, encompassing ancient Nubian culture, Sai Island archaeology, theoretical approaches, and an overview of stable isotope analysis. Chapter three is focused on the methodology used to process the samples for stable isotope research. Chapter four provides an overview of the results. Chapter five includes a discussion and interpretation of the results. Chapter six is focused on the conclusion, including an overview of limitations and possibilities for future research.

CHAPTER TWO: LITERATURE REVIEW

The literature review chapter will begin with an overview of Nubian culture during the Meroitic period (332 BC – AD 640). Then, a more focused discussion of Meroitic period archaeology on Sai Island is provided. After establishing the cultural and historical background for this study, a basic overview of bone biology and stable isotopes is provided.

Nubian Culture During the Meroitic Period

Presently, there is not a large body of research dedicated to understanding the cultural practices associated with the Meroitic period (332 BC – AD 640) in Sudan (Ambrose et al., 2003; Edwards, 2007; Iacumin et al., 1998). This is also true for early descriptions pertaining to funerary practice in the ancient Meroitic capital of Meroe, the earliest available information on Meroitic funerary practice which comes from the 2nd and 5th centuries AD accounts by Herodotus and Agatharchides respectively (Francigny, 2012). Later records from traveler's descriptions and the first excavations in the lower Nubian region are available in the 19th century (Edwards, 2007). Most of the research in the region has been the result of salvage archaeology due to dam construction and the flooding of the Nile (Edwards, 2007). An ambivalent colonial attitude towards Sudan has also contributed to the lack of research in the region, creating a gap in the literature in regard to the political, social, and economic components of the region, particularly concerning the Meroitic period (Crawford, 1948; Wengrow, 2003; Edwards, 2007). To better understand the Meroitic period and its associated culture, it is pertinent to look at funerary practice, because burial practice is deeply rooted in the perpetuation and alteration of socio-economic order and social identity (Brass, 2014). The

known history of the region and occupation sites in the Sudan will also be discussed to provide a holistic view of the research available on the topic and to outline the sociocultural background that this isotopic analysis will rely on. To accomplish this, a brief history of Sudan, from the early Holocene through the Meroitic period, will be provided followed by an overview of archaeological occupation and burial sites.

Sudan is a region of importance as it hosted the earliest kingdoms in Africa including Kerma, Napata, and Meroe (Edwards, 2007). These kingdoms were located in northern Sudan near the Nile river. Through time this region also overlapped with the Egyptian empire and, consequently, the Roman empire during the Egyptian Greco-Roman Period (Table 1 and Figures 3 and 4). The capitals at Kerma, Napata and Meroe as well as the Egyptian/Hellenistic influences overlap significantly with Sai Island throughout time (Figure 4) (Derived from Shaw, 2000, Bagnall, 2009,and Fisher et al., 2012). The history of the Sudan dates back to the early Holocene around 8500 BC when a shift of the desert margins to the north led to an increase in colonization and population in the area (Edwards, 2007; Kuper and Kropelin, 2006). This time period saw a rise in evidence for hunter gatherer populations and pottery production (Edwards, 2007). During the Neolithic period domesticated crops and pastoralism became evident in the Sudan with the domestication of cattle around 5000-6000 BC (Gifford-Gonzales, 2005; Wendorf and Schild 1998; Marshall, 2000). By the fourth millennium people began to fragment into distinct cultural groups and there was an increase in organized trade which would later become a staple of elite society (Edwards, 2007). The second and third millennium saw the rise of Kerma (Kush) as a major political center around 2500 BC, until its demise when Egypt conquered Kerma in 1450 BC (Edwards, 2007; Bonnet, 1990; Gratien, 1978; Reisner, 1923). The

heavy colonial influence in this region left behind a well-documented Egyptian colonial history but neglected Sudan as its own entity (Edwards, 2007). Later into the second millennium/early first millennium the Egyptian colonial presence lessened. The decline of Egyptian influence and rule in the Napatan region, however, is not well documented (Edwards, 2007). Two distinct periods followed Egyptian rule: the Napatan (722-332 BC) and the Meroitic (350 BC– AD 300) (Fisher et al., 2012). The Napatan/Meroitic kings adopted many Egyptian practices, including Egyptian cult worship, monumental architecture, and pyramid burial which intermixed traditional Nubian symbolism (elephants, giraffes, sorghum, and cattle) with Egyptian symbols and religious beliefs (Edwards, 2007; Francigny, 2012). The social conditions during this time are not well-documented (Edwards, 2007).

Table 1: Table showing the Egyptian and Sudanese periods of time relevant to this research (Derived from Shaw, 2000, Bagnall, 2007,and Fisher et al., 2012)

Dates	Egyptian Time Period	Dates	Sudanese Time Period
2160-2055 BC	First Intermediate Period	**2150-2008 BC**	Early Kerma Period
2055-1650 BC	Middle Kingdom	**2008-1685 BC**	Middle Kerma Period
1650-1550 BC	Second Intermediate Period	**1685-1550 BC**	Classic Kerma Period
1550-1069 BC	New Kingdom	**1550-1077 BC**	Egyptian Occupation
1069-664 BC	Third Intermediate Period	**1076-723 BC**	Independent Nubian Culture
664-332 BC	Late Period	**722-332 BC**	Napatan Period
332-30 BC	Ptolemaic Period	**350 BC– AD 300**	Meroitic Period
30 BC – AD 395	Roman Period	**AD 300 – 640**	Post-Meroitic Period
AD 300-700	Byzantine/Christian Period	**AD 641-1400**	Christian Period
AD 700 – Present	Islamic Period	**AD 1400 – Present**	Islamic Period

Figure 3: Side by side timeline of the Egyptian and Sudanese time periods (Derived from Shaw, 2000, Bagnall, 2009,and Fisher et al., 2012)

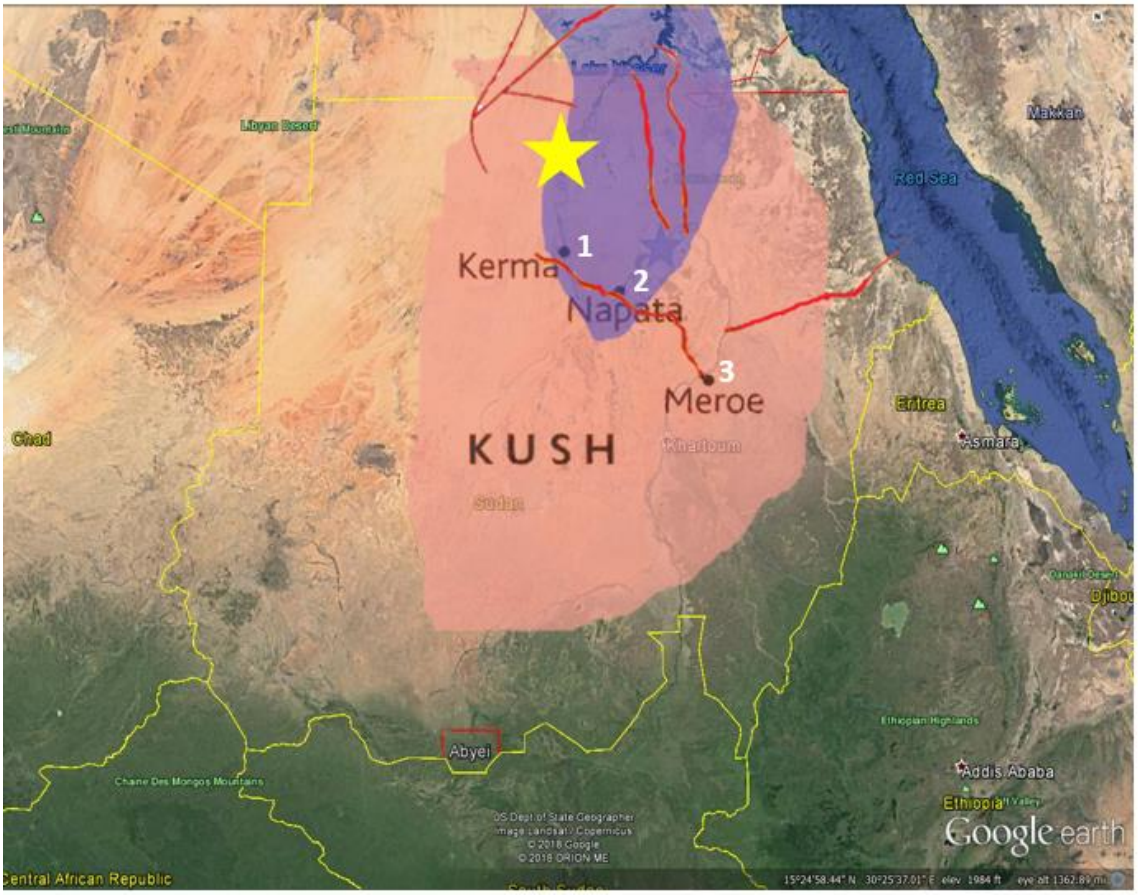

Figure 4: Map showing the kingdom of Kush (Light Pink), Kerma, Napata, Meroe, Sai Island (Yellow star) and the Egyptian empire during the Greco-Roman Period. Trade routes are indicated by red lines. The white numbers indicate the order in which each city became the capitol to demonstrate the movement of political power in the region (Derived from Edwards, 2007 and Quora.com).

The Meroitic period began around 332 BC and coincides with a shift in the location of the elite cemeteries from the Napata region to the new capital of Meroe and the creation of a distinct imperial culture based on external trade (Edwards, 2007; Lenoble and Sharif, 1992). This was one of the largest organized states in the region prior to the 19th century AD (Edwards, 2007). During this period, there was a mosaic of mortuary practices in use, ranging from Roman to Egyptian in influence. These practices included the construction of pyramid burials, Egyptian cult worship, circular graves, and traditional Nubian burials (Edwards, 2007). The tombs most often associated with elite status during this time were rectangular or square pyramid burials

constructed using 330x162.5x100 mm bricks made from silt and could range in size from 10x10 meters to less than 1x1 meters (Edwards, 2007; Francigny, 2012). The size of these monuments has not been shown to correlate with the age of the interred individual(s) (Francigny, 2012). These monumental burials were constructed by filling the empty space with rubble making them relatively unstable (Francigny, 2012). Oftentimes these monuments would contain places for offerings oriented to the east, monolithic niches (cornices), capstones, statues, offering tables, and painted plaster (Francigny, 2012). Most common Meroites, however, were not buried associated with monumental structures but rather in tumuli, which are large circular raised mounds of earth (Francigny, 2012). Other types of graves include tombs with a shaft oriented from east to west with an ellipsoidal base, a north-west oriented shaft with an ellipsoidal chamber, graves with a circular chamber to the west of the tomb shaft, and tombs with a circular chamber to the south of an irregular tomb shaft (Usai et al., 2014). The covering of these tombs is currently unknown, but some evidence in the form of small pebble concentrations indicates that the tombs may have been covered at some point (Usai et al., 2014). Some burials also include wooden sticks at the top of the burial chamber which could have also been used as a covering. Another interesting component of burials during this time period is the disinterment of previously buried individuals to make room for subsequent burials or the burial of more than one individual in a tomb (Usai et al., 2014; Francigny, 2012).

In terms of positioning, individuals could be buried in a flexed position oriented from west to east, a supine position with the head to the west, or a crouched position with the head to the south (Usai et al., 2014; Francigny, 2012). In this position, their head would be to the west and they would be laying on their left side facing the north (Usai et al., 2014). There are

some exceptions to this positionality, however. In addition, botanical elements and textiles have also been found in conjunction with Meroitic tombs (Usai et al., 2014). Many types of grave goods are found in association with the Meroitic period, including carnelian, lydian stone, faience, glass and quartzite beads, figurines (Bes and Amun ram depicted with the sun disc), pottery, bronze vessels (for elites only), amulets, bracelets, carnelian, zeolite, shells from the Red Sea, ivory labrets and nose plugs, makeup pallets with remnants of red ochre, malachite, copper alloy, glass bottles, shrouds, ivory kohl pots, coffin fittings, tweezers, oil, perfume and Wheel-made red-ware (Brass, 2014; Haaland, 2012; Francigny, 2012). Grave goods have been shown to be non-discriminate based on gender (Brass, 2014).

Specific cultural practices can also be associated with the Meroitic period. One cultural practice, that affected the skeleton by chipping the tooth enamel, was the adornment of the lower lip with studs (Labrets), which was common among females (Brass, 2014). These lip studs/labrets were either metal or wooden, but oftentimes are not found in the mortuary context. This could be due to removal or the decay of a wooden lip stud (Brass, 2014). The alteration of teeth or removal of teeth during life which has been associated with pastoral societies was another common cultural practice visible on the skeleton (Brass, 2014). This practice has also been correlated with pastoral societies (Brass, 2014). Another link to pastoral society seen in Meroitic archaeological populations is based on the absence of harvesting tools in the archaeological record as well the presence of cattle figures in non-mortuary contexts as well as the discovery of many cattle, dog and goat remains (Brass, 2014).

In addition to the aforementioned cultural practices, a distinctly Hellenistic influence can be seen in some cultural and societal practices during the Meroitic period (Edwards, 2007).

This is most notable in Meroitic pottery, which emulates a Hellenistic style. It has been suggested that this is due to the creation of a large network based on external exchange, which contributed to the establishment of an elite Meroitic culture (Edwards, 2007). The pottery associated with this time period also suggests that there was increased variation in the material culture related to serving and consuming food and drink based on the presence of variable types of serving ware (Haaland, 2012). This relationship between food consumption and elitism was further affirmed by the previously mentioned elaborate trade networks and the domestication of cattle which formed a basis for elite culture (Haaland, 2012).

The Meroitic period also displayed distinctive beer culture, the elite consumption of wine, and a competitive feasting culture surrounding funerals (Haaland 2012). The creation of a beer culture was determined based on evidence for beer in elaborate ceramic jars and the continued dominance of this beer culture into the modern day (Haaland, 2012; Armelagos et al., 2001). It is postulated that beer was served on special occasions to delineate rank (Brass, 2014). The class component of this culture and the competitive feasting practices was deduced based on the presence of varied drinkware associated with different social status (Haaland, 2012; Armelagos et al., 2001; Valbelle, 2004). This variation can also be seen in relation to wine consumption. While beer was more prevalent among all classes, with the class distinctions being made based on drinking vessel, wine was more elitist in nature based on the fact that it had to be imported through the elite controlled trade networks and stored in elaborate amphorae from Palestine (Haaland, 2012; Valbelle, 2004). Additionally, the consumption of wine is seen in conjunction with funerary rites and in religious images during the Meroitic period (Haaland, 2012; Valbelle, 2004).

In addition to beer and wine culture, archaeological evidence from the Meroitic period demonstrates a competitive funerary feasting culture (Haaland, 2012). This is based on the discovery of many bucrania (Cattle and goat crania) deposits near funerary sites and the importance of cattle in elite trading culture (Haaland, 2012). Another item that made class distinctions was bread. At sites like Western Deffuffa, large centers with audience halls, houses and ovens were found indicating elite status. Bread molds associated with the Egyptian cult of Amun were also found at Jebel Barkal, Kawa and Kerma (Haaland, 2012). These class distinctions based on food consumption and class differentiation makes isotopic analysis of diet of extreme importance in determining the class of an individual. In addition to food, site location also played a major role in determining status. This is evidenced by the differentiation of sites by tasks. For example, at Zakieb, which is near a river, archaeological evidence suggests that the site was used primarily for dry season fishing and herding (Haaland, 2012). In contrast, Um Dereiwa is more consistent with cultivation and herding (Haaland, 2012). Based on the distinction of class by location and food consumption it is clear that a greater understanding of elite culture can be gained through isotopic analysis.

Sai Island Archaeology

Having outlined the broader history of the region, the archaeology specific to Sai Island (Cemetery 8.B.5A) will be presented. This island has four Meroitic necropolises in the northern portion of the island and one in the southern portion (Francigny, 2009). The individuals used in this research were excavated from the cemetery 8.B.5A, located in the northern portion of Sai Island near an ancient town (Francigny 2009; Francigny, 2010) (Figure 2). 8.B.5A is an elite

cemetery in the northern portion of the island. This determination was based on the presence of a bracelet depicting the god Amun in 8.B.5A, suggesting the presence of an elite religious class or priesthood (Francigny, 2009). This is further supported by the presence of monumental pyramid structures in the necropolis indicative of elite status (Francigny, 2009). The north western and eastern boundaries of the cemetery were located during the 2009 excavations. The southern boundary is most likely covered by a modern Muslim cemetery which prohibits excavations (Francigny, 2009; Francigny 2012).

Cemetery 8.B.5A is dated to the 1st and 2nd centuries AD based on dates from two artefacts: a long-necked bottle and a bowl (David, 2009). The bottle yielded a date corresponding to the 1st century AD, while the bowl was dated to the 1st-2nd century AD (David, 2009). This suggests that the cemetery grew from the north west to the south east (David, 2009).

The first excavations of the 8.B.5A cemetery took place from 1997-2004 during which time a large backlog of artefactual and skeletal material was created, including 11 adult individuals and 55 juvenile individuals (Francigny, 2010; Francigny, 2009). Following this, the next excavations were undertaken in 2009 with the goal of working through the backlog, mapping the excavations, and focusing primarily on pottery (Francigny, 2010). The mapping of the excavation area showed that smaller graves tend to cluster around larger graves which is consistent with funerary practice in the Meroitic period (Francigny, 2010). Additionally, a progression of Meroitic, post-Meroitic, Christian and Ottoman graves was discerned over time (Francigny, 2010). The Christian infant and child burials tended to be on top of or in the burial shafts of the Meroitic graves, with pottery vessels being used as coffins for infants. Juvenile

remains were typically wrapped in shrouds without any grave goods present (Francigny, 2010). Christian adult burials are typically found surrounding the Meroitic cemetery. Ottoman burials, however, cut through the Meroitic funerary architecture with no pattern of placement. It should also be noted that there was significant disturbance of the cemetery, in many cases creating co-mingled skeletal material in most tombs. This is important to note for this research in that it explains why there are instances of individuals of unknown sex and age in the sample. The co-mingled state of the remains made it impossible in some cases to discern biological information beyond the "adult" classification.

The second season of excavation resulted in the discovery of seven Meroitic graves and the remnants of four pyramids (Francigny, 2010). The pyramids yielded some information on the way monumental funerary structures were erected. Smaller satellite pyramids tended to have foundations built of different materials, such as sand and silt, while larger pyramids typically had foundations made of sand, gravel, and small pebbles (Francigny, 2010). In addition to these pyramids, textiles and ceramics were also found, including a large number of tumblers, Meroitic Imitation Roman Ware, and bottles (David, 2009). Many stelae, statues of Ba (an Egyptian god), and capstones were also recovered (Francigny, 2010). However, the amount of grave goods present was relatively low due to several phases of looting (Francigny, 2009).

The graves discovered during the 2009 excavations were typically composed of a sloping descending shaft and axial burial chamber oriented to the west with walls made of mud bricks (although later excavations showed no use of mudbrick was more common, Dupras pers. comm.). Slabs of schist and mortar or mudbricks and mortar were often used to seal the burial chamber (Francigny, 2010; Francigny, 2012). Multiple burials were typical in the burial

chamber, and the presence of two or four shallow holes with remnants of wood in them at either end of the chamber was also common and could be indicative of a funerary bed being present (Francigny, 2010). Initial bioarchaeological analysis of the individuals recovered in these burials, indicated a protein and iron rich diet and a relatively healthy, non-violent and non-strenuous lifestyle. This conclusion was based on gracile areas of muscle attachment and a lack of traumatic injury present on the remains (Francigny, 2010).

In addition to these excavations, two studies using stable isotope analysis have been published about Sai Island. The first publication assessed the utility of archaeological dental calculus in paleodietary reconstruction (Eerkens et al., 2014). This analysis compared the results of carbon and nitrogen isotope values derived from human bone collagen and bone apatite samples. This study demonstrated that calculus can be useful in assessing between site differences in carbon and nitrogen isotope values and identifying dietary differences across regions during the same time period when bone is not available for sampling (Eerkens et al., 2014). The second study that has been published evaluated childhood diet using carbon and nitrogen isotopes values from third molars (Eerkens et al., 2018). This study found that the average weaning age was 2.7 years with significant levels of individual variation. Additionally, this study suggests that C_4 pants were vital to the weaning process with no significant variations based on biological sex (Eerkens et al., 2018).

While the information gained from the 1997-2004 and 2009 excavations, the two previously published studies, and subsequent excavations not yet published, is invaluable for a greater understanding of Meroitic culture and mortuary practice, there are still many areas that

necessitate further research at this site. This literature review has outlined major gaps in the following areas related to Nubian archaeology:

1. The singular focus on the binary experience.
2. A lack of understanding of intra- and inter-status variation.
3. Significant gaps in understanding of Meroitic political, mortuary, economic, and social practice.

By using an isotopic approach framed within a post-processual cultural lens, this research will strive to fill these gaps of understanding in the literature. The post-processual approach and theoretical ideologies, such as social identity theory, utilized in the interpretation of this data will be outlined next.

Theoretical Approaches

Post-Processualism

Post-processualism came out of a dissatisfaction in the 1960s and 1970s in archaeology due to the inability of archaeologists to address cognitive ideas in the past (Johnson, 2010). This dissatisfaction was primarily rooted in the processual approach of the time. Processual archaeology assumes that culture is based on adaptation and these adaptations are responses to a cultural-environmental interchange (Gibbon, 2014). This approach treated human subjects in the past as passive actors in their society and the view of past societies was very generalized (Gibbon, 2014).

Post-processualism began with Ian Hodder who initially used statistics and computer simulation to model trade and markets in Iron Age Roman Britain (Johnson, 2010). Over time Hodder began to notice that his work lacked equifinality – the idea that many alternate explanations are possible for the same outcome. Hodder eventually found that to understand human patterns you also need to understand their attitudes and beliefs or worldview (Johnson, 2010). This led to a wider reliance on symbolism and an understanding that the worldview is central to making interpretations about patterns in the past (Johnson, 2010). From these ideas came a school of thought now known as post-processualism which treats individuals as active agents, rejects positivism and absolutes, treats material culture like a text, interprets cultural change in the archaeological record as a result of human agency and is heavily reliant on context.

This approach is appropriate to this research because it allows for the beliefs and cultural practices known about the individuals to be taken into consideration. It is also effective in making inferences about behavior through symbolism and worldview which will be instrumental in drawing conclusions about the differences in elite lifestyles in terms of intra-class hierarchy and the differences in lived experiences between males and females, and age categories.

Social Identity

Identity is a socially constructed idea that is unstable, fluid, and constantly undergoing changes (Johnson, 2010). Social Identity theory is a school of thought which was first discussed by Tajfel (1978, 1979) and Tajfel and Turner (1979) that seeks to explain thought and behavior

through group processes (Trepte, 2006). The primary tenet of this theory is that the self, or one's identity, is predicated by a person belonging to social groups. Within these social groups, humans exhibit behavior which will solidify their own social group while solidifying the position of those in the outgroup (Trepte, 2006). Studies on the minimal group paradigm prove this pattern of behavior true in the sense that we will always favor our own group over the outgroup (Tajfel et al., 1971; Trepte, 2006). Within this theory, assumptions about the social group are the starting point from which to make assumptions about the individual (Trepte, 2006).

Social Identity Theory is pragmatic for this project because it adds a cognitive component to the life history and reconstruction of lived experience for intra-status comparison. The strong influence of this theory on in- and out-groups will also help facilitate any possible differentiations between the elite individuals in the sample to provide information on the differences within this elite group.

Stable Isotopes

Bone Biology

Collagen and hydroxyapatite are two components of bone that yield different isotopic data. Collagen comprises about 90% of the organic component of bone and is a protein that forms elastic fibers in the bone (White et al., 2012). Hydroxyapatite is another component of bone which is an inorganic mineral (White et al., 2012). Each of these components reflect a different part of an individual's diet. The collagen component of bone is more useful when evaluating the protein portion of the diet because the majority of the carbon content

(approximately 75%) is obtained from the amino acids in proteins (Scherer et al. 2007; Sehrawat and Kaur, 2017). The remaining 25% is derived from carbohydrates and lipids. Hydroxyapatite is a less reliable indicator of diet because it is more susceptible to diagenetic changes (Scherer et al., 2007; Sehrawat and Kaur, 2017). This research focuses on the information obtained from human bone collagen.

Another important aspect of bone biology to consider is bone turnover rate. This must be considered because the rate of bone turnover determines which period of an individual's life is captured. These rates vary across tissues, by bone type, and between cortical and trabecular bone (Ambrose, 1993; Klepinger 1984). The rate of bone turnover is highly debated with some scholars suggesting turnover rates of 30 years (Stenhouse and Baxter, 1979) and others suggesting a more conservative value of 10 years (Libby et al., 1964).

Considering that the majority of the samples used for this research were femoral shaft fragments, the 30-year bone turnover rate suggested by Hedges and Reynard (2007) is assumed to be most representative of the bone turnover rate in the sample. This is based on the conclusions drawn by Hedges and Reynard (2007) in their study of bone turnover, which was based on femoral shaft fragments. It was demonstrated that the bone turnover rates in females after the cessation of growth was between 3.1-5.1% and between 1.5-4.5% for males (Hedges et al., 2007). This correlates to a turnover rate of 33.3 years in males aged 23-27 and 24.4 years in females aged 18-20 (Hedges et al., 2007).

History of Stable Isotope Research

The history of stable isotopes began not in anthropology, but in chemistry, physics, and biology in the late 20th century (Katzenberg et al., 2011; Schoeninger, 2014). The term 'isotope' was coined by Margaret Todd in 1912 but stable isotopes, were not recognized until 1913 or described until the 1930s (Britton, 2017; Katzenberg et al., 2011). Stable isotopic research as a field emerged out of radiocarbon dating and the Manhattan project during World War II when Alfred Nier built the first mass spectrometer to analyze materials created by Harold Urey, the father of the bomb (Schoeninger, 2014; Makarewicz and Sealy, 2015). These experiments led Samuel Epstein to apply isotopic methods to photosynthetic pathways and, subsequently, for Michael DeNiro to apply this research to the detection of diet sources from tissues (Makarewicz and Sealy, 2015; DeNiro and Epstein, 1981). The first use of the mass spectrometer to measure petroleum occurred in 1942, and by the 1950s and 1960s this methodology began to take root in new disciplines such as botany and geochemistry (Katzenberg et al., 2011). By 1970 stable isotopes and mass spectrometry were used for the first time in archaeology with a focus on paleo-dietary reconstruction (Katzenberg et al., 2011). The 1980s saw a vast improvement in detection, resolution, and design of these methods which subsequently led to the increase in popularity of stable isotopes because more samples could be run at a lower cost which made it possible to analyze archaeological materials from larger human and non-human populations (Katzenberg et al., 2011; Makarewicz and Sealy, 2015). Today, stable isotopes and mass spectrometry have a wide range of applications including reconstruction of paleo-diet, origins and movement, subsistence, weaning patterns, trade, and life history (Makarewicz and Sealy, 2015; Katzenberg et al., 2011; Sehrehwat and Kaur, 2017).

Stable Isotope Definition and Analytical Methodology

Having discussed the history of stable isotopic research and its permeation into archaeology and bioarchaeology, it is necessary to outline what stable isotopes are and the methods that are implemented to obtain isotopic data. To accomplish this, the fundamentals of stable isotopes will be addressed.

Stable isotopes are atoms of the same element where each isotope has the same amount of protons, but a variable amount of neutrons (Katzenberg et al., 2011; DeNiro, 1987; Sehrehwat and Kaur, 2017). The amount of an isotope present is expressed by the isotope ratio, which is the ratio of the heavy isotope to the light isotope of the same element in correlation with the known standard for that element (Hedges and Reynard, 2007; Sehrehwat and Kaur, 2017). This ratio is usually expressed in parts per million (Sehrehwat and Kaur, 2017). Stable isotopes do not decay over time and are variable in their masses based on element (Katzenberg et al., 2011). These variable masses result in different chemical and physical properties for each isotope, which makes heavier isotopes react more slowly than lighter isotopes (Katzenberg et al., 2011). These differences in reaction are termed 'fractionation', which occurs when the isotope ratios in the products of a reaction differ from the reactant ratio of isotopes (DeNiro, 1987). This variation in reaction creates different ratios of stable carbon and nitrogen in certain foods which can be grouped by photosynthetic pathway (DeNiro, 1987).

To retrieve and measure the isotopic values associated with an individual or population, many tissues are used including the organic and inorganic components of bone, or the collagen and hydroxyapatite, teeth, skin, hair, nails, and muscle (Katzenberg et al., 2011, Scherer et al., 2007).While many methods exist for isolating these components in bone, the

general approach begins by chemically breaking the bone down into collagen or hydroxyapatite. Then, the sample undergoes mass spectrometry. The standard approach is then to measure how much higher or lower the isotope values of the individual are based on known environmental standards (Hedges and Reynard, 2007). The standard used for nitrogen is atmospheric nitrogen (AIR) and the standard for carbon is Vienna Pee Dee Belemnite (VPDB). The isotopic values for these standards are 0.003676‰ and 0.0112372‰ respectively (Katzenberg, et al., 2011; Hoefs, 1997, and Coplen, 1994). The procedure used for this research is the methodology outlined by the University of Central Florida's Bioarchaeological Sciences Laboratory in the Department of Anthropology, which is founded on the basic aforementioned principals. A more detailed description of this procedure will be outlined to establish the standards and protocols used in the processing of these samples following an overview of the literature pertaining to stable carbon and nitrogen isotopes in bioarchaeology.

Stable Carbon Isotopes in Bioarchaeology

Carbon isotopes can be used for studies on paleodiet, differentiating between marine and terrestrial diets, and determining the types of plants consumed (Katzenberg et al., 2011; Blake et al., 1992; Chisholm et al., 1982; Hayden et al., 1987; Keegan and DeNiro, and Weiner, 1988; Lubell et al., 1994; Norr, 1991; Tauber 1981; Walker and DeNiro, 1986; DeNiro and Epstein, 1978). This determination is based on photosynthetic pathways for different types of plants (van der Merwe and Vogel, 1978; Vogel and van der Merwe, 1977). C_3 plants, with lower $\delta^{13}C$ values than C_4 plants, consist of trees, herbaceous plants, wheat, rice, beans, tubers, nuts, cool season grasses, and most other plants (DeNiro, 1987). These plants use the enzyme

ribulose biphosphate carboxylase to fix atmospheric CO_2. C_4 plants are terrestrial plants that utilize the enzyme phosphoenol pyruvarate carboxylase to fix CO_2 (DeNiro, 1987). C_4 plants are comprised of maize, teosinte, amaranth, sugar cane, sorghum, and millet. Together C_3 and C_4 plants make up most of the terrestrial plants that serve as food sources (DeNiro, 1987). There is a third photosynthetic pathway that can sometimes be used as a food source, which is made up of CAM (Crassulacean Acid Metabolism) plants which use Phosphenol Pyruvate carboxylase in arid environments, and ribulose biphosphate carboxylase in other environments, to fix CO_2 (DeNiro, 1987). CAM plants isotopic values will vary depending on environment, and these include yucca, pineapple, agave, and prickly pear. While other photosynthetic pathways do exist, they are not discussed here because they are not considered to affect food sources (DeNiro, 1987; Schoeninger, 2014).

Based on these photosynthetic pathways, food webs can also be constructed. For example, humans who eat animals that have consumed C_4 plants will have tissues that express more of the heavier isotope (Katzenberg et al., 2011). The same biological processes apply when discerning between marine and terrestrial diets. The main source of carbon for marine animals is dissolved carbonate whereas terrestrial animals derive their carbon from atmospheric CO_2 (Tauber, 1981). Because of these different sources of carbon, there is a 7‰ difference in carbon values for mammals as compared to marine animals (Tauber 1981; Chisholm et al., 1982; Chisholm et al., 1983). These differences in carbon source and photosynthetic pathways are the basis for isotopically determining the diet of an organism.

Stable Nitrogen Isotopes in Bioarchaeology

Nitrogen is used in isotopic studies to make trophic level distinctions, in water stress studies, in protein stress studies, in infant weaning studies, and to evaluate freshwater resources (Katzenberg et al., 2011). These studies rely on the amount of nitrogen found in an organism and how it is fixed (Katzenberg et al., 2011; Brill, 1977). Nitrogen fixation is the process by which nitrogen is combined with other elements to make it processable for the plant (Brill, 1977). Plants like legumes have a symbiotic relationship with bacteria from the genus *Rhizobium*. These bacteria live in plant roots and can fix nitrogen (Brill, 1977). Other plants, without this symbiotic relationship, obtain nitrogen from decomposed organic matter which creates ammonia (NH_2) and nitrate (NO_3) which transforms the nitrogen into a usable form for the plant (Katzenberg et al., 2011; Brill, 1977). Because of these different sources of nitrogen, legumes have a nitrogen value more similar to atmospheric nitrogen while non-leguminous plants have higher nitrogen values (Katzenberg et al., 2011).

The same principal applies for herbivore and carnivore nitrogen values which are about three parts per mille higher than the $\delta^{15}N$ values of the animals or plants they consume (Katzenberg et al., 2011). Enrichment through successively higher trophic levels was a principal first discussed by Minagawa and Wada (1984) and Schoeninger and DeNiro (1984) and provided the basis for using stable nitrogen to distinguish between trophic levels. This is done by using a range of plants, animals, and humans from the environment being studied and comparing their nitrogen values to each other (Katzenberg et al., 2011).

This trophic level effect also extends to freshwater studies, with some overlap in the use of carbon isotope data. It was originally understood that freshwater fish have carbon isotopes

similar to C_3 consuming organisms, but little was known at the time about nitrogen and freshwater (Katzenberg et al., 2011). It was eventually demonstrated that freshwater fish exhibit a trophic level effect which results in higher nitrogen levels in carnivorous fish and elevated $\delta^{13}C$ values (Katzenberg, 1989). Additionally, freshwater fish have more variable $\delta^{13}C$ values than was initially thought because freshwater plants have numerous sources of carbon compared to terrestrial plants which rely solely on atmospheric CO_2 (Zohary et al., 1994). Freshwater plants can get carbon from rocks, soil, and decomposing matter which means that fish in different habitats will reflect variable carbon values (Zohary et al., 1994). This means that both carbon and nitrogen can be useful in differentiating freshwater sources of food based on the differing sources of carbon and the trophic level distinctions based on nitrogen values.

In addition to trophic level distinctions, nitrogen is also used to evaluate water stress. The variation of nitrogen levels has been noted in coastal versus inland regions and in arid regions as compared to wetter regions (Heaton, 1987; Scherer et al., 2007; Virginia and Delwiche, 1982). The nitrogen isotope values of animals of the same species have also been shown to be similar in arid and wet regions (Heaton et al., 1986; Sealy et al., 1987). It is, however, important to note that the uptake of nitrogen in the human body is not well understood and therefore can result in misinterpretations of diet based on the aforementioned criteria (Hedges and Reynard., 2007; Katzenberg et al., 2011).

Despite the fact that there are parts of the nitrogen cycle that are not well understood, there are many areas to which nitrogen can be applied isotopically. One of these areas is protein stress studies. Protein stress occurs when insufficient protein is consumed and the breakdown of bodily tissues rich in nitrogen occurs as a result (Katzenberg et al., 2011). This

was first observed in studies by Hobson et al. (1993) and Hobson and Clark (1992) in which birds exemplified this response to low protein intake. Katzenberg and Lovell (1999) have conducted studies suggesting that the same may be true for humans, however more research in needed in this area.

Related to protein stress, nitrogen isotopes can also be used in studies on illness and pregnancy which are both related to metabolism and the use of nitrogen by the body. To understand this relationship, nutritional stress must be discussed first. Nutritional stress is, for the purposes of this thesis, an acute or chronic protein deprivation which can be caused by metabolic disease, cultural factors, or environmental factors (Roberts and Manchester, 2007). Nutritional stress affects nitrogen because is a vital part of the maintenance of bodily tissues, which means that if the proper diet is not taken in by an individual, their nitrogen levels will be deficient resulting in poor maintenance of tissue (Katzenberg and Lovell, 1999). This tissue production is regulated by nitrogen levels through either recycling the nitrogen in the body or excreting it which results in three stages of nitrogen balance: positive nitrogen balance, negative nitrogen balance, and nitrogen equilibrium (Katzenberg and Lovell, 1999). A positive nitrogen balance is the result of more nitrogen being consumed than is excreted which reflects tissue growth (Katzenberg and Lovell, 1999). It has been suggested that a positive nitrogen balance in the body is correlated with lower nitrogen values isotopically (Fuller et al., 2004). A negative nitrogen balance is produced by an insufficient amount of nitrogen to maintain tissues and is indicated by higher nitrogen values (Katzenberg and Lovell, 1999).

Pregnancy, and specifically pregnancies with accompanying morning sickness, result in increased nitrogen isotope values during times when morning sickness or weight loss was

experienced (Fuller et al., 2005). This is because the body metabolizes the protein in its tissues and excretes more nitrogen to access the protein needed by the mother and fetus within the tissues (Fuller et al., 2005). This increase in nitrogen levels is not observed in cases where morning sickness was not experienced (Fuller et al., 2004).

Similarly to pregnancy, illnesses in which starvation is a component, like anorexia or bulimia, also cause nitrogen levels to fluctuate. The extended protein stress produced by these illnesses causes protein to be broken down which enriches nitrogen levels (Orten and Neuhaus 1982). This difference in nitrogen level as a result of illness induced starvation can be seen most readily in tissue samples as opposed to bone sample due to the higher turnover rate of some tissues (Holder et al., 2017). Nitrogen enrichment has been attributed to fasting and starvation as well (Hobson et al., 1993).

In addition to nitrogen enrichment due to mental health problems, there are also pathological conditions which can cause nitrogen levels to change. White and Armelagos (1997) investigated the effects of pathology on nitrogen values and found that individuals with osteopenia had higher nitrogen isotope values. This relationship could be due to urea excretion or dietary stress which would cause reduced collagen synthesis and bone mineral formation (White and Armelagos, 1997). In a study by Katzenberg and Lovell (1999), the relationship between isotopic values in normal bone as compared to bone affected by pathology was investigated. This was done by comparing the nitrogen values from a modern sample with periostitis, osteomyelitis, fracture, and atrophy to normal bone nitrogen levels. It was found that only a small decrease was present in the samples with fractures and periostitis and no change for bone with atrophy (Katzenberg and Lovell, 1999). Osteomyelitis resulted in higher

nitrogen isotope values. They argued that the new bone resulting from fracture repair is correlated to the practice of dieting during the bone repair process, which accounts for the higher nitrogen levels (Katzenberg and Lovell, 1999; Hill, 1998).

Another study took a similar approach to this problem while also including considerations of tissue turnover rate. Olsen (2013) examined the relationship between nitrogen isotope values and rickets, degenerative diseases, fractures, osteomyelitis, and periostitis. Rickets and degenerative disease did not yield any differences while periostitis, fractures, and normal bone were inconclusive. Enrichment in nitrogen isotope values was present, however, in samples affected by osteomyelitis (Olsen, 2013).

Another prominent area of study related to bodily stress metabolism is infant weaning. The study of the weaning process in relation to stable isotope analysis is based on the nitrogen levels of an infant over time. When an infant is born, a breast feeding infant will have a nitrogen level that is a trophic level above their mother's because the child is essentially consuming the tissue of the mother via breastmilk (Fuller et al., 2004; Fogel et al., 1989). This means that the nitrogen values for nursing infants will be 2-3% higher than the mother (Fuller et al., 2004). As a child is weaned, their nitrogen values will begin to approximate that of their mother as weaning foods are introduced (Fuller et al., 2004). This theory was tested isotopically by analyzing the fingernails of mothers and infants. This study showed that there is an increase in nitrogen levels in infants shortly after birth (Fogel et al., 1989; 1997). However, there are still many issues with weaning studies as well. Chief among these issues is the inability to determine if the higher nitrogen values are attributable to the individual's untimely death in infancy or the

weaning process (Katzenberg, 1999). It has been suggested that using tissues developed post-partum could rectify the issue (Wright and Schwarcz, 1998; Wright, 1999).

In addition to the aforementioned applications, nitrogen can also be useful in terms of the investigation of social organization. Mulder et al. (2009) assessed the diet of Bishops and other clergy at the Whithorn Cathedral Priory to determine if ranking could be discerned from diet. They were able to determine that the known upper-class individuals consumed more meat and fish than lower ranking persons and identified an outlier in this ranking. The outlier was a deformed clergyman who, according to biblical texts, should not have been allowed to possess a high-ranking position in the church, but had nitrogen values associated with high status foods (Muldner et al., 2009). This study shows how the interpretation of nitrogen values in dietary studies can be used to interpret other social phenomenon, such as class, from dietary practices related to nitrogen values. Similar to these studies is the work of Schoeninger et al. (1983), which analyzed the diets of Inuit's, Haida and Tlingit Indians, Havihuh agriculturalists and manioc farmers to show that stable nitrogen isotopes can be used to determine the amount of terrestrial and marine components in a population's diet.

Stable nitrogen isotopes can also be used in forensic contexts as demonstrated by Bakovic et al. (2016), who used nitrogen isotopes to forensically assess the cause of death for a 95-year-old man found dead in his apartment. In this case, nitrogen and carbon values were used to corroborate that the cause of death was starvation based on hair samples (Bakovic et al., 2016). From different portions of the hair it was shown that periods of starvation or nutritional stress were present throughout life based on the decrease in carbon isotope values and a corresponding increase in nitrogen isotope values observed periodically. Prior to death, a

decrease in carbon isotopes and increase nitrogen isotopes was noted (Bakovic et al., 2016). Based on this observation and consistencies in this trend in other studies, the authors concluded that the cause of death was starvation (Bakovic et al., 2016).

These examples serve to illustrate the variable ways in which nitrogen can be used to make inferences and interpretations about lived experience. Having outlined the various applications of stable carbon and nitrogen isotopes, the methodology used in the processing of the samples for this thesis will be described next.

CHAPTER THREE: METHODOLOGY

Sample and Methods Description

The materials used for this research are primary data consisting of skeletal femur samples from the 8.B.5A cemetery on Sai Island, located in northern Sudan, which were acquired by Dr. Tosha Dupras. These skeletal samples consisted of 53 elite adult male and females of various ages from the Meroitic period (see Table 2 for a complete list of samples). Within the sample there were 31 males, 19 females and 3 individuals of unknown sex (Figure 5). In terms of age, the sample consisted of 5 young adults, 19 middle adults, and 9 old adults (Figure 6). The total number of individuals based on age is lower than 53 because some individuals had unknown ages or were removed from the analysis due to poor preservation. The male age values had a range of approximately 18 to 50 years with a median age of 36.25. Most male individuals fell between 30 and 42 years of age. The female ages ranged from 19 to 47.5 years with a median of 28.75. Most of the females fell within 22 and 42 years of age. Overall, the average age of the males was higher than the females, but the spread of ages was greater among females (Figure 7). It is important to note that it was not always possible to assess age and sex for all individuals. In these cases the sample was removed from analysis when appropriate. The femoral samples were removed using a cutoff wheel and Dremel tool. Sample preparation and collagen extraction was conducted at the UCF Laboratory for Bioarchaeological Sciences and sent to the Department of Geological Sciences at the University of Florida Lab for final analysis.

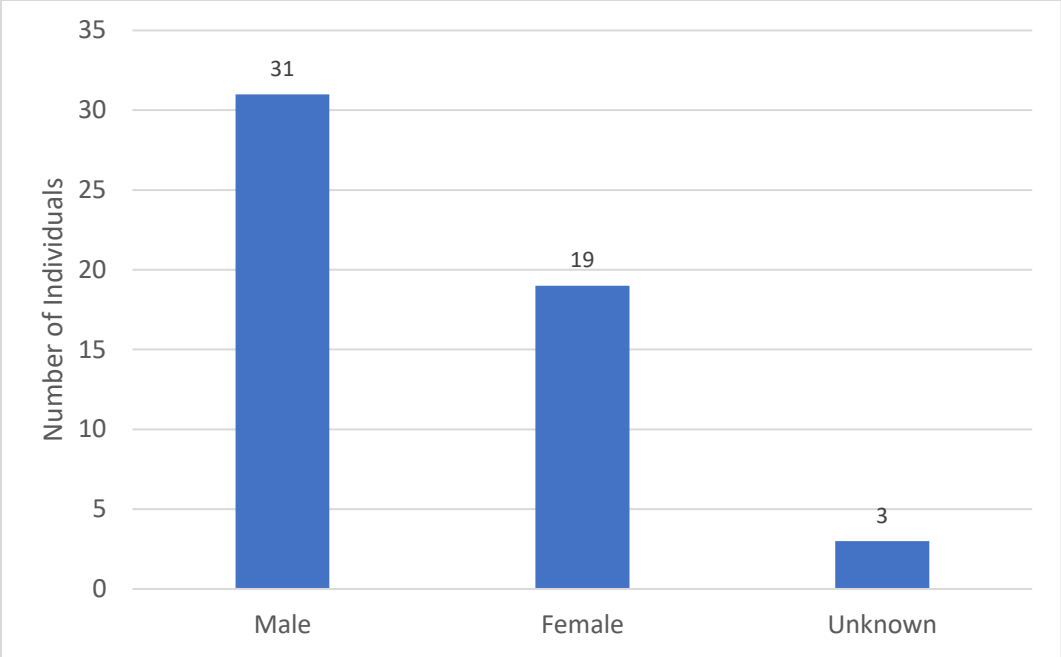

Figure 5: Graph showing the distribution of sex in the sample.

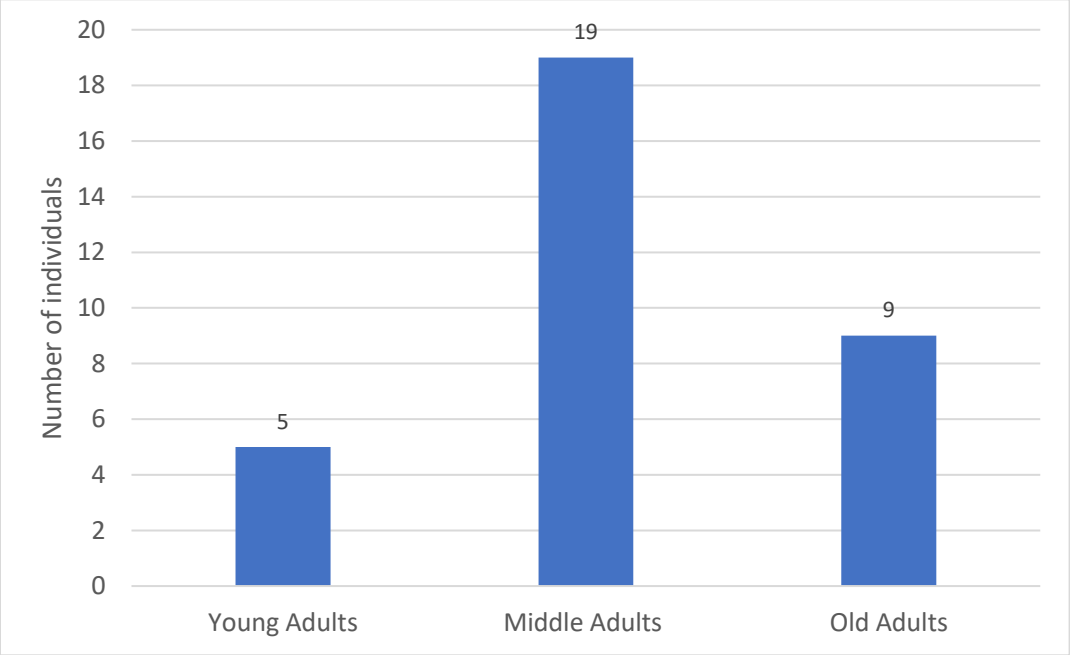

Figure 6: Graph showing the distribution of age in the sample.

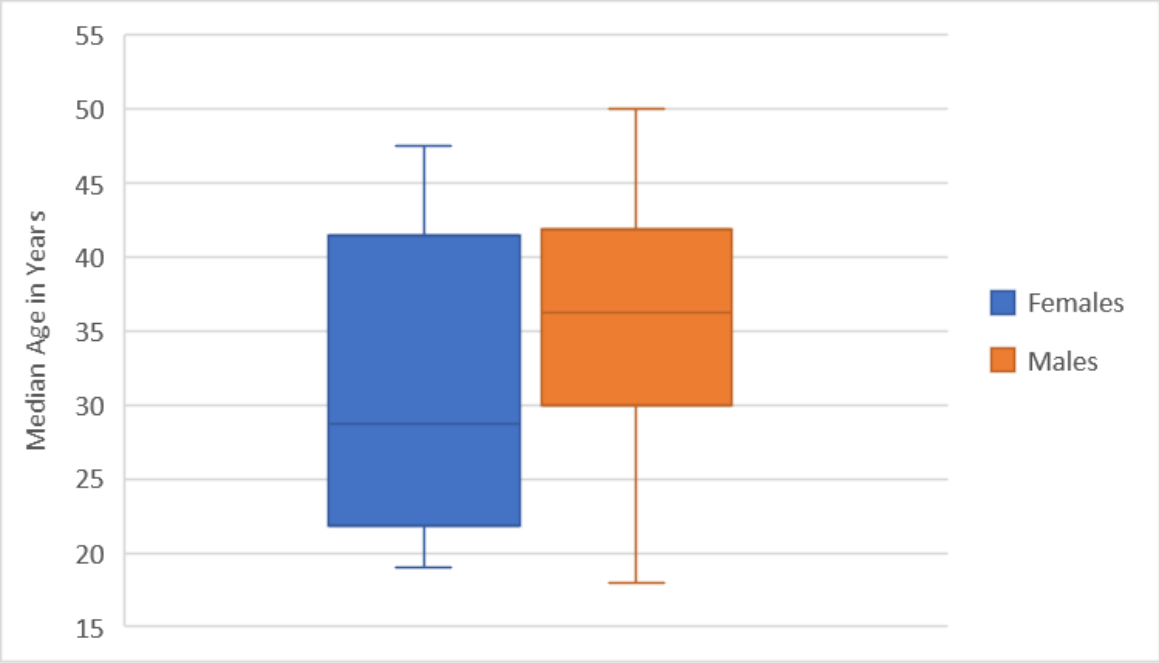

Figure 7: Box and Whisker plot showing the range of ages among males and females.

Table 2 : Table showing all of the samples analyzed for this study. The blue shading indicates samples that were analyzed multiple times to calculate accuracy

Original Sample ID	Sex	Age	%Collagen	$\delta^{15}N$ (permil, vs AIR)	$\delta^{13}C$ (permil, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-001 Ind 5	Male	35-50 years	8.50	11.5	-17.3	15.59	41.68	2.67	3.12
To-004 Ind 1	Male	25 years	0.37	11.6	-17.2	12.45	34.2	2.75	3.20
To-004 Ind 2	Female	young adult	2.98	12.3	-15.9	15.4	42.19	2.74	3.20
To-005 Ind 1	Male	40 years	12.85	11.5	-17.5	15.84	43.74	2.76	3.22
To-005 Ind 2	Male	45 years	13.46	12.2	-16.5	16.13	44.07	2.73	3.19
To-005 Ind 3	Male	30 years	7.36	11.8	-15.4	15.50	41.98	2.71	3.16
To-017 Ind 2	Female	45-50 years	14.13	11.1	-16.7	15.06	40.65	2.70	3.15
To-017 Ind 3	Female	20 - 29 years	11.89	12.3	-16.6	16.18	43.68	2.70	3.15
To-017 Ind 4	Male	45 years	10.32	12.2	-13.8	15.44	42.37	2.74	3.20
To-017 Ind 5	Female	old adult	7.78	11.1	-17.3	12.61	35.01	2.78	3.24
To-018 Ind 1	Male	40 years	8.23	11.4	-13.6	15.41	42.37	2.75	3.21
To-018 Ind 2	Female	20 years	16.42	10.8	-17.9	16.76	45.06	2.69	3.14
To-018 Ind 3	Female	30 years	6.93	11.9	-17.6	15.12	41.87	2.77	3.23
To-024	Male	40 years	2.14	13.9	-14.4	3.69	11.49	3.11	3.63
To-024	Male	40 years	0.33	13.6	-16.7	0.81	9.67	11.96	13.96
To-026A	Female	35 Years	0.178	11.8	-17.3	6.42	24.09	3.76	4.38
To-026B	Male	18 years	4.87	11.3	-16.8	13.92	38.51	2.77	3.23
To-026C-2	Unknown	35 Years	1.6	13.1	-17.2	4.32	13.42	3.11	3.62
To-027	Female	25 - 30 years	0.422	14.5	-14.7	8.06	26.27	3.26	3.80
To-027 Ind 1	Female	25 - 30 years	4.76	11.2	-17.3	15.79	43.36	2.75	3.20
To-027 Ind 2	Female	28 - 34 years	2.28	11.1	-16.9	14.41	39.39	2.73	3.19
To-027 Ind 3	Female	19 years	2.91	8.6	-16.4	15.71	43.01	2.74	3.19
To-027 Ind 4	Male	35 - 44 years	1.47	11.5	-15.9	6.06	17.01	2.81	3.27
To-027 Ind 5	Male	35 years	4.63	13.6	-14.8	6.26	17.55	2.80	3.27
To-027 Ind 6	Unknown	25 - 28 years	2.29	12.2	-16.1	6.98	19.79	2.84	3.31
To-028 Ind 1	Male	38 years	10.839	12.1	-15.3	14.13	40.22	2.85	3.32

Original Sample ID	Sex	Age	%Collagen	δ15N (permil, vs AIR)	δ13C (permil, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-028 Ind 2	Male	38 years	8.965	14.5	-14.8	14.92	41.35	2.77	3.23
To-029	Female	30 - 34 years	0.27	13.3	-14.9	12.47	35.73	2.87	3.34
To-029A	Female	38 years	1.954	14.0	-13.7	12.64	35.40	2.80	3.27
To-030 Ind 1	Male	30 - 40 years	4.42	11.4	-16.9	15.1	41.22	2.73	3.18
To-030 Ind 3	Male	45 - 61 years	0.67	13.6	-13.2	12.53	34.28	2.74	3.19
To-031 Ind A	Unknown	Unknown	6.24	9.8	-17.0	14.67	41.14	2.80	3.27
To-034A Ind 1	Male	50 years	9.301	11.4	-15.8	10.80	31.41	2.91	3.39
To-034A Ind 2	Female	40 - 50 years	9.63	11.1	-17.5	15.27	42.89	2.81	3.28
To-034A Ind 3	Female	25 - 30 years	10.351	10.8	-17.0	15.24	42.20	2.77	3.23
To-035 Ind 1	Male	35 - 50 years	9.957	11.7	-16.6	15.40	43.18	2.80	3.27
To-035 Ind 2	Male	35 - 40 years	10.124	12.9	-15.2	14.85	41.37	2.79	3.25
To-036 Ind 1	Male	35 years	2.6	13.2	-14.9	13.03	35.61	2.73	3.19
To-038 Ind 2	Male	35 years	5.42	11.6	-15.6	14.61	39.59	2.71	3.16
To-040	Male	35 Years	6.38	11.6	-12.6	13.58	39.17	2.88	3.36
To-040	Male	25-35 years	6.38	11.5	-12.6	13.81	39.86	2.89	3.37
To-040 (Average)	Male	25-35 years	6.38	11.6	-12.6	13.69	39.51	2.89	3.37
To-041	Female	Unknown	8.1	11.3	-17.5	15.64	42.85	2.74	3.20
To-042 Ind 1A	Male	25 years	7.27	10.8	-15.2	13.94	41.51	2.98	3.47
To-042 Ind 1B	Male	25 years	10.99	11.2	-15.9	13.34	39.21	2.94	3.43
To-042 Ind 1A/1B (Average)	Male	25 years	9.13	11.0	-15.6	13.64	40.36	2.96	3.45
To-042 Ind 2A	Female	old adult	9.86	11.2	-15.3	14.95	41.89	2.80	3.27
To-042 Ind 2B	Female	old adult	11.6	11.6	-17.5	15.75	43.60	2.77	3.23
To-042 Ind 2A/2B (Average)	Female	old adult	10.73	11.4	-16.4	15.35	42.75	2.79	3.25
To-043	Male	30 years	9.64	11.6	-18.0	15.72	42.75	2.72	3.17
To-043 Ind 1	Male	30 years	13.17	11.9	-15.7	15.11	42.62	2.82	3.29
To-043 Ind 2	Male	middle adult	10.36	12.1	-16.6	14.24	42.15	2.96	3.45
To-049 Ind 1	Male	30 years	0.93	15.2	-14.7	4.89	21.95	4.48	5.23

Bone Collagen Preparation Procedure

The first step in stable isotope analysis is the extraction of the collagen from the bone. The procedures used in the Laboratory for Bioarchaeological Sciences at The University of Central Florida are based on modified methods described in Longin (1971). The process began with the washing of the bones in deionized water in an ultrasonicator. Samples were agitated for ten minutes stints, replacing the water each time until the sample was clean. After the samples were washed, they were placed into a 60℃ oven for approximately 24 hours or until dry.

Once the samples were dry, each sample was crushed into small fragments of uniform size (approximately 2-5mm) , when possible, using a mortar and pestle. The crushed sample was then weighed using a digital scale to obtain a sample weight of 0.5-1g. The weighed-out portion of the sample was then placed into a clear 50 ml centrifuge tube, clearly labeled with the sample's identification information. The remainder of the sample, if any, was stored for future analysis in the Laboratory for Bioarchaeological Sciences.

After all of the samples were weighed and placed into centrifuge tubes, the samples were treated with a 2:1 chloroform-methanol solution to remove any lipids from the sample. This was accomplished by adding approximately 10 mL of chloroform-methanol to each tube and letting the sample rest for 20 minutes. The samples were then placed in the centrifuge for 10 minutes at 2400 rpm. Next, the chloroform methanol solution was removed using a 9-inch glass pipette. This process was repeated three times to ensure that all lipids were removed from each sample. The tubes were then left uncapped in the fume hood for 24 hours to allow the samples to dry.

After drying, approximately 10 mL of 0.25 M hydrochloric acid (HCl) was added to each tube. The samples were then left in the fume hood for 24 to 48 hours which allowed time for the HCl to begin demineralization by removing the hydroxyapatite from the bone. After 24-48 hours, the samples were spun down in the centrifuge at 2400 rpm for 10 minutes and the HCl in each tube was removed and replaced if the sample had not finished the demineralization process. This process is repeated until all of the samples were demineralized.

Once all of the samples were demineralized, 10 mL of deionized water was added to the centrifuge tube and the sample was spun down at 2400 rpm for 10 minutes. The water was then removed using a nine-inch glass pipette. This process was repeated until a pH of 2.5-3.0 was reached. Then, approximately 10 mL of 0.1 M NaOH was added to each sample and left to rest for 20 minutes. This process is completed to remove any remaining humic acids from the sample. After 20 minutes, if a color change was observed, indicating the presence humic acids, the sample was spun down in the centrifuge, the NaOH removed and replaced, and this process was repeated until no color change was observed. After this, 10 mL of water was added to the sample and spun down at 2400 rpm for 10 minutes. The sample was rinsed in this way five more times. After the sixth spin, the pH of the samples was assessed. The pH should be 7.0 ± 1.0, and if it was not, additional rinses were completed until the proper pH level was obtained.

After obtaining the proper pH, the water was removed and 10 mL of 0.25 M HCL was added to each sample. The samples were spun down at 2400 rpm for 10 minutes. The HCL was then removed and 5 mL of water was added. The pH was measured with a goal of 2.5 - 3.0. If the pH was too high or too low, a buffer solution was added to achieve this range. After obtaining the correct pH, the sample tubes were placed into beakers and put into a 90℃ oven

overnight. The samples were then spun down at 2400 rpm for 10 minutes. A glass 2 dram vial was labeled for each sample and the weight of the vial was recorded. A 9-inch pipette was then used to move the liquid from the sample tubes into the dram vials. The vials were placed in the 90℃ oven for 24-36 hours. The collagen yield was then calculated and recorded for each sample (Equation 1). This preparation process is summarized in Figure 8.

$$\% \text{ collagen yield} = (\text{vial w/ collagen} - \text{vial w/out collagen}) \div (\text{sample dry weight}) \times 100 \quad (1)$$

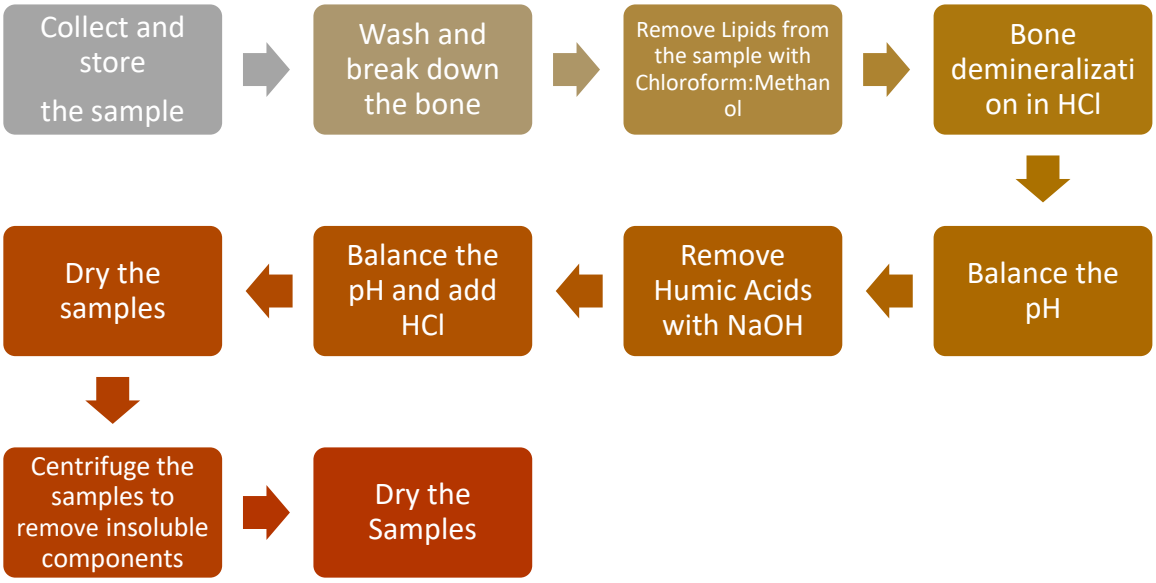

Figure 8: Flowchart summarizing the bone collagen extraction process. Derived from Somerville et al., 2016; Reitsema, 2015; Jørkov et al., 2007; DeNiro and Epstein, 1981; Brown et al., 1998; Richards and Hedges, 1999; Koch et al., 1997 and the protocol developed by the University of Central Florida Laboratory for Bioarchaeological Science.

Mass Spectrometry

After the collagen yield was recorded, the samples were put into labeled trays and sent to the Department of Geological Sciences at the University of Florida Laboratory for mass spectrometry. At this laboratory, a portion of each sample is weighed into a tin capsule and placed into trays. The capsules are then loaded in to a Thermo Delta V Advantage isotope ratio

mass spectrometer with a ConFlo II interface that is attached to a Carlo Erba elemental analyzer. The capsules drop into the furnace, which converts the sample into gas form. Helium gas is used as a carrier to transfer these gases into the mass spectrometer where they are separated from each other. Then, one of the gasses that is being analyzed is let into the ion source of the mass spectrometer and the gas is ionized by electron bombardment. This allows the gas molecules to be focused into a beam, which is then directed into the analyzer component of the machine. This area has two poles of a magnet that allow the larger beam to be separated into smaller beams. This creates the mass spectrum and allows the ion beams to be measured by the ion collector in the mass spectrometer (Figure 9). The intensities of these beams are then measured and reported as isotope ratios.

Statistical Analysis

The last form of analysis employed in the processing of these data was a T-Test and a Mann-Whitney test to determine if the reported results for each identified group were significantly different from other groups. These statistical tests were carried out due to the small sample size used in this research. To conduct these tests, the T-Test and Mann-Whitney functions in Excel were used with a significance level of 0.05 using a two tailed hypothesis and the assumption of unequal variance. These tests yielded p-values, which were then used to determine if the difference between two groups was significant. P-values below 0.05 were determined to be significant, while p-values above 0.05 were not significant. The results of these tests are and their relationship to the conclusions presented here will be discussed below

in relation to each of these sections respectively.

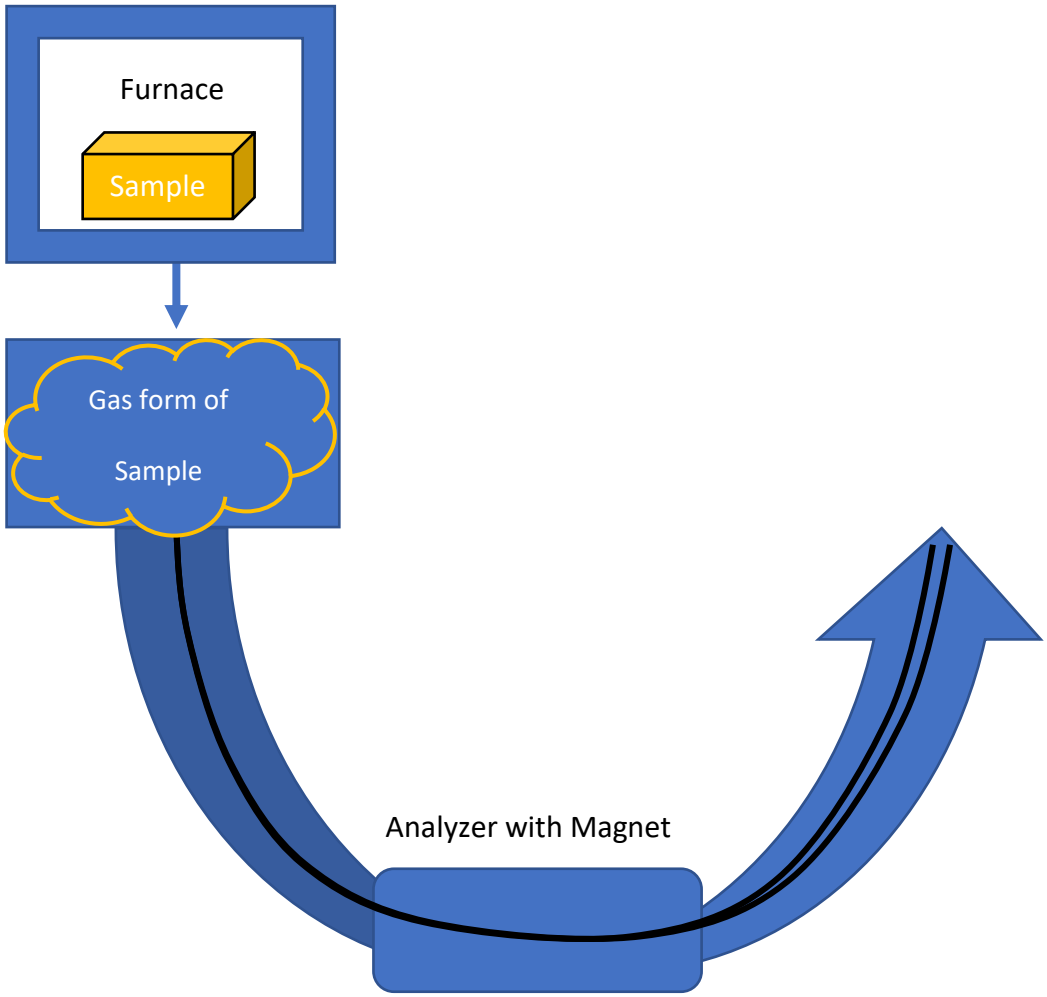

Figure 9: Image showing the different components of the mass spectrometer (Adapted from Katzenberg et al., 2011)

CHAPTER FOUR: RESULTS

This chapter includes a discussion of the results of this study including sample preservation, overall general trends in the isotope data, the assessment of the percentage of C_4 food in each group's diet , and the results of the statistical tests performed. The analysis of these data consisted primarily of identifying differences and similarities between the biological sexes and across age groups. Following this overview, a discussion of these results will be provided.

Accuracy and Precision

As mentioned previously, the final analysis of the samples used in this research were analyzed at the University of Florida. The samples used for this research were processed in three different batches on three different dates. Based on these separate runs, the precision for the equipment for each of the three days was reported as follows: Day one, $\delta^{15}N = \pm 0.13‰$ and $\delta^{13}C = \pm 0.10‰$ (N=5), Day two, $\delta^{15}N = \pm 0.07‰$ and $\delta^{13}C = \pm 0.05‰$ (N=7), and Day three, $\delta^{15}N = \pm 0.18‰$ and $\delta^{13}C = \pm 0.02‰$ (N=7). Three samples from this dataset were run as repeat samples to determine accuracy, which was calculated by averaging the differences in $\delta^{13}C$ and $\delta^{15}N$ values for each run. The accuracy for the $\delta^{13}C$ measures was approximately 0.25‰ and the accuracy for the $\delta^{15}N$ values was approximately 0.99‰ (Table 3). Interestingly, the difference in $\delta^{15}N$‰ for individual To-042 Ind 2A is relatively high at 2.23‰. This could be due to sample contamination, a machinery malfunction, or a data transcription error. However, the accuracy measures for the other two individuals suggest that the values presented here are accurate and precise.

Table 3: Table summarizing the accuracy of the $\delta^{13}C$ and $\delta^{15}N$ measurements based on the three samples that were run twice.

Sample ID	Differences in $\delta^{13}C‰$	Differences in $\delta^{15}N‰$
To-040	-0.07	0.04
To-042 Ind 1A	-0.35	0.7
To-042 Ind 2A	-0.33	2.23
Accuracy	**0.25**	**0.99**

Preservation of the sample

Because bone undergoes many taphonomic processes after it has been exposed to a burial environment for a long period of time, it is necessary to determine how well preserved the sample is. This is because isotopes isolated from poorly preserved samples may not reflect accurate values. To ensure that the collagen is suitable for analysis the preservation of each sample was determined by assessing the percent collagen yield, atomic C:N ratio, %wt nitrogen, and %wt carbon (Ambrose, 1990).

The percent collagen yield was assessed by calculating the collagen yield for each sample (Equation 2).

(2)

$$collagen\ yield\ (\%)\ = \frac{collagen\ weight\ (g)}{ample\ dry\ weight\ (g)} \times 100$$

The minimum percent collagen deemed reliable for this research is 2%, which is consistent with the appropriate values for collagen yield proposed by DeNiro and Weiner (1998). DeNiro and Weiner (1998) demonstrated that sample preservation dramatically declined when the collagen yield falls below 2%. It is recognized, however, that the percentage of acceptance for collagen yields in isotope research is highly variable with some scholars using a value of 1% or higher (White and Schwarcz, 1989; White et al., 1993) and other suggesting higher values up to 5 or 6% (Schoeninger and DeNiro, 1982; Tuross et al., 1988). It is also recognized that this measure of preservation must be used in conjunction with the other criteria given the possibility of losing sample during the extraction process.

The atomic ratio of carbon to nitrogen was calculated using the %C and %N (carbon and nitrogen concentration levels) (Equation 3). This calculation was made because the mass spectrometer calculates C:N ratios that are lighter compared to the accepted standards put forth by DeNiro (1985). To mitigate this discrepancy the C:N ratio is increased by a factor of 14/12 (Katzenberg, 2008). According to DeNiro (1985), the appropriate C:N ratio for a well-preserved sample will fall between 2.9 and 3.6.

(3)

$$\text{atomic C:N} = \frac{14}{12} \times \text{(weight \% C:N)}$$

Out of the 46 samples analyzed, three samples were removed from the study due to poor collagen preservation (i.e, low percent collagen), two were removed because their atomic

ratio C:N was too high, and five were eliminated for both low percent collagen and atomic C:N ratios that were out of the acceptable range (Figure 10 and Table 4).

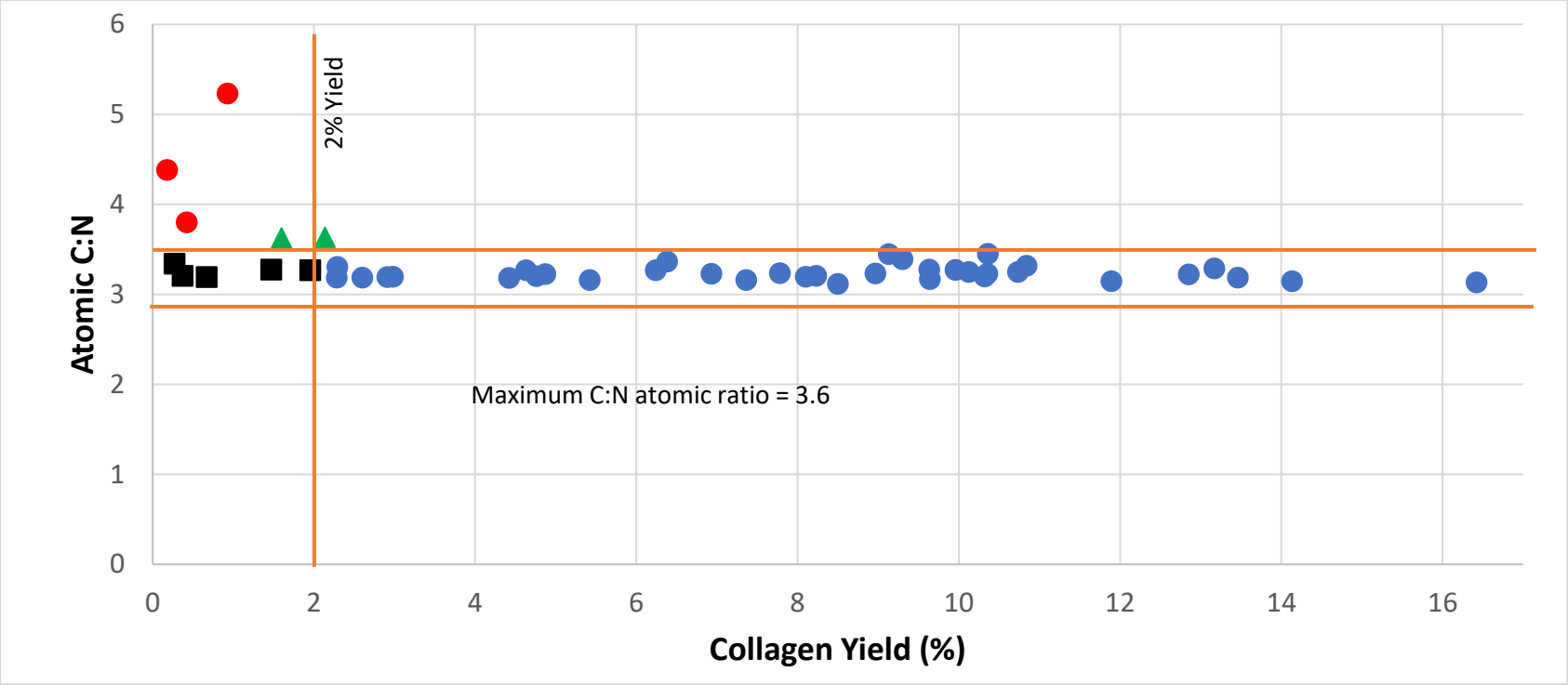

Figure 10: Graph of collagen yield and atomic ratio. The vertical orange line indicates the 2% minimum collagen yield cut off used in this study. The horizontal line positioned higher on the graph indicates the atomic ratio C:N cut off for this study. The horizontal line positioned lower on the graph indicates the minimum acceptable atomic ratio. The red dots represent samples that were eliminated due to poor collagen preservation. The green triangles represent samples eliminated based on atomic ratio C:N. The black squares indicate samples that were eliminated due to both poor collagen preservation and atomic ratio C:N. The blue dots indicate the samples that were used in this study.

Table 4: Table summarizing the mean and standard deviations of the measures used to assess sample preservation after all samples below the 2% threshold were removed.

Measures of Preservation			
Average %wtC	**Average %wtN**	**Collagen Yield (%)**	**Atomic C:N Ratio**
39.99 ± 5.89	14.43 ± 2.22	8.28 ± 3.60	3.24 ± 0.08

In addition to assessing the collagen yield, the carbon and nitrogen concentrations (%wt) were also assessed based on the assertion by Ambrose (1990) that these values can provide information about sample preservation. Ambrose (1990) found that modern animals have carbon %wt values ranging from 15-47% and %wt nitrogen values ranging from 5-17% (Ambrose, 1990). These ranges are the standard accepted values for human bone %wt carbon and nitrogen values. Any samples found to be outside of the acceptable %wt C and N ranges were also rejected (Figures 11 and 12). It is noted that the samples reflected a strong linear relationship between the carbon and nitrogen concentrations, which is normal for bone collagen samples (Figure 13).

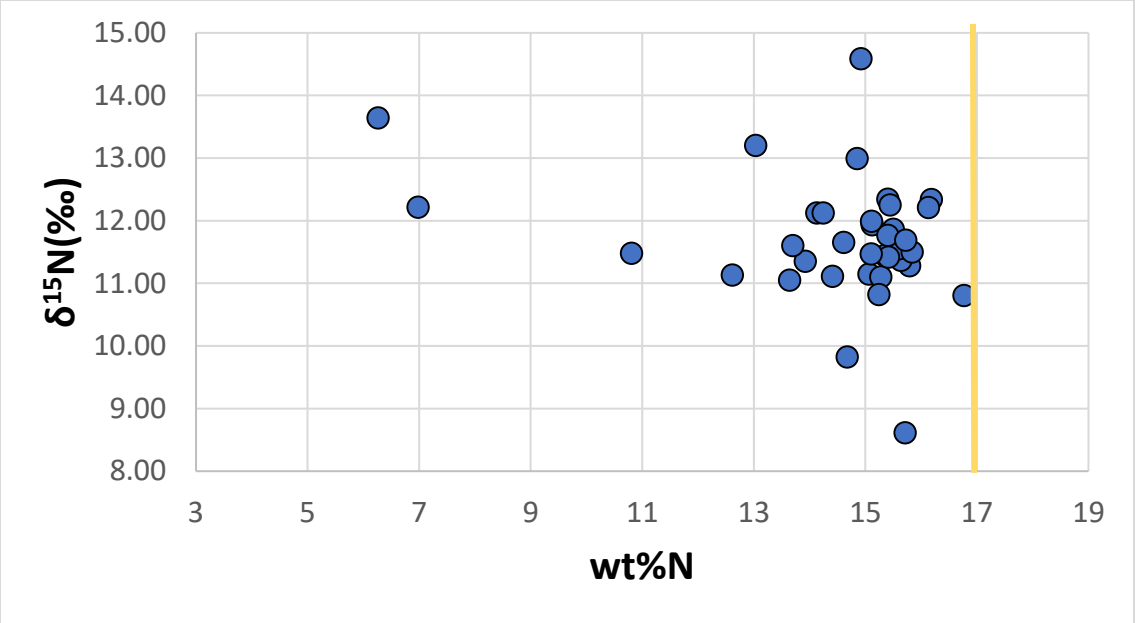

Figure 11: Graph showing that all the sample used in this study fall below the 17% threshold for nitrogen concentration. This cut off level is indicated by the yellow line on the right. The lower threshold of 5% is indicated by the yellow line on the left.

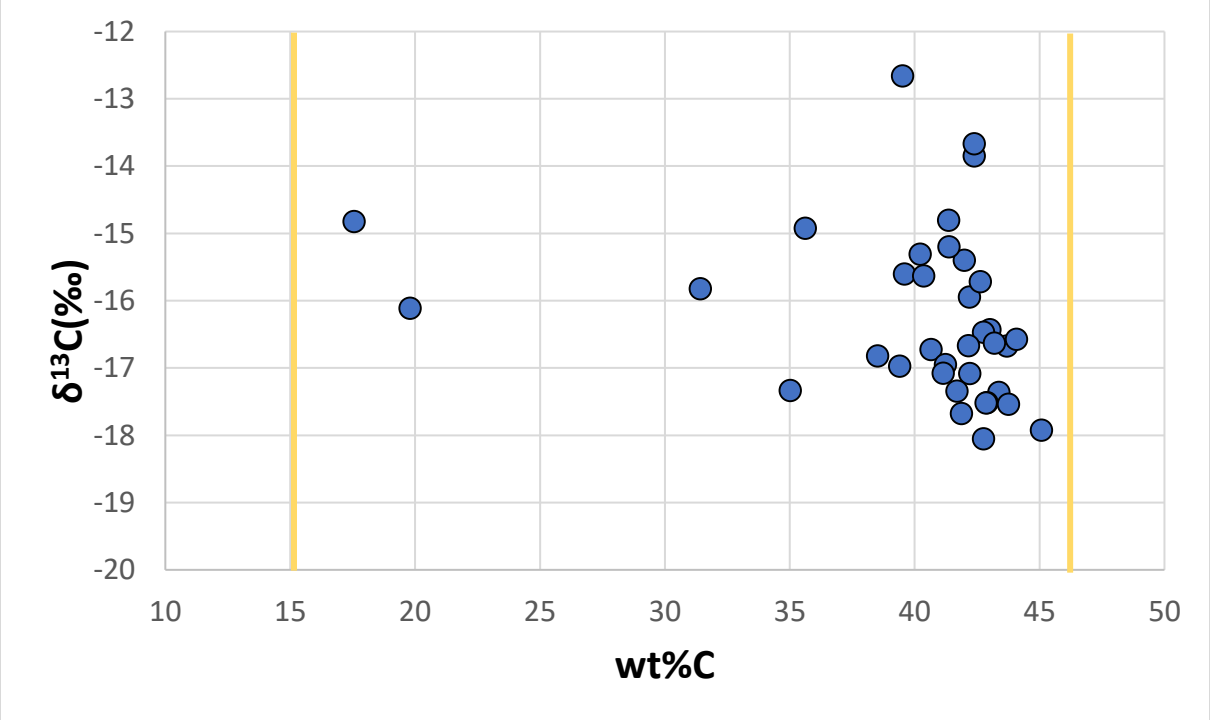

Figure 12: Graph showing that all of the samples used in this study fall below the 47% threshold for carbon concentration. This threshold is indicated by the yellow line on the right. The lower threshold of 15% is indicated by the yellow line on the left.

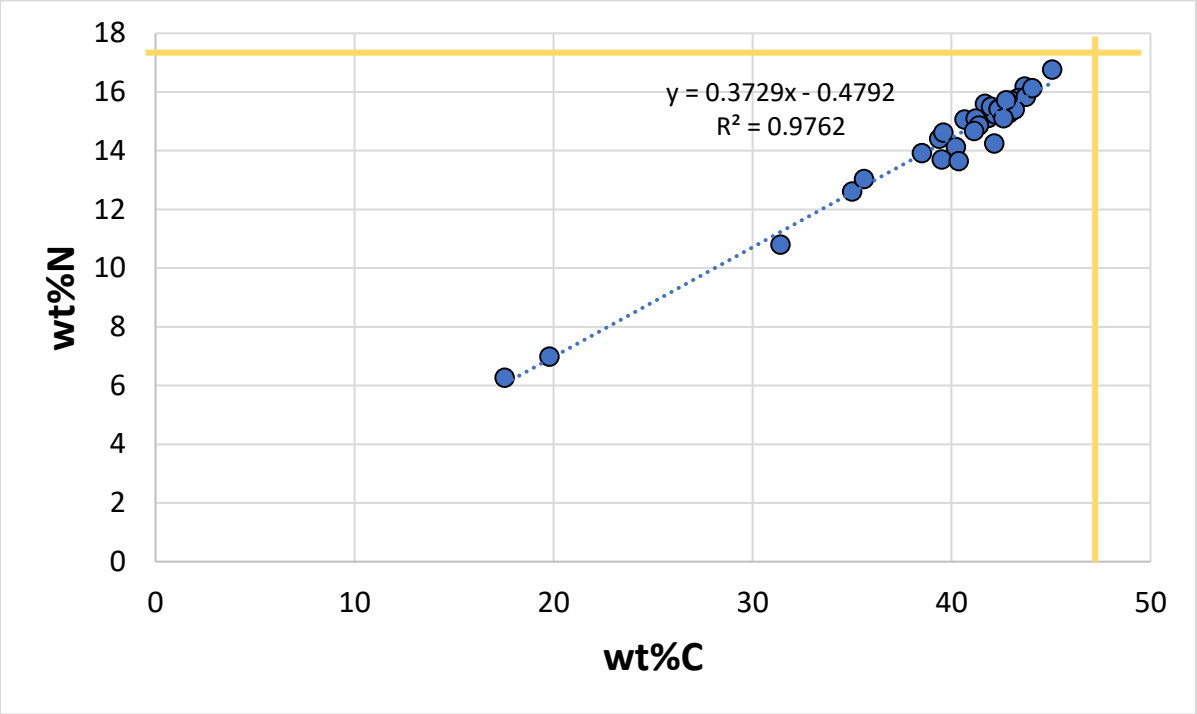

Figure 13: Graph showing the strong linear relationship between the carbon and nitrogen concentrations in the samples. The cut off levels for carbon and nitrogen are indicated by the yellow lines on their respective axis.

The last measure of preservation to be assessed was the wt%C and wt%N compared to the percent collagen yield. When assessing the wt%C and percent collagen yields, a positive linear correlation was noted (Figure 14), in that as wt%C values increase so do the percent collagen yields. This correlation was also noted for the wt%N as compared to the percent collagen yield (Figure 15). This assessment also resulted in the elimination of the same individuals from the samples as the assessment of collagen yield and wt% carbon/nitrogen. Both the wt%N and wt%C are highly variable across the sample. The remainder of the study thus focuses on 36 individuals. Of these 36 individuals, 13 were female, 21 were male and 2 were unknown (Table 4). The average percent nitrogen, collagen yield percentage, and atomic

ratios for the remaining samples are within the bounds of the accepted standards for each measure (Table 5).

Table 5: Table showing all individuals in the sample for this study. The samples eliminated due to poor preservation are indicated in yellow. The samples that were ran twice to measure accuracy are indicated in blue. For the samples that were run twice, the numbers reflected in this table are an average of the two runs.

Sample ID	Collagen Yield (%)	$\delta^{15}N$	$\delta^{13}C$	%N	%C	atomic ratio C:N
To-001 Ind 5	8.50	11.5	-17.3	15.59	41.68	3.12
To-004 Ind 1	0.37	11.6	-17.2	12.45	34.2	3.20
To-004 Ind 2	2.98	12.3	-15.9	15.4	42.19	3.20
To-005 Ind 1	12.85	11.5	-17.5	15.84	43.74	3.22
To-005 Ind 2	13.46	12.2	-16.5	16.13	44.07	3.19
To-005 Ind 3	7.36	11.8	-15.4	15.50	41.98	3.16
To-017 Ind 2	14.13	11.1	-16.7	15.06	40.65	3.15
To-017 Ind 3	11.89	12.3	-16.6	16.18	43.68	3.15
To-017 Ind 4	10.32	12.2	-13.8	15.44	42.37	3.20
To-017 Ind 5	7.78	11.1	-17.3	12.61	35.01	3.24
To-018 Ind 1	8.23	11.4	-13.6	15.41	42.37	3.21
To-018 Ind 2	16.42	10.8	-17.9	16.76	45.06	3.14
To-018 Ind 3	6.93	11.9	-17.6	15.12	41.87	3.23
To-024	2.14	13.9	-14.4	3.69	11.49	3.63
To-024	0.33	13.6	-16.7	0.81	9.67	13.96
To-026A	0.178	11.8	-17.3	6.42	24.09	4.38
To-026B	4.87	11.3	-16.8	13.92	38.51	3.23

Sample ID	Collagen Yield (%)	$\delta^{15}N$	$\delta^{13}C$	%N	%C	atomic ratio C:N
To-026C-2	1.6	13.1	-17.2	4.32	13.42	3.62
To-027	0.422	14.5	-14.7	8.06	26.27	3.80
To-027 Ind 1	4.76	11.2	-17.3	15.79	43.36	3.20
To-027 Ind 2	2.28	11.1	-16.9	14.41	39.39	3.19
To-027 Ind 3	2.91	8.6	-16.4	15.71	43.01	3.19
To-027 Ind 4	1.47	11.5	-15.9	6.06	17.01	3.27
To-027 Ind 5	4.63	13.6	-14.	6.26	17.55	3.27
To-027 Ind 6	2.29	12.2	-16.1	6.98	19.79	3.31
To-028 Ind 1	10.839	12.1	-15.3	14.13	40.22	3.32
To-028 Ind 2	8.965	14.5	-14.8	14.92	41.35	3.23
To-029	0.27	13.3	-14.9	12.47	35.73	3.34
To-029A	1.954	14.0	-13.7	12.64	35.40	3.27
To-030 Ind 1	4.42	11.4	-16.9	15.1	41.22	3.18
To-030 Ind 3	0.67	13.6	-13.2	12.53	34.28	3.19
To-031 Ind A	6.24	9.8	-17.0	14.67	41.14	3.27
To-034A Ind 1	9.301	11.4	-15.8	10.80	31.41	3.39
To-034A Ind 2	9.63	11.1	-17.5	15.27	42.89	3.28
To-034A Ind 3	10.351	10.8	-17.0	15.24	42.20	3.23
To-035 Ind 1	9.957	11.7	-16.6	15.40	43.18	3.27
To-035 Ind 2	10.124	12.9	-15.2	14.85	41.37	3.25
To-036 Ind 1	2.6	13.2	-14.9	13.03	35.61	3.19

Sample ID	Collagen Yield (%)	$\delta^{15}N$	$\delta^{13}C$	%N	%C	atomic ratio C:N
To-038 Ind 2	5.42	11.6	-15.6	14.61	39.59	3.16
To-040 (Average)	6.38	11.6	-12.66	13.69	39.51	3.37
To-041	8.1	11.3	-17.	15.64	42.85	3.20
To-042 Ind 1A/1B (Average)	9.13	11.0	-15.6	13.64	40.36	3.45
To-042 Ind 2A/2B (Average)	10.73	11.4	-16.4	15.35	42.75	3.25
To-043	9.64	11.69	-18.05	15.72	42.75	3.17
To-043 Ind 1	13.17	11.99	-15.71	15.11	42.62	3.29
To-043 Ind 2	10.36	12.12	-16.66	14.24	42.15	3.45
To-049 Ind 1	0.93	15.25	-14.75	4.89	21.95	5.23

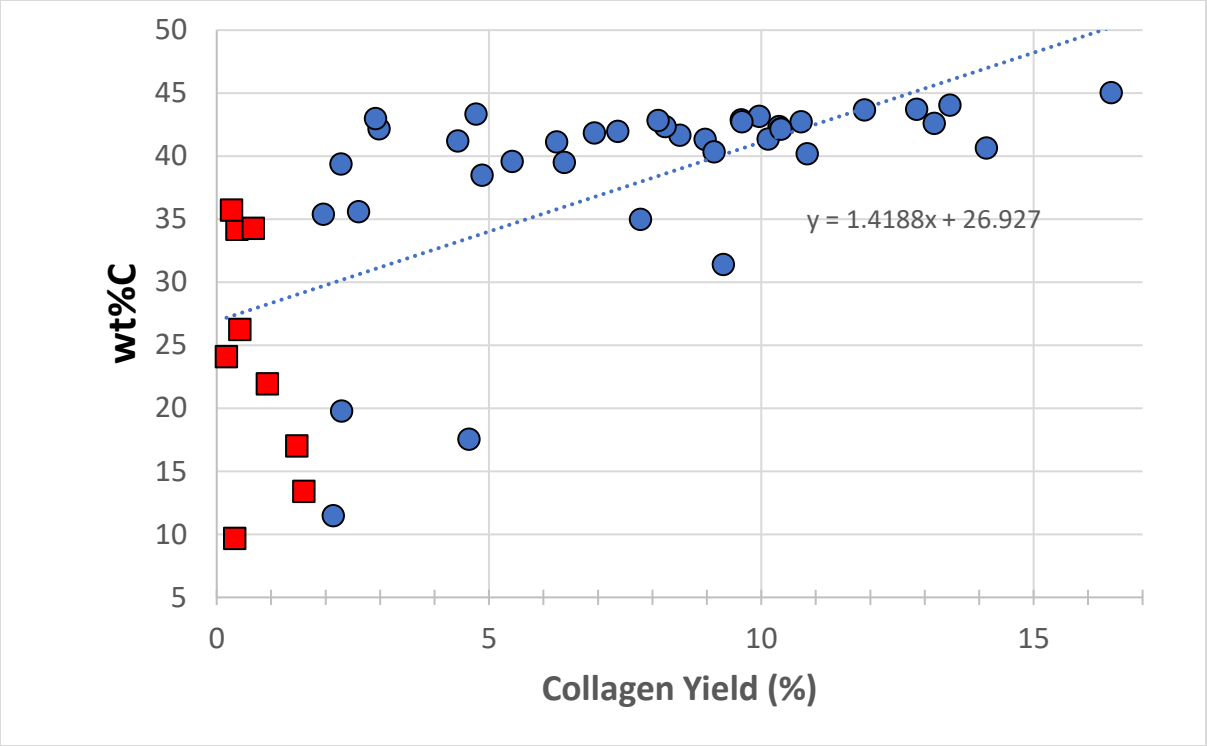

Figure 14: Graph demonstrating the positive correlation between percent collagen yield and wt%C. The red squares indicate the samples eliminated from the study.

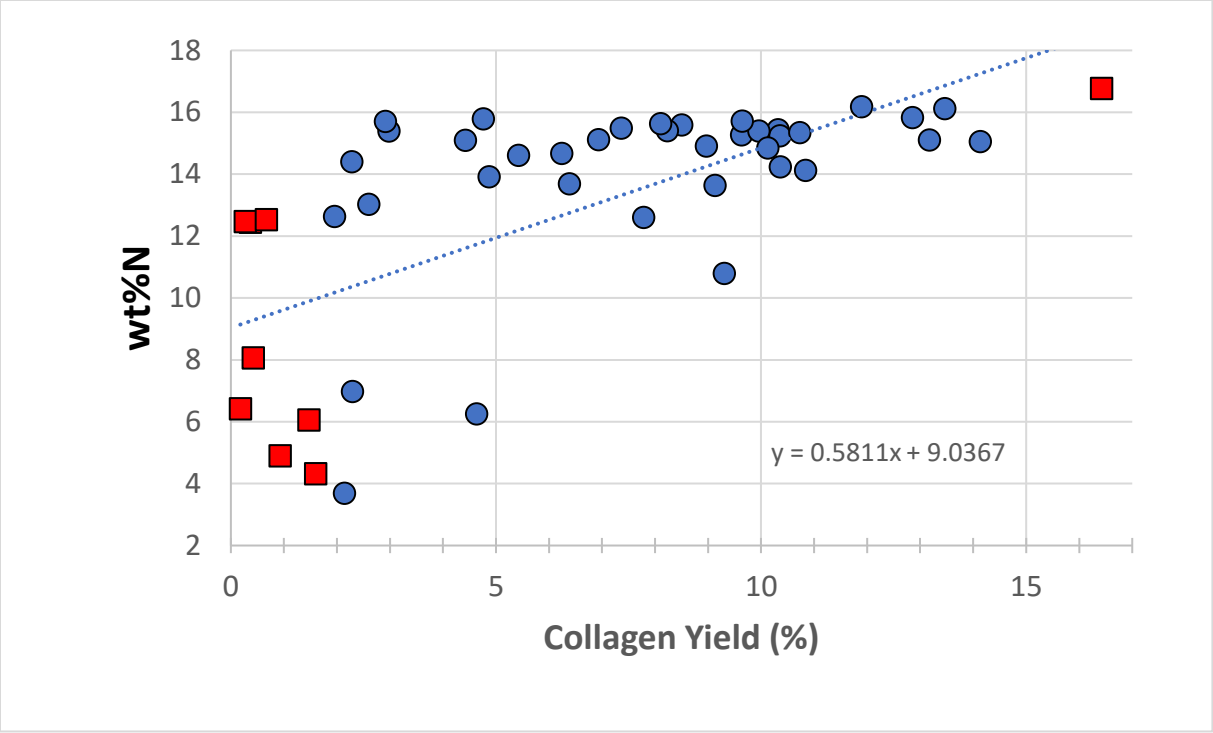

Figure 15: Graph demonstrating the positive correlation between percent collagen yield and wt%N. The red squares indicate the samples eliminated from the study.

Interpretation of Diet by Sex and Age Categories

Stable carbon and nitrogen isotope values were assessed for an elite Meroitic cemetery population of 36 samples. This research was conducted to assess similarities and differences in lived experience between the biological sexes and age categories within the framework of social identity theory. The goal of this analysis was to discuss these similarities and differences in terms of lived experience.

First, the $\delta^{13}C$ and $\delta^{15}N$ values of all 36 individuals were graphed, revealing a wide range of variation in the male population and a general clustering of individuals in the female population. The two individuals with an unknown biological sex both fall in the middle between the male and female populations (Figures 16 and 19). From this point onwards, the two

unknown individuals were removed from consideration since these individuals do not fall within a recognizable sex group. This was necessary for the interpretation of the data through the lens of social identity theory which posits that individuals base their identity on their belonging to and exclusion from groups (Trepte, 2006). Without falling within a biological sex group, these two individuals cannot be interpreted in terms of their creation of an identity based on group involvement.

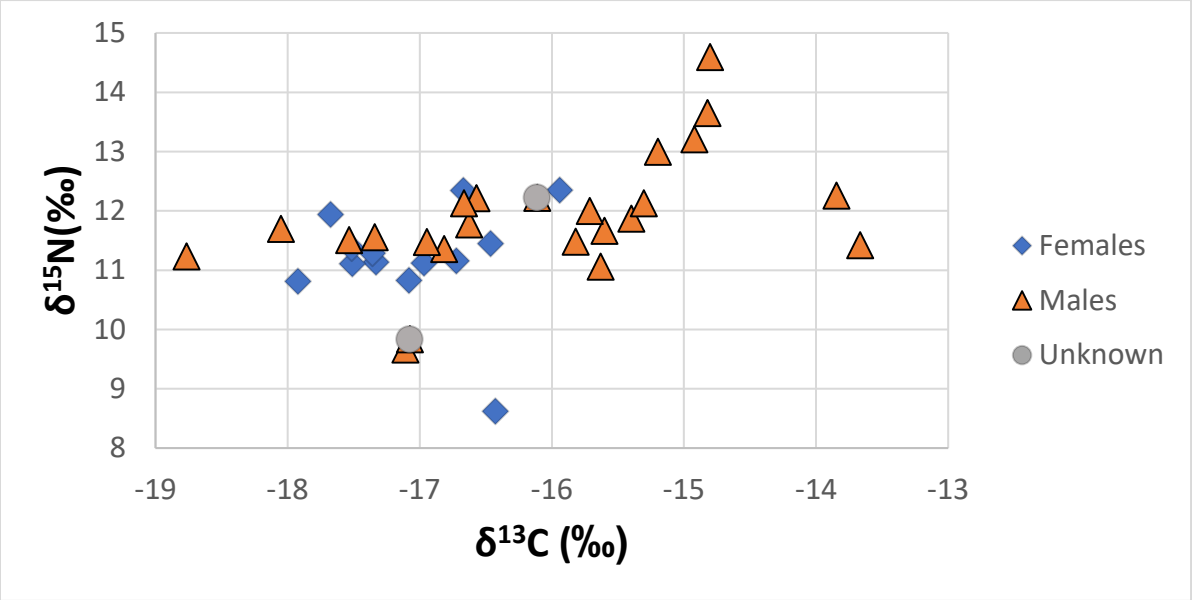

Figure 16: Graph showing the δ13C and δ15N values of all 36 individuals. A wide range of variation among the males and clustering of the females can be seen.

After the elimination of these two unknowns, the males and females as well as various age groups could be compared based on their $\delta^{13}C$ and $\delta^{15}N$ values. Based on the comparison of males and females, it was determined that the males had a greater range of $\delta^{13}C$ and $\delta^{15}N$ values. The male $\delta^{13}C$ values had a range of -18.05‰ to -12.66‰ with a median of 15.62‰ and a standard deviation of 1.35‰. The female $\delta^{13}C$ values had a range of-17.92‰ to -16.43‰ with a median of -17.22‰ and a standard deviation of 0.58‰ (Figure 17). The male $\delta^{15}N$ values had

a range of 8.62‰ to 11.94‰ with a median of 11.11‰ and a standard deviation of 0.86‰. The female $\delta^{15}N$ values had a range of 11.05‰ to 14.59‰ with a median of 11.73‰ and a standard deviation of 0.92‰ (Figure 18). There is not a strong linear relationship between carbon and nitrogen stable isotope values for this sample based on the low R-value of 0.21 (Figure 16). On average, the male $\delta^{13}C$ and $\delta^{15}N$ values were higher than the female $\delta^{13}C$ and $\delta^{15}N$ values (Figures 17 and 18). In terms of range, the females had a greater range of nitrogen values and the males had a greater range of carbon values.

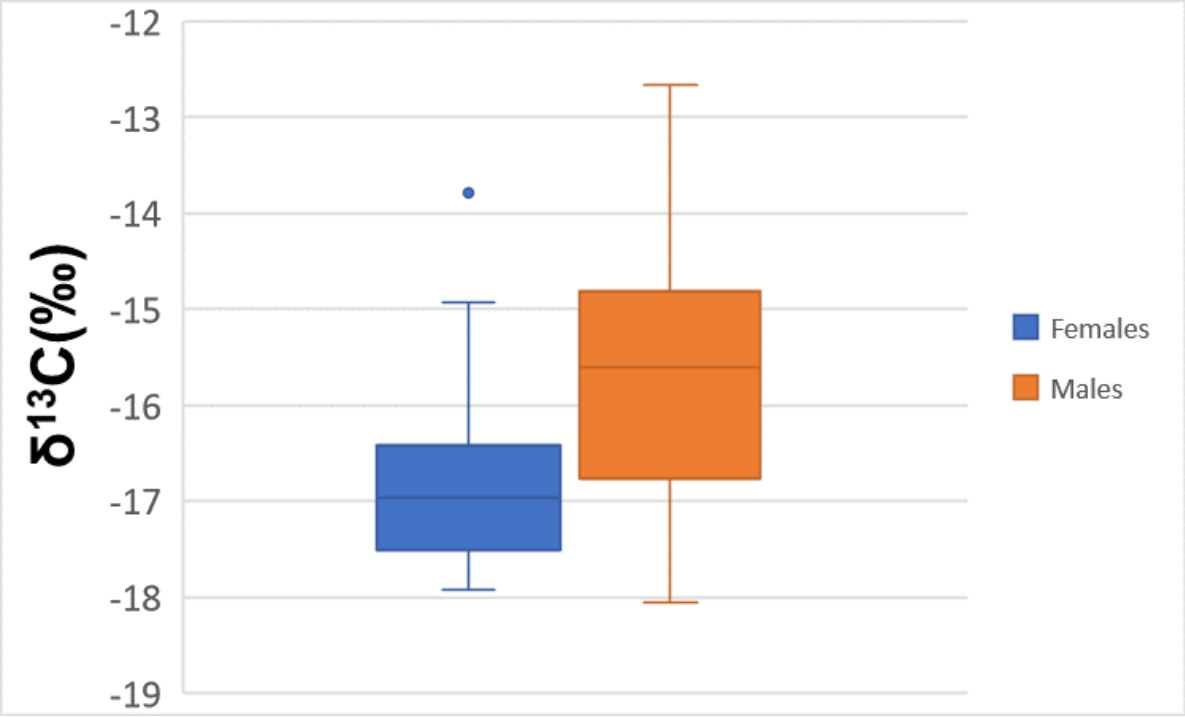

Figure 17: Graph showing the range and median of $\delta^{13}C$ values for males and females.

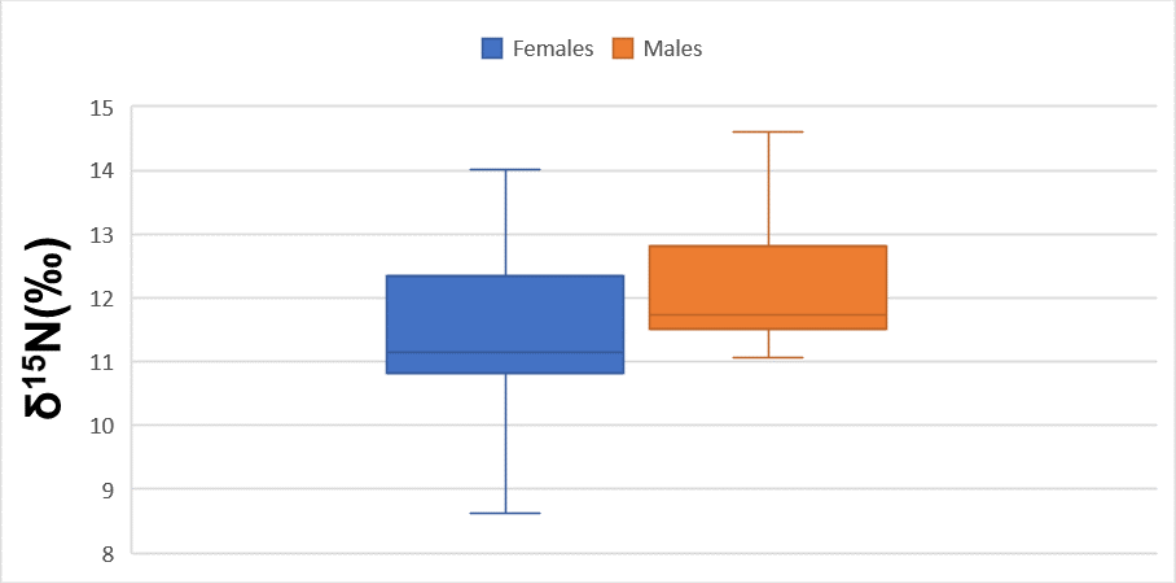

Figure 18: Graph showing the range and median of $\delta^{15}N$ values for males and females.

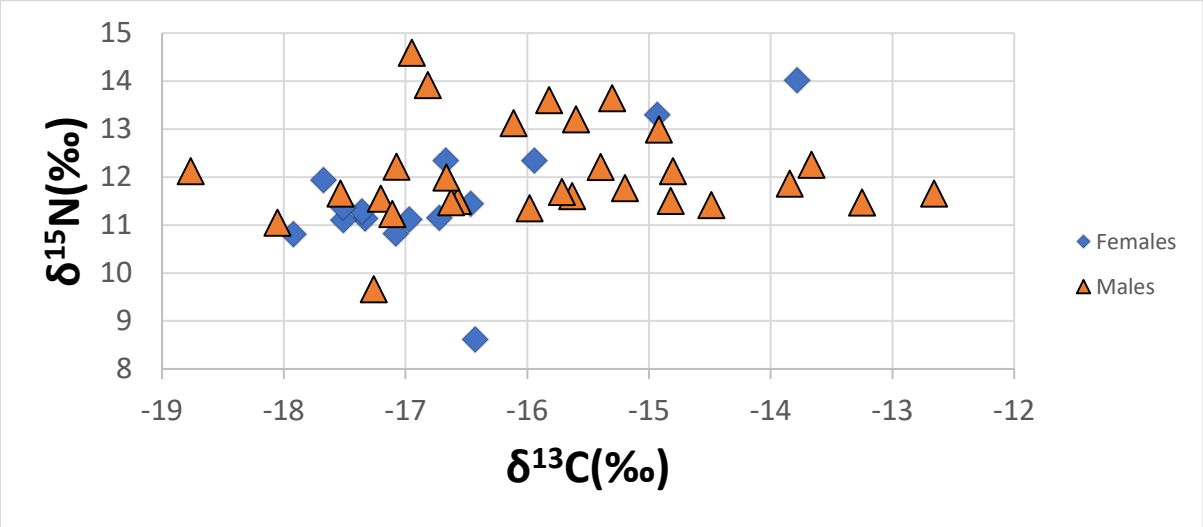

Figure 19: Graph of the $\delta^{13}C$ and $\delta^{15}N$ values for the sample, excluding the two individuals of unknown biological sex.

The median ages of the individuals are presented in relation to $\delta^{13}C$ and $\delta^{15}N$ values (Figures 20 and 21). Overall, the range of $\delta^{13}C$ values for the samples was wide. The females

had similar carbon values for ages 18-48 that ranged from -16‰ to -15‰. The male $\delta^{13}C$ values were more variable. The highest male $\delta^{13}C$ values occurred between the late 30s and early 40s, but there was still a significant amount of variation observed in this age range (Figure 20). The female $\delta^{15}N$ values increase slightly with age, while the male $\delta^{15}N$ values remain consistent. There is a slight increase in male $\delta^{15}N$ levels between the ages of 35 and 40. The unknown individual has values more consistent with the female values.

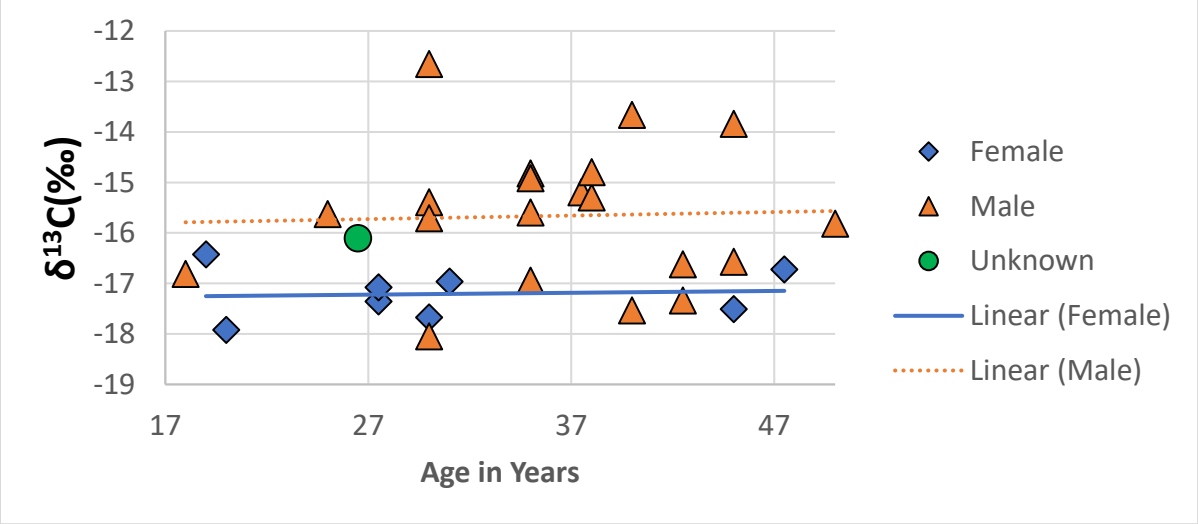

Figure 20: Graph showing the spread of $\delta^{13}C$ values for males (orange triangles), females (blue diamonds) and the unknown individual (green circle) as compared to median age in years. The slight positive correlation between age and the female $\delta^{13}C$ values is shown with a dotted line.

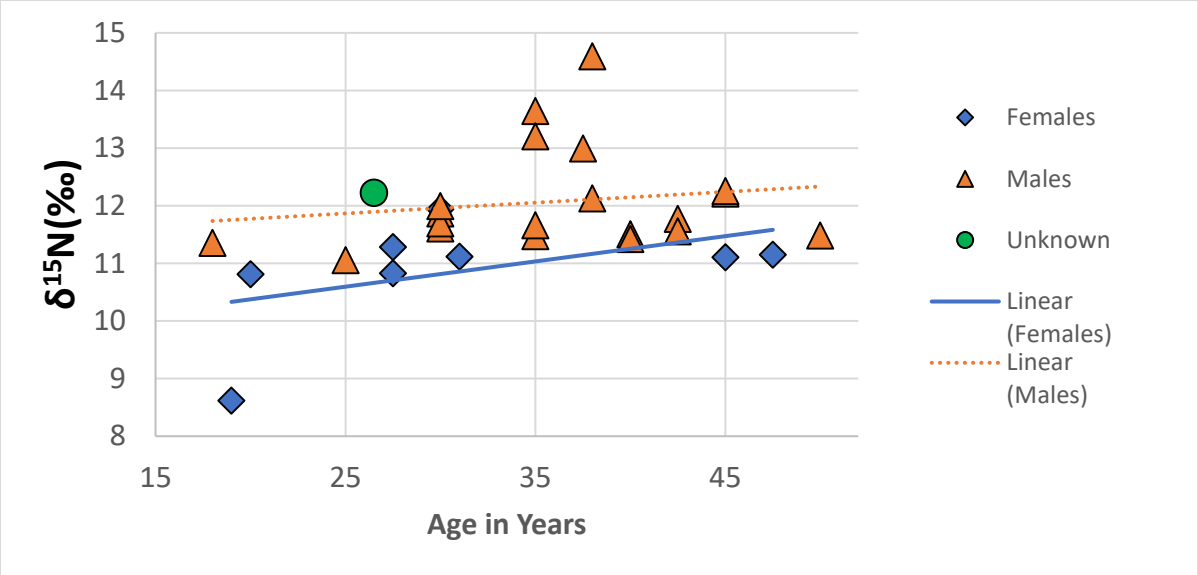

Figure 21: Graph showing the δ15N values in relation to median age in years. Males are indicated by an orange triangle, females by a blue diamond and the unknown individual by a green circle.

Because of the wide age ranges and overlapping age ranges given for these individuals, the individuals were also grouped into one of three age groups to assess trends by age group. The groups were young adult (18-30 years old), middle adult (30-45 years old), or old adult (45+). These groupings were slightly adjusted based on the average age at death observed in other studies wherein most individuals from the Meroitic period in northern Sudan died prior to 50 years of age (White and Schwarcz, 1994). Because of this, age considered to be "old adult" was lowered to 45 plus years. Based on these groupings there were five young adults, 19 middle adults, and nine old adults. The $\delta^{13}C$ and $\delta^{15}N$ values were graphed against these groupings (Figures 22, 23 and 24).

Overall, the middle adults had the largest average $\delta^{15}N$ values with an average of 12.04‰ with a standard deviation of 0.94‰ and the young adults had the smallest average values with an average of 11.01‰ and a standard deviation of 1.46‰ (Figures 25 and 26). The

middle adults also had the largest average $\delta^{13}C$ values with an average of -15.85‰ and a standard deviation of 1.34‰ and the young adults had the smallest average $\delta^{13}C$ values with an average of -16.96‰ and a standard deviation of 0.83‰ (Figures 23 and 26). This analysis also shows that the young adults have the largest variation in nitrogen values and middle adults have the greatest variation in carbon values (Figures 23 and 24). These values do not appear to increase or decrease consistently when moving across age groups. Overall, the majority of all individuals fall within -17 and -18‰ $\delta^{13}C$ and 11-12‰ $\delta^{15}N$ (Figures 24 and 26).

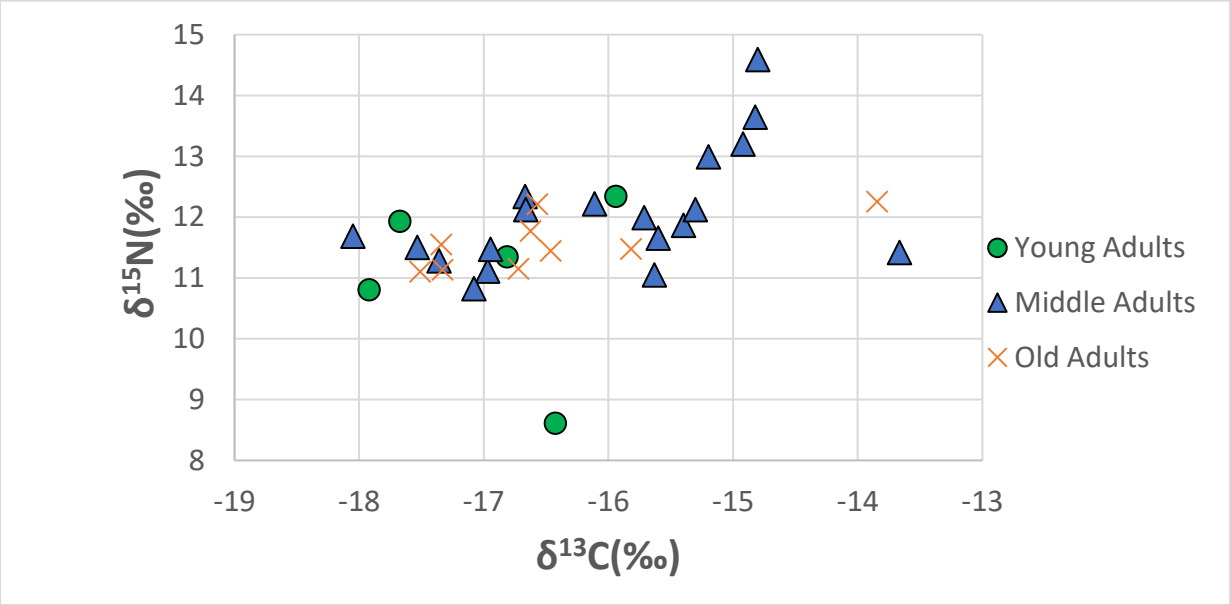

Figure 22: Graph showing the distribution of carbon and nitrogen isotope values based on age grouping.

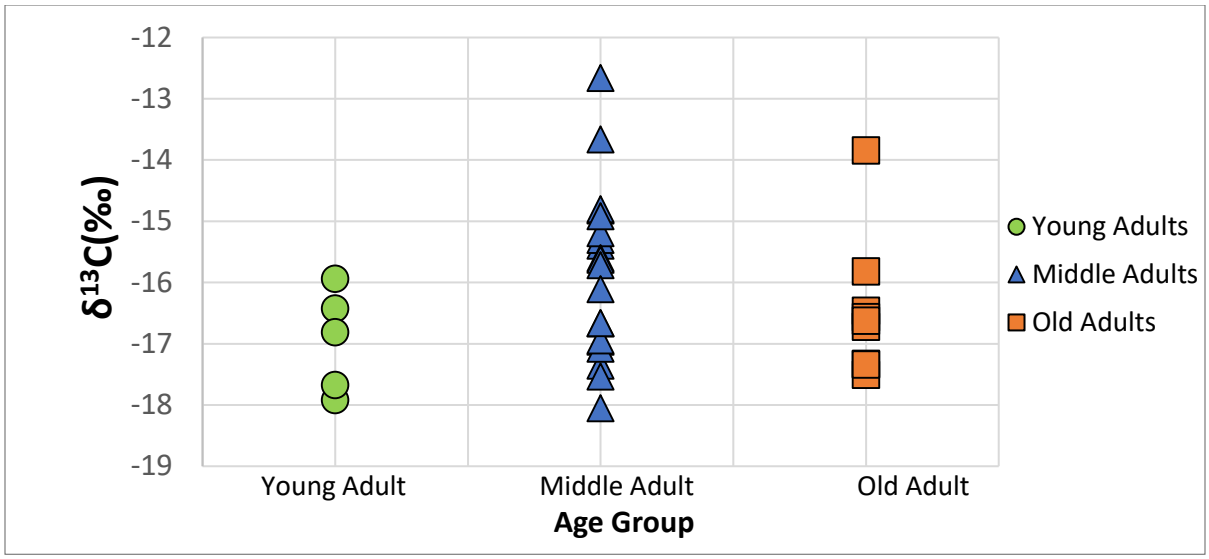

Figure 23: Graph showing the distribution of carbon values by age category.

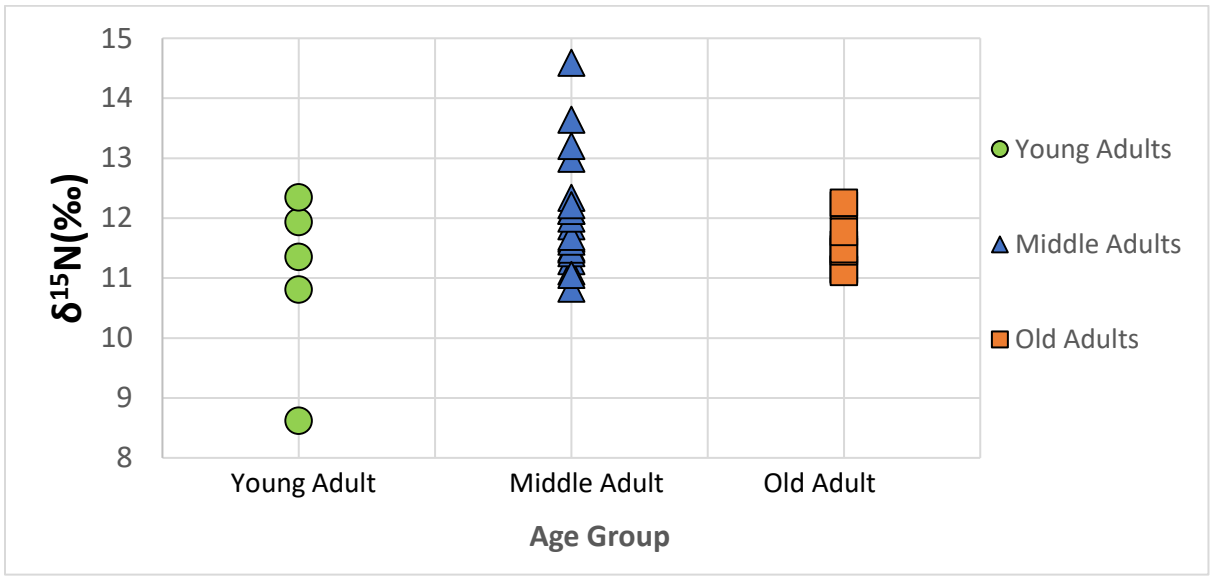

Figure 24: Graph showing the distribution of nitrogen values by age category.

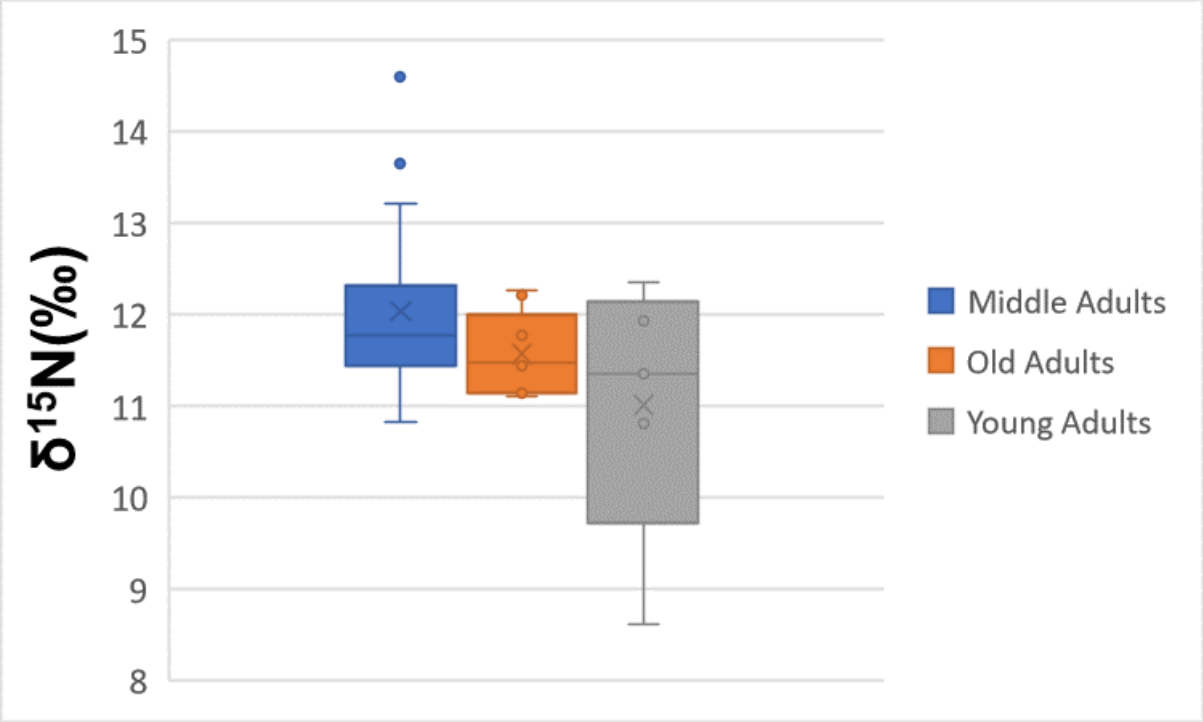

Figure 25: Box plot showing the distribution of nitrogen isotope values by age group.

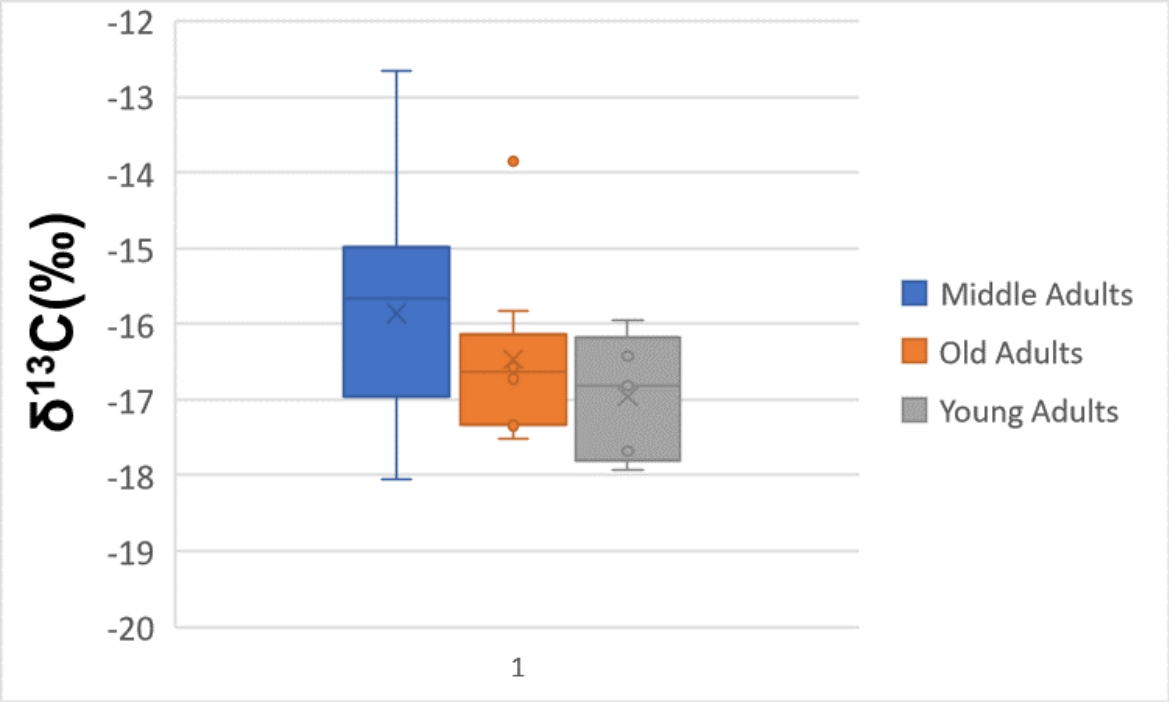

Figure 26: Box plot showing the distribution of carbon isotope values by age group.

Interpretation of Diet Based on C_4 Values

The final assessment was an analysis of the percentage of C_4 foods in the diet. The equation used to calculate the percentage C_4 for an individual using $\delta^{13}C$ values was originally developed by White and Schwarcz (1989) (Equation 4). In this equation δ_c= sample $\delta^{13}C$ value, Δ_{dc}=-5‰, δ_3=-26‰ and δ_4=-9‰ where the values for Δ_{dc} (difference in diet and consumer tissues), δ_3 (average value for C_3 plants) and δ_4 (average value for C_4 plants) are known constants based on the standard equation used by White and Schwarcz (1989). Individuals without a known age or sex were eliminated, leaving 30 individuals available for analysis. Of these 30 individuals 9 were female, 20 were male and 1 was unknown (with a known age) (Table 6).The C_4 percentages for males and females, for males and females as compared to median age, and for each age group was examined.

(4)

$$\text{Percentage } C_4 = \frac{(\delta c - \delta 3 + \Delta dc)}{(\delta 4 - \delta 3)} \times 100$$

Table 6: Table summarizing all of the individuals available for the analysis of percent C_4 compared to age.

Sample ID	C_4 (%)	Sex	Median Age (Years)*
To-018 Ind 2	18.11	Female	20.00
To-018 Ind 3	19.56	Female	30.00
To-034A Ind 2	20.53	Female	45
To-027 Ind 1	21.42	Female	27.5
To-034A Ind 3	23.06	Female	27.5
To-027 Ind 2	23.72	Female	31
To-017 Ind 2	25.16	Female	47.50
To-017 Ind 3	25.47	Female	24.50
To-027 Ind 3	26.90	Female	19
To-043	17.35	Male	30
To-005 Ind 1	20.38	Male	40
To-001 Ind 5	21.53	Male	42.50
To-030 Ind 1	23.84	Male	35

Sample ID	C_4 (%)	Sex	Median Age (Years)*
To-026B	24.61	Male	18
To-035 Ind 1	25.73	Male	42.5
To-005 Ind 2	26.05	Male	45.00
To-034A Ind 1	30.47	Male	50
To-043 Ind 1	31.09	Male	30
To-042 Ind 1A/1B (Average)	31.59	Male	25
To-038 Ind 2	31.76	Male	35
To-005 Ind 3	32.96	Male	30.00
To-028 Ind 1	33.51	Male	38
To-035 Ind 2	34.14	Male	37.5
To-036 Ind 1	35.77	Male	35
To-027 Ind 5	36.34	Male	35
To-028 Ind 2	36.46	Male	38
To-017 Ind 4	42.09	Male	45.00
To-018 Ind 1	43.14	Male	40.00
To-040 (Average)	49.07	Male	30
To-027 Ind 6	28.76	Unknown	26.5

*In cases where an age range is provided for the individual (Table 2), the mid-point of the range was given for the age for the purpose of graphing.

The overall percent C_4 in this sample ranged from 17.32% to 49.07% with a mean of 28.69% ± 7.82. Of the 30 individuals assessed, 10 had a diet consisting of less than 25% C_4 input and 20 had a diet consisting of 25-50% C_4 dietary component. The majority of the females had a diet consisting of less than 25% C_4 plants (Figure 30). Only three females, To-027 Individual 3, To-017 Individual 2, and To-017 Individual 3, had C_4 percentages higher than 25%. The ages for these individuals with higher percentages was 19, 48 and 24-25 respectively. However, all females had C_4 levels below 30%. The males had a greater range of C_4 percent values, but most of the males had levels below 40%. Five males had diets consisting of 25% or less C_4 and 15 had

values suggesting their diet was 25-50% C_4 (Figures 27 and 29). The unknown individual had a C_4 percentage closer to the female values (Figure 29).

After making these comparisons based on biological sex, the C_4 percentage was compared to the median age. No correlation was found between median age and C_4 levels (Figure 28). Because of this, the age groupings previously used to assess $\delta^{13}C$ and $\delta^{15}N$ values were employed for the interpretation of C_4 values as well.

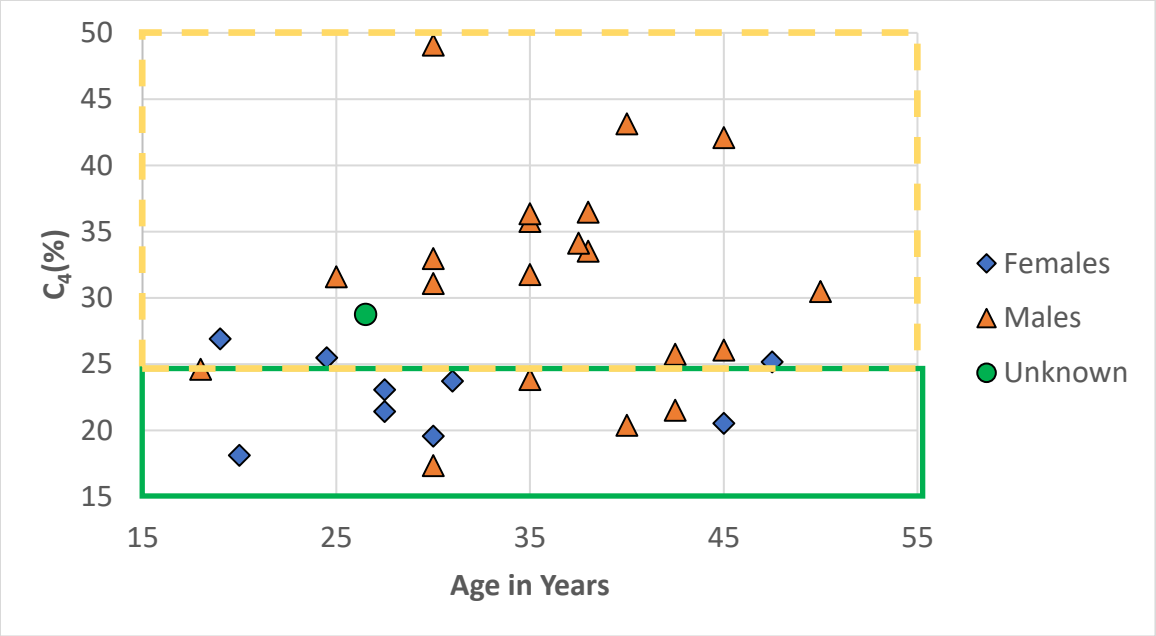

Figure 27: Graph showing the percent C_4 compared to age. The green box with the solid line indicated a diet consisting of less than 25% C_4 plants and the box with the yellow dashed line indicates a diet consisting of 25-50% C_4 plants. The males are indicated by an orange triangle, the females by a blue diamond and the unknown by a green circle.

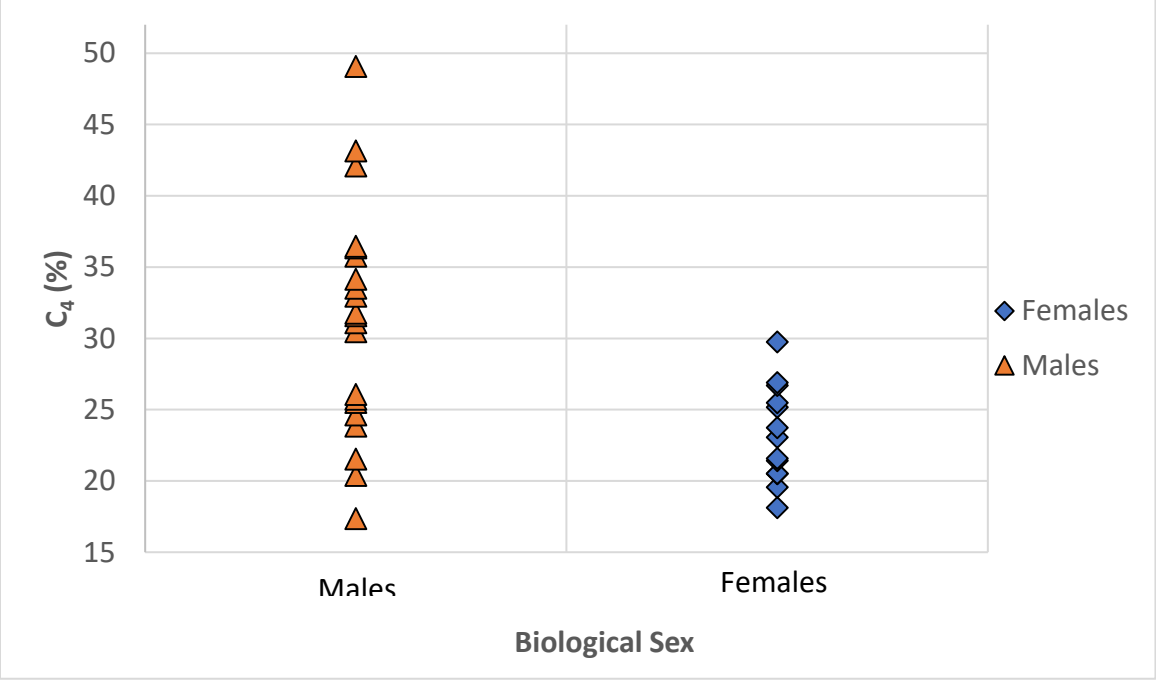

Figure 28: Graph showing the percent C4 compared to biological sex.

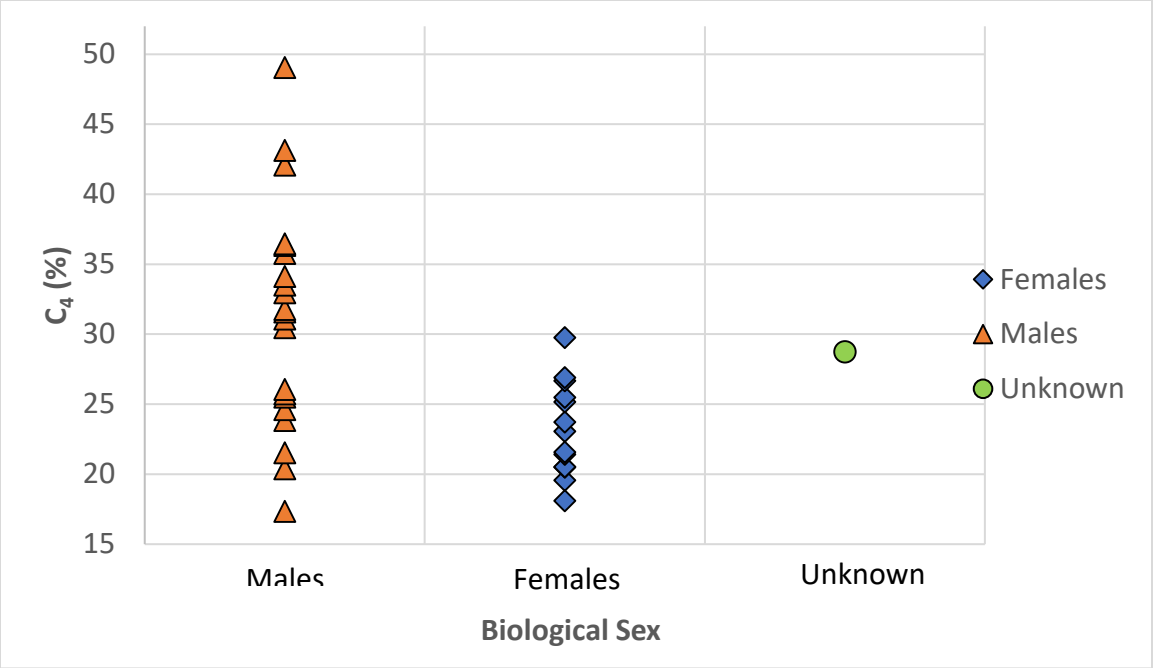

Figure 29: Graph of biological sex and percent C4 including the one unknown individual with a known age. The similarity of this individuals C_4 values to the females can be seen.

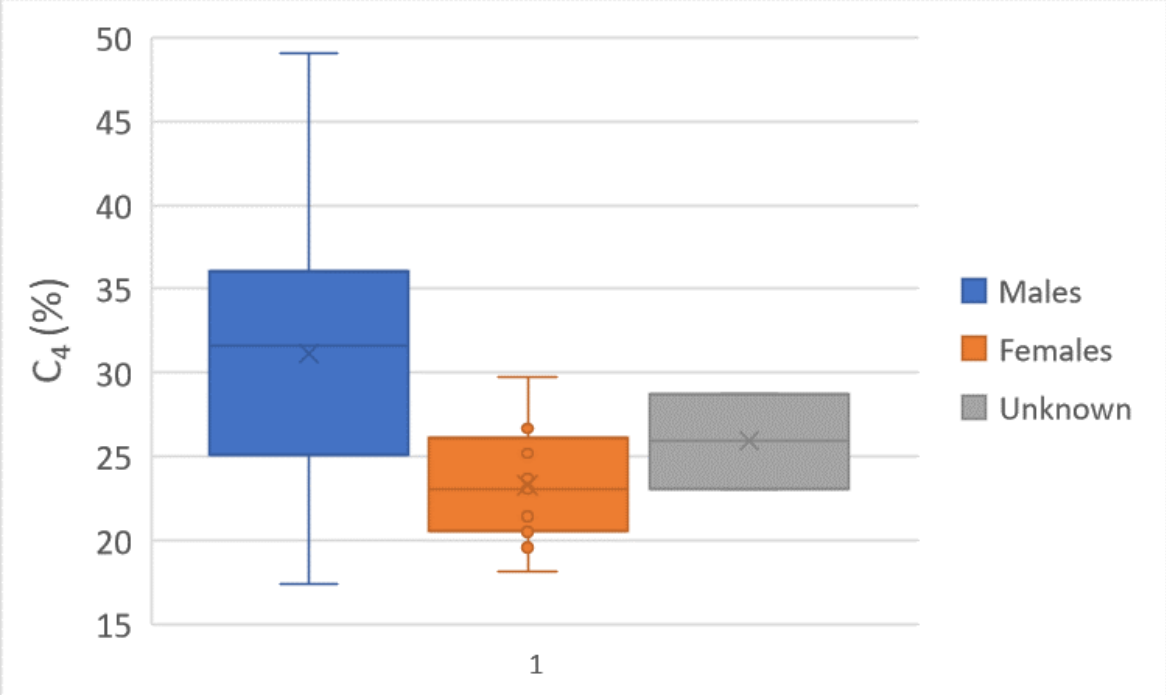

Figure 30: Box plot showing the distribution of C_4 values for males, females, and individuals of unknown biological sex.

The C_4 percentages as compared to the three assigned age groups showed that the middle adults had the widest range of C_4 values (Figure 31). The old adults and young adults were both clustered around the same range of approximately 17-30% with one old adult outlier. This range of values also applies to the majority of the middle adults. If outliers are excluded from the middle and old adult categories, it can be determined that the young adults had diets comprised of 30% C_4 or less with a range of 17-30%, middle adults had diets evenly distributed across their range of 16-36% C_4 input, and old adults had diets consisting of approximately 21-27% C_4.

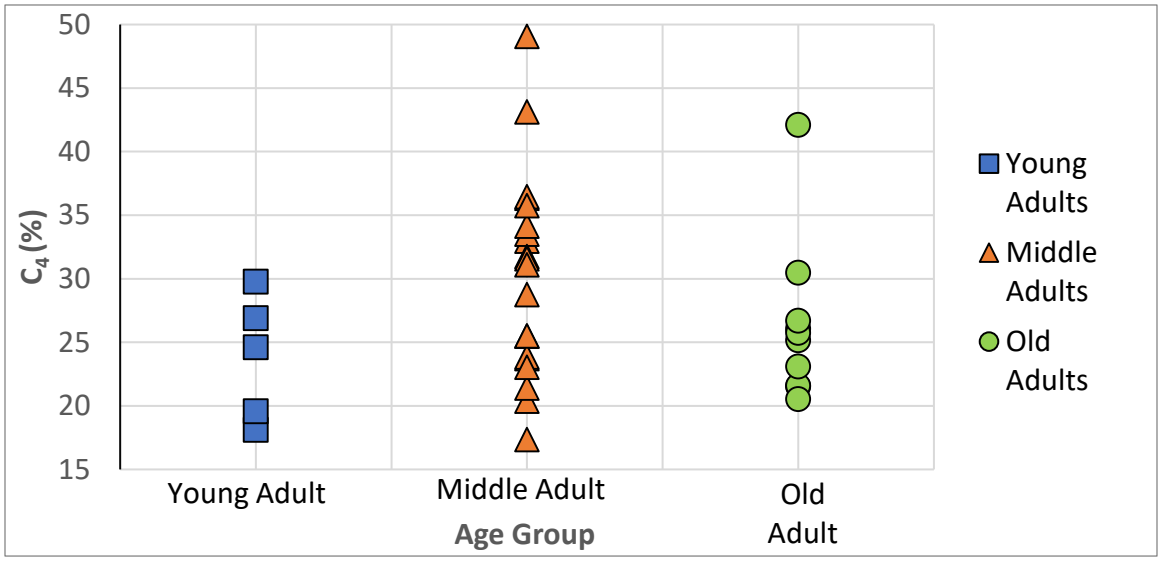

Figure 31: Graph showing the percentage of C4 in the individual's diet based on assigned age groups.

Statistical Analyses

The results of the T-Tests and Mann-Whitney tests indicate that all of groups based on biological sex were significantly different (Tables 7). Significant differences were noted between the male and female percent C_4 values based on the T-Test ($p = 0.0008$) and the Mann Whitney test ($p = 0.0026$). There was also a significant difference between male and female nitrogen

values based on the T-Test p-value of 0.0207 and the p-value of the Mann-Whitney test, which was 0.0045 and the male and female carbon isotope values based on the T-Test p-value of 0.0004 and the Mann-Whitney p-value of 0.0026. The comparison of age groups did not yield any significant statistical differences (Table 8).

Table 7: Table showing the results of the T-Test and Mann-Whitney test for male and female groups.

	Male Versus Female Percent C_4	**Male Versus Female $\delta^{15}N$**	**Male Versus Female $\delta^{13}C$**
T Test P-Value	0.0008	0.0207	0.0004
Mann-Whitney P-Value	0.0026	0.0045	0.0026
	Significant	Significant	Significant

Table 8: Table showing the results of the T-Test and Mann-Whitney test by age group.

	Young Versus Middle $\%C_4$	Young Versus Middle $\delta^{13}C$	Young Versus Middle $\delta^{15}N$	Young Versus Old $\%C_4$	Young Versus Old $\delta^{13}C$	Young Versus Old $\delta^{15}N$	Middle Versus Old $\%C_4$	Middle Versus Old $\delta^{13}C$	Middle Versus Old $\delta^{15}N$
T Test P-Value	0.0442	0.0442	0.1971	0.3766	0.3766	0.4493	0.2147	0.2147	0.0779
Mann-Whitney P-Value	0.0969	0.0969	0.2076	0.5028	0.5028	0.6891	0.2501	.25014	0.2501
Significance	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant

CHAPTER FIVE: DISCUSSION

The primary goal of this research was to compare adult stable carbon and nitrogen values based on sex and age groups, to assess possible differences within the elite Meroitic from Cemetery 8.B.5A. In addition, the research completed for this thesis sought to identify, isotopically, any possible indicators of cultural practice. These areas will be addressed followed by a discussion of the limitations of this research, and future research directions.

Diet Reconstruction

While sufficient animal remains for the construction of a food web have not been recovered from Sai Island, other archaeological data from surrounding sites and modern data on foodways are available to construct a hypothetical food web for the ancient inhabitants. These data are primarily from contemporaneous Sudanese archaeological sites at the Al Khiday spanning the pre-Mesolithic, Mesolithic, Neolithic, and Meroitic periods (Iacumin et al., 2016; Hildebrand and Schilling, 2016; White and Schwarcz, 1994). This information allowed for the construction of a potential food web in the absence of sufficient animal remains to construct a web based on data from Sai Island (Figure 32).

According to archaeological and modern data, the C_3 plants available in Sudan would have included wild grasses, barley, legumes, cucurbits, wheat, ziziphus fruit (e.g., jujuba), acacia beans, fruit of dum palm, melon celtis fruit, onions, rosella, dates and eggplant (Iacumin et al., 2016; DeNiro, 1987; Haaland, 2012; Hildebrand and Schilling, 2016; White and Schwarcz, 1994; Krzyzaniak, 1978). The available C_4 plants would have included millet, sorghum, panicum,

setaria, and echinocloa (Iacumin et al., 2016; DeNiro, 1987; Haaland, 2012). Possible animal protein during the Meroitic period would have been primarily comprised of sheep, goats, chickens, ducks, pigeons and cattle (Gifford-Gonzales, 2005; Haaland, 1992; Haaland, 2012; Blench, 2000; Mwacharo et al., 2013). Other sources of protein documented archaeologically include freshwater fish and land/swamp snails (Krzyzaniak, 1978;. Haaland, 1992; Haaland, 2012; Iacumin et al., 2016). Domesticated dogs have also been documented in funerary contexts, but these animals would not have been used as a food source (Iacumin et al., 2016). The wild animals present in the region include lions, leopards, cheetahs, antelope, hippos, rhinos, warthogs and foxes, but there is no archaeological evidence to suggest that these animals were a primary source of food (Iacumin et al., 2016; Sikainga et al., 2019). In addition, pepper, other spices, wine, and olive oil would have been available via the elite trade network (Haaland, 2012). Other plants and animals could have been available but have not been documented archaeologically. The more likely composition of the human diet based primarily on archaeological evidence and with humans situated at the top of the food chain is illustrated in Figure 33. From this image it is evident that humans relied primarily on livestock and a wide variety of plants.

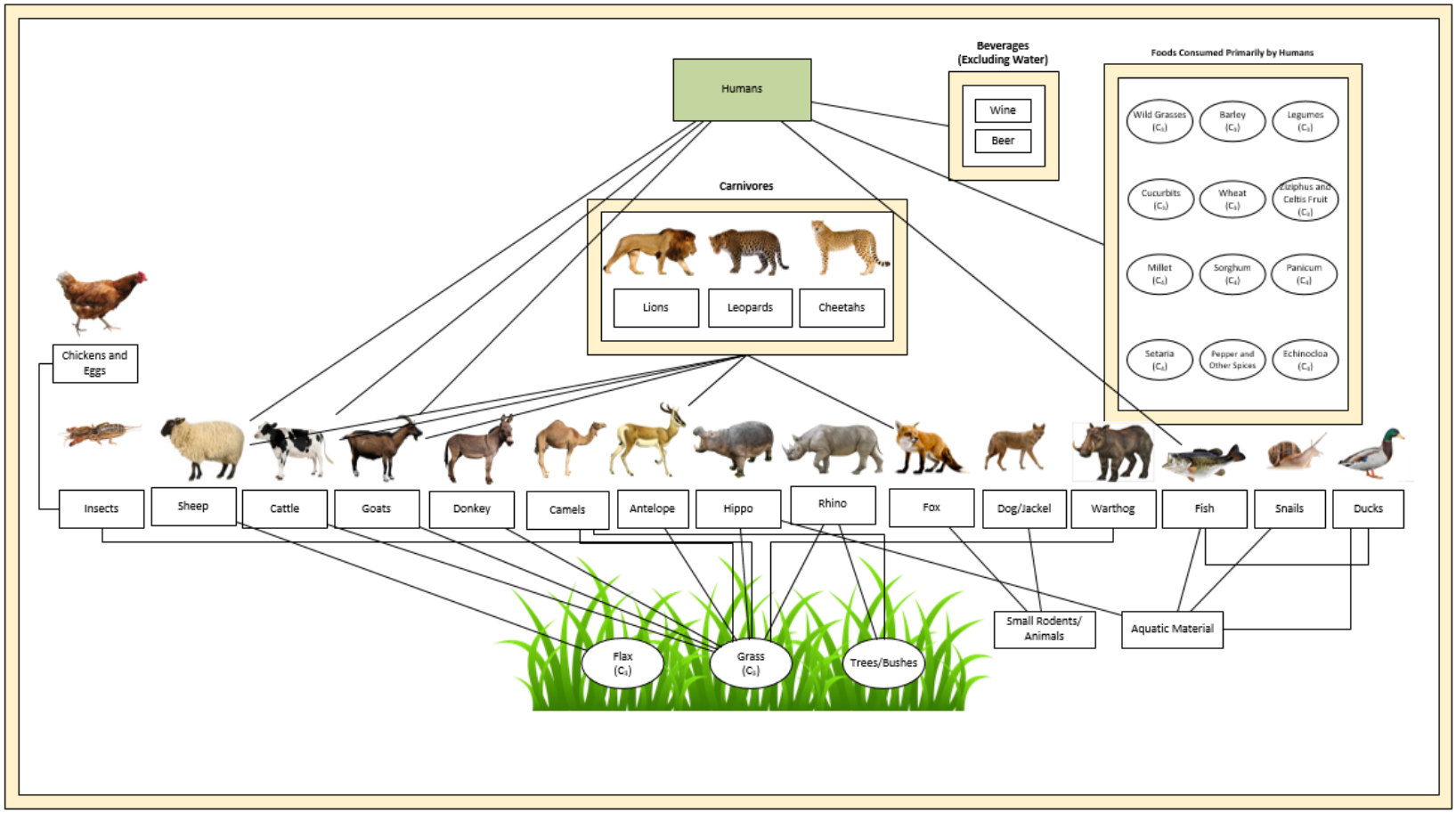

Figure 32: Possible food web based on modern and archaeological data (derived from Iacumin et al., 2016; DeNiro, 1987; Haaland, 2012; Gifford-Gonzalez, 2005; Haaland, 1992 and Sikainga et al., 2019).

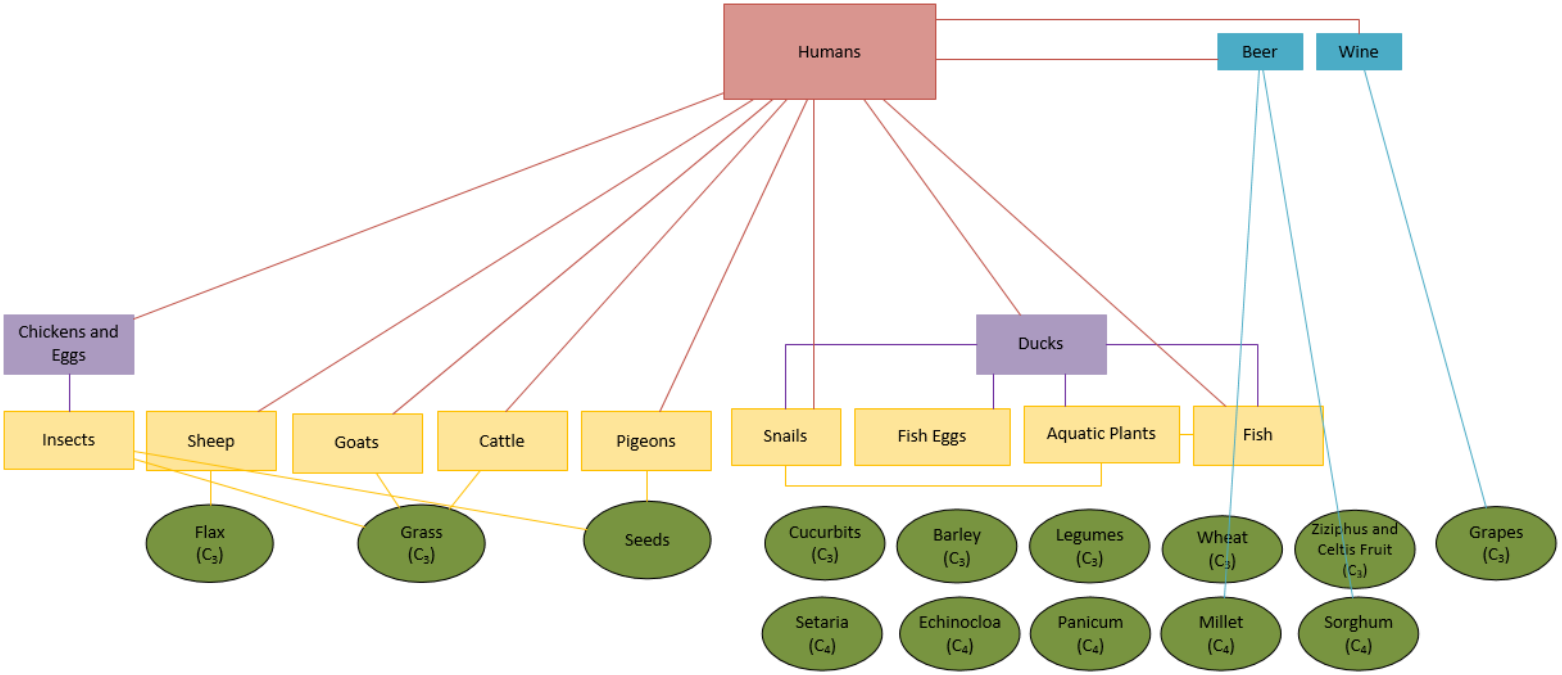

Figure 33: Food web with humans positioned at the top of the food chain to demonstrate what human diet during the Meroitic period could have included based on archaeological data (Iacumin et al., 2016; DeNiro, 1987; Haaland, 2012; Gifford-Gonzalez, 2005; Haaland, 1992).

Male and Female Carbon Values

The overall trends presented in the results section indicate that males have higher carbon isotope values as well as more variable carbon isotope values with statistically significant differences in carbon isotope values. The significance of these differences is evident in the results of the T-Test and Mann-Whitney test, which have p-values below 0.05 indicating significant differences between male and female carbon isotope values (Table 7). The higher carbon values, in conjunction with higher nitrogen values, seen in the male sample indicates that the males were most likely eating more protein from animal sources than the females (Petzke et al., 2005). Additionally, this intake of protein from animal sources would have been highly variable between male individuals.

Considering these trends, a possible explanation for the observed differences between males and females could be a higher ranking of males within the elite class. This is suggested based on the higher intake of protein from animal sources. Animal protein and ritual feasting consistent with the Meroitic period as well as the pastoral nature of this society suggests that meat would have been a higher status food (Haaland, 2012).

Another possible explanation for these differences could be variation in migration and residence patterns between males and females. For example, the males or females could be non-local to the area. Migration in Sudan is not uncommon and throughout history many Nubian migrations from southern to northern Sudan have occurred (Carlson and Gerven, 1979). This includes the migration of the C-group people from lower Nubia to the upper Nile in the 17th dynasty and from lower Nubia to Upper Nubia in the New Kingdom Period to form the Napatan

Kingdom (Carlson and Gerven, 1979). These migrations, as well as numerous others, suggest that Nubians were consistently moving across the landscape in response to environmental and climactic conditions. Additionally, studies using strontium stable isotopes have suggested that Nubians and Egyptians were moving across the landscape and interacting with one another (Buzon et al., 2007; Buzon and Simonetti, 2013). Considering this, it is highly possible that the males or females represent non-local individuals. This is further supported by the fact that this population was heavily involved in the elite trade network (Haaland, 2012). These trade routes covered large distances from western Sudan to the Nile, Egypt, and the Red Sea (Haaland, 2012) (Figure 34). To fully evaluate the possibility of non-locals in this sample, strontium analysis would be useful in identifying individuals of non-local origin.

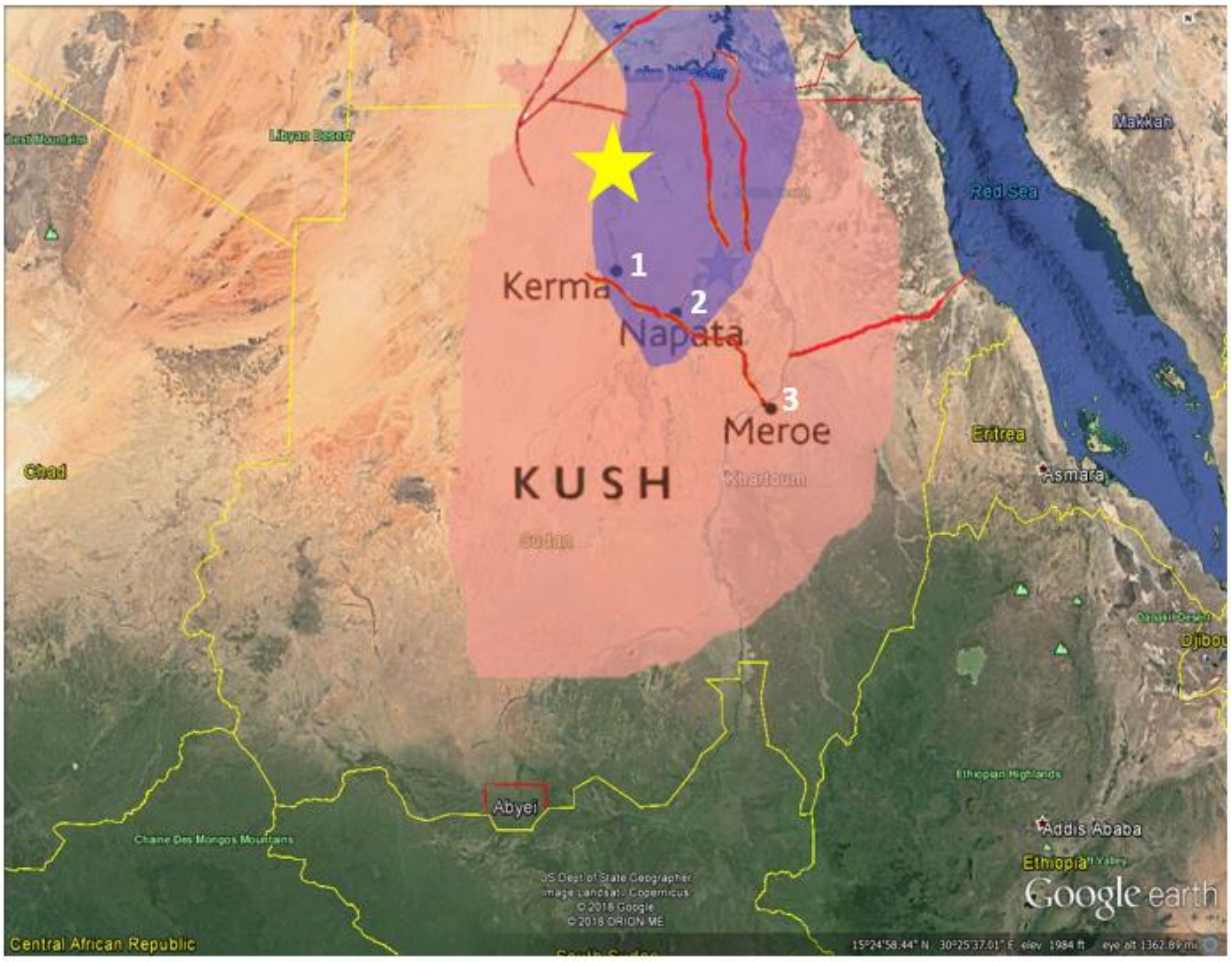

Figure 34: Map pictured again to illustrate the trade routes associated with the elite trade network. Derived from Edwards, 2007 and Quora.com).

In addition to interpreting the carbon isotope values for males and females, the data were also compared to contemporaneous studies in Sudan to provide a basis for discussing the elite values in comparison to other carbon isotope values in Sudan during and around the Meroitic period.

The carbon values were first compared to Iacumin (1998) (Figure 35). The sample used for comparison consisted of carbon isotope values from human bone collagen from 22 individuals from Kerma, which is about 130 km south of Sai Island. One individual in this sample

was from the Meroitic period (332 BC - AD 640) , but the other individuals were from the Christian (1050 AD-1300 AD) and Kerma period (1750–1500 BC) (Murail et al., 2004; Green et al., 1974). While not an ideal comparative sample, it is from the same approximate region. When comparing this data to the current study, it is clear that the Iacumin (1998) values have a much larger range and that the values for the current study are higher on average.

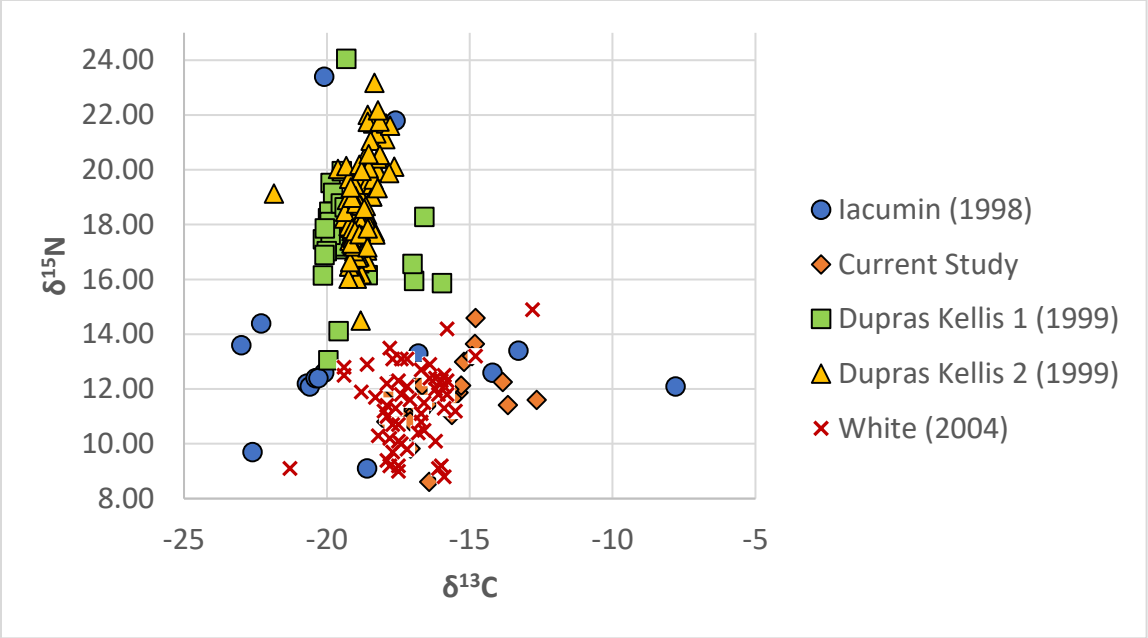

Figure 35: Graph showing the carbon and nitrogen values for the current study, the Iacumin (1998) study, the White (2004) and the Dupras (1999) study.

Following this assessment, the sample was then compared to another study by Dupras (1999) (Figure 35). This comparative data came from the Kellis 1 and Kellis 2 cemeteries which are located in the Dakhleh oasis about 340 miles north of Sai Island. This sample is based on 42 individuals from the Kellis 1 cemetery and 113 individuals from the Kellis 2 cemetery. When compared to the current study, the carbon values for the individuals from Kellis 1 and Kellis 2 are much lower than the carbon values seen in this study.

Lastly, the sample was compared to a study by White et al. (2004) (Figure 35). This study included a bone collagen sample of 56 individuals from Wadi Halfa (northern Sudan) dating to AD 350- AD 1400, which coincides with the later part of the Christian period in Sudan. This sample included juveniles, adults, males and females (White et al., 2004). The carbon values for the individuals in this study are most similar to the values in the White et al. (2004) sample.

Overall, the sample fell within the ranges seen in the Iacumin (1998) and White et al. (2004) studies suggesting that the carbon values seen in the individuals assessed in this study are relatively similar to other Sudanese individuals during this time.

Male and Female Diet Based on C_3 vs. C_4 Plants

Overall, the elite group represented in this study has a diet primarily comprised of C_3 plants, with in some cases, significant inclusion of C_4 plants. The majority of females had a diet of up to 25% C_4 plants and up to 75% C_3 plants. The majority of the males had a diet of 25-50% C_4 plants and 50-75% C_3 plants, but many males had diets more similar to the females. This suggests that the female diet was more homogeneous across age groups and individuals, while the male diet was more variable. The results of the T-Test and Mann-Whitney test support this conclusion because the p-values for these tests were 0.0008 and 0.0026 respectively, which indicates that the male and female intake of C_4 was significantly different.

Age Distinctions Based on Carbon Values

The carbon isotope values for the different defined age categories indicate that the middle adult group had a wide range of carbon isotope values, while the young and old adults had lower values that were very similar to each other. The higher carbon values, in conjunction with the higher nitrogen values, seen among the middle adults suggest that they were consuming more protein derived from animal sources than the young and old adults (Petzke et al., 2005). However, the differences observed were not shown to be significantly different based on the p-values in excess of 0.05 from the T-Test and Mann-Whitney test. Due to these p-values, the differences discussed here cannot be definitely attributed to variation based on age category. The lack of significance could be due to a sample size error, but until additional samples are processed clear conclusions about age group differences cannot be made. Therefore, the distinctions presented here and in relation to social identity are considered trends in the sample and not definitive statements applicable to the population as a whole pending further analysis.

Age Distinctions based on C_4 Values

Considering the assigned age groups, it can be suggested that the middle adults (ages 30-45) had the most variable range in C_4 percentages while young adults had the least amount of variation. Young adults would have had diets of up to 30% C_4 plants and 70% C_3 plants. Middles adults primarily had diets consisting of up to 37% C_4 plants and 63% C_3 plants. However, two of these middle-aged individuals had diets consisting of significantly more C_4 plants (up to 50%). The old adults had diets consisting of up to 32% C_4 plants and 68% C_3 plants.

One of these individuals had a significantly higher percentage of C_4 plants in their diet (43%). It is important to note that the distribution of males and females across the age groups is not consistent. This could impact the distribution of C_4 values and their interpretation. Additional samples should be included to evenly distribute males and females within the age groupings, which would allow for a more accurate interpretation of age distinctions.

Nitrogen Enrichment

Assessing the nitrogen enrichment levels for this sample was difficult because extensive comparative data for this region and time period were unavailable. However, the nitrogen values of this sample were compared to a study by Iacumin (1998) (Figure 36). The sample used for comparison consisted of nitrogen isotope values from human bone collagen. The comparative samples came from 22 individuals from Kerma, which is about 130 km south of Sai Island. One individual in this sample was from the Meroitic period (332 BC - AD 640) , but the other individuals were from the Christian (1050 AD-1300 AD) and Kerma period (1750–1500 BC) (Murail et al., 2004; Green et al., 1974). While not an ideal comparative sample, it is from the same approximate region. This comparison suggests that the nitrogen values in this study fall within the expected range for the region along the Nile River. Most of these values fall below the $\delta^{15}N$ value of 13‰, and the $\delta^{13}C$ value of -10 ‰. If it is assumed that values above these ranges are enriched in nitrogen or carbon respectively, there are three samples from the current study that could be considered nitrogen enriched. This includes individuals To-034A Ind 2, To-027 Ind 2 and To-005 Ind 1. These individuals are female (40-50 years old), female (28-34 years old) and male (40 years old) respectively. Possible causes for this enrichment include a

marine based diet or nutritional stress. Pregnancy was not considered due to the age of the individuals. These possible explanations will be discussed in detail below.

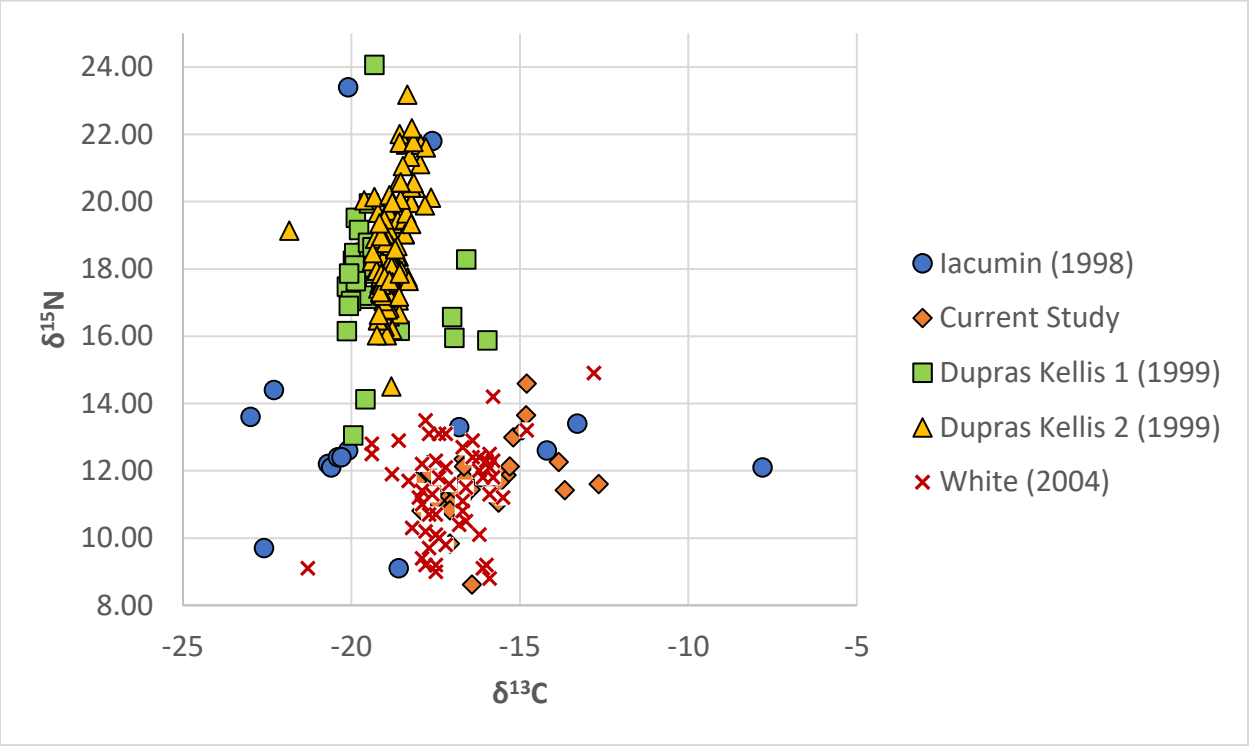

Figure 36: Graph showing the carbon and nitrogen values for the current study, the Iacumin (1998) study, the White (2004) and the Dupras (1999) study.

The current study was also compared to data from a study by Dupras (1999) (Figure 36). This comparative data came from the Kellis 1 and Kellis 2 cemeteries which are located in the Dakhleh oasis about 340 miles north of Sai Island. This sample is based on 42 individuals from the Kellis 1 cemetery and 113 individuals from the Kellis 2 cemetery. The values reported from this sample reflect extremely high nitrogen values (Figure 36). This could indicate that these individuals were eating a diet with a marine component, but it is more likely that nitrogen enrichment across all levels of the food chain could be attributed nitrogen enriched values of plants in arid climates (Schwarcz et al., 1999). Another explanation for nitrogen enrichment in

arid plants causing nitrogen enrichment in the food chain is the decreased level of precipitation (Hoefs, 1997).

Lastly, the sample was compared to a study by White et al. (2004) (Figure 36). This study included a bone collagen sample of 56 individuals from Wadi Halfa (northern Sudan) dating to AD 350- AD 1400, which coincides with the later part of the Christian period in Sudan. This sample included juveniles, adults, males and females (White et al., 2004). When comparing these values to the sample used in this thesis, the carbon and nitrogen values are very similar. White et al. (2004) also have values comparable to Iacumin et al. (1998). However, the White et al. (2004) study differs significantly from the study by Dupras et al. (1999).

The values from the aforementioned studies in relation to the current study suggest that nitrogen enrichment is unlikely because the average nitrogen level was 11.7‰. This is more consistent with the values seen in the Iacumin et al. (1998) and White et al. (2004) studies, which were not nitrogen enriched. A 4‰ enrichment level would indicate that only individuals with nitrogen values over 15.7‰ have enriched nitrogen values due to a marine component of the diet. However, if everyone in the population were consuming a small amount of fish from the Red Sea, then the average nitrogen levels would be elevated. This would prevent the ability to determine the appropriate 4% enrichment level needed to determine if a marine dietary component was present (Ambrose, 1993). This possibility is considered because of the extensive trade and gift giving culture that characterized the elite class and the position of the Meroitic empire along major trade routes from the Nile and the Red Sea (Haaland, 2015). Heavy reliance on fishing has been noted in the Meso-lithic period in Sudan, and some fish bones have been recovered at Meroitic archaeological sites in Kerma (Thompson et al., 2008).

These fish remains are primarily tilapia and catfish (Thompson et al., 2008; Linseele and Pollath, 2015). Additionally, some marine shells have been recovered at Gala Abu Ahmed in central Sudan, which most likely originated from the Red Sea (Linseele and Pollath, 2015). However, there is no way to definitively support the possibility of foreign fish consumption because the fish remains recovered belonged to freshwater fish from the Nile and the marine shells could be the remnants of a previous body of water (Krzyzaniak, 1978; Haaland, 1992; Iacumin et al., 2016; Linseele and Pollath, 2015). Considering this, the most likely explanation for this nitrogen enrichment would be nutritional stress due to illness. Additional data would be needed to certify this assertion, but the older ages of these individuals helps to suggest that they were older and possibly ill prior to death. Additional demographic and dietary information would be needed to support this assertion.

These variable explanations in conjunction with our poor understanding of nitrogen uptake in the human body makes a definitive assessment of nitrogen enrichment impossible (Hedges and Reynard., 2007; Katzenberg et al., 2011).

Social Identity

The analysis of these individuals in terms of social identity theory suggests that there are some differences and similarities between age and biological sex groups. These differences and similarities will be used to discuss the social identity of the elite class as well as the males, females, young adults, middle adults, and old adults.

Based on the overall consumption of primarily C_3 plants by all groups some level of homogeneity in the elite class can be inferred. This homogeneity is evident when looking at the

distribution of males and females by age group in comparison to C_4 values (Figure 37). The graph in Figure 37 demonstrates that males and females in all age categories are eating a diet of 35% or less C_4 with some variation in the middle adult category. Based on this consistency in C_4 values, it could be argued that the constructed social identity of these individuals was based primarily upon their belonging to the elite class. This is because the overall composition of the samples diet is not affected by age or sex when the sample is considered holistically. The lack of significance when age and sex are considered simultaneously is further demonstrated by the p-values in Table 9, which indicate that there are no significant differences between the values of young females, old females, middle aged females, middle aged males and old males. The young males were not able to be assessed because there was only one present in the sample, which is not a large enough group to run a T-Test or Mann-Whitney test.

Table 9: Table demonstrating that there are no significant differences between groups based on age and sex simultaneously based on the p-values of a T-Test.

	Percent C_4	**$\delta^{13}C$**	**$\delta^{15}N$**
Young Females v. Middle Females	0.9585	0.9584	0.6335
Young Females V. Old Females	0.9775	0.9775	0.759
Middle Females V. Old Females	0.9684	0.9684	0.6256
Middle Males v. Old males	0.4861	0.4861	0.27

However, there are some notable differences in diet composition when assessing each age and sex category in isolation that are indicative of social identity components beyond the elite status marker. The differences noted between some of the age and sex groups could be used as indicators of secondary components of social identity within the elite class, which would denote differences between the males, females, young, middle aged, and old individuals in the sample. To demonstrate this, a 'social identity profile' will be discussed for each of the major groupings that are believed to be integral to these individuals' creation of a social identity.

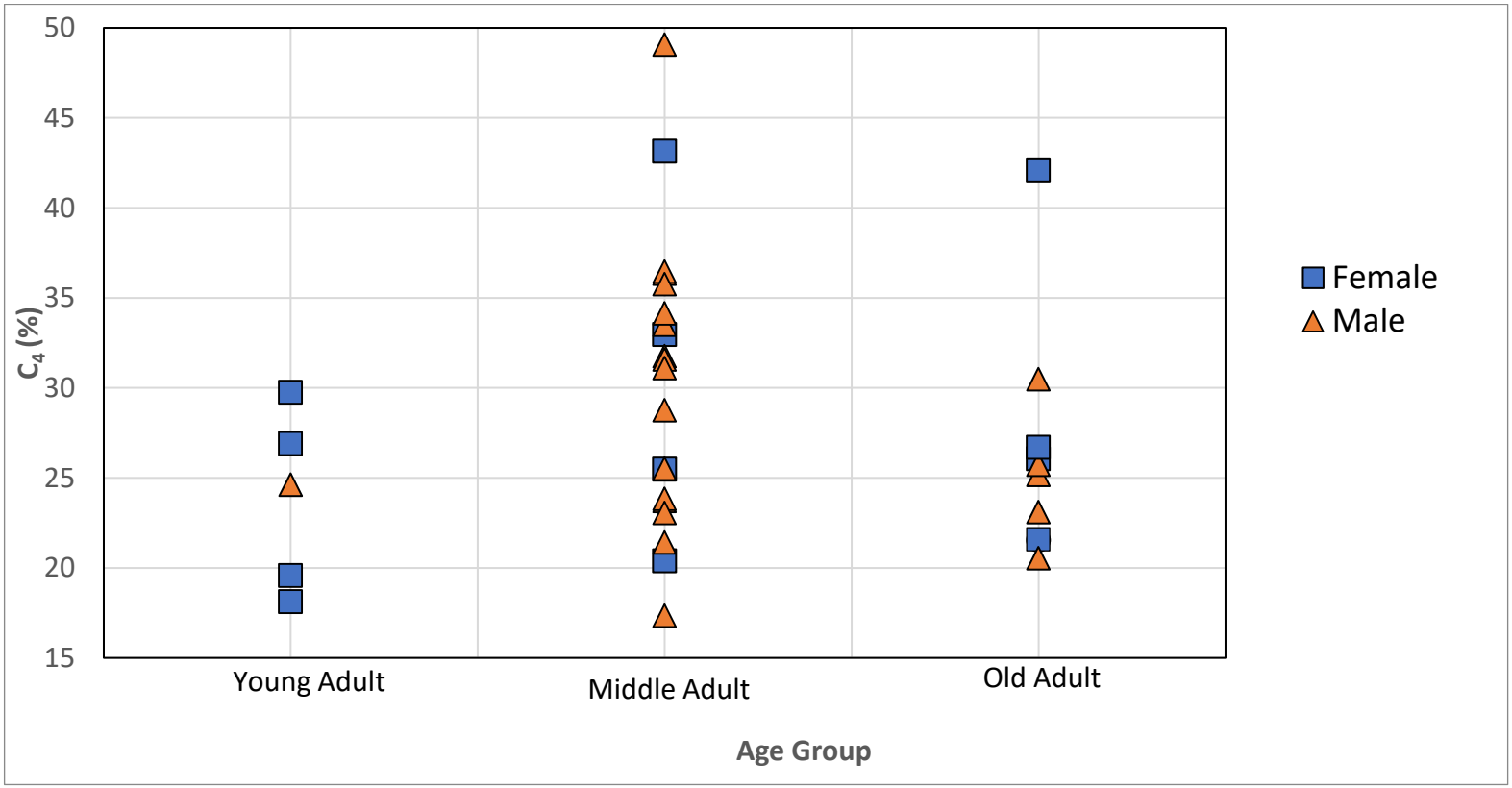

Figure 37: Graph showing the percentage of C4 in the individual's diet based on assigned age groups including the biological sex of each individual.

Based on the percent C_4 in the diet of this sample, it was determined that the elite class relied primarily on C_3 plants with C_4 plants acting as a supplement. Additionally, the elite group is characterized by variable carbon and nitrogen values. The similarity in diet composition can be attributed to the fact that all of these individuals were buried in the same cemetery for elite members of the society. It could also be suggested that these individuals all participated in the same activities as elites, including similar food intake. This is supported by the assertions by Haaland (2012) that the elite class was based on a network of trade. Another explanation is supported by the assertion that the cemetery at Sai was erected in response to the creation of a religious elite group (Francigny, 2009). Both of these possibilities would indicate that the elite population of Sai was a part of an established high-ranking group. This would explain why the overall dietary composition of the elite class is relatively similar across age and sex groups when all age and sex factors are considered in tandem.

The social identity profile for the females would look a little different. This group would be characterized by a higher consumption of C_3 plants, lower nitrogen values, and lower carbon values. The lower percentage C_4 values among females could indicate that the females were eating more wheat, barley, and other C_3 plants. In terms of nitrogen and carbon, the lower values observed among the females could indicate that they were consuming less protein derived from animal sources (Petzke et al., 2005).

For males, the profile would reflect higher carbon and nitrogen values with a wide range and increased consumption of C_4 plants as compared to the female group. This suggests that the male social identity is based on a highly variable diet with a higher intake of protein derived from animal sources (Petzke et al., 2005). The variation in the dietary composition and the

amount of protein derived from animal sources are the primary differences between the male and female social identity profiles.

The young adults would be characterized by a higher consumption of C_4 plants and lower levels of carbon and nitrogen. Interestingly, this is similar to the female group. This means that the diets of the females and the young adults were similar. However, the majority of the individuals in the young adult's group were female, therefore a larger and more representative sample would be needed to make the assertion that these two groups are truly similar. The middle adults would be characterized by a large intake of C_4 plants and a wide range of carbon and nitrogen values. The old adult's profile would indicate lower consumption of C_4 plants and mid-range levels of carbon and nitrogen. This is also similar to the young adult group, but like the comparison to females, more data would be needed. To facilitate a more descriptive and holistic social identity for the elite class, the groups aforementioned, and additional groups more data would be needed. The social identity profiles discussed above are summarized in Figure 38.

The role of agency in the creation of these profiles and the possibility of individuals that do not identify with the labels here must also be recognized. It is possible that individuals categorized into one of these groups based on dietary practices, did not in life identify with this group. Unfortunately, no alternative or non-binary groups were able to be identified with the

sample available. However, the presence of such groups and the possibility for error in the creation of these profiles is noted.

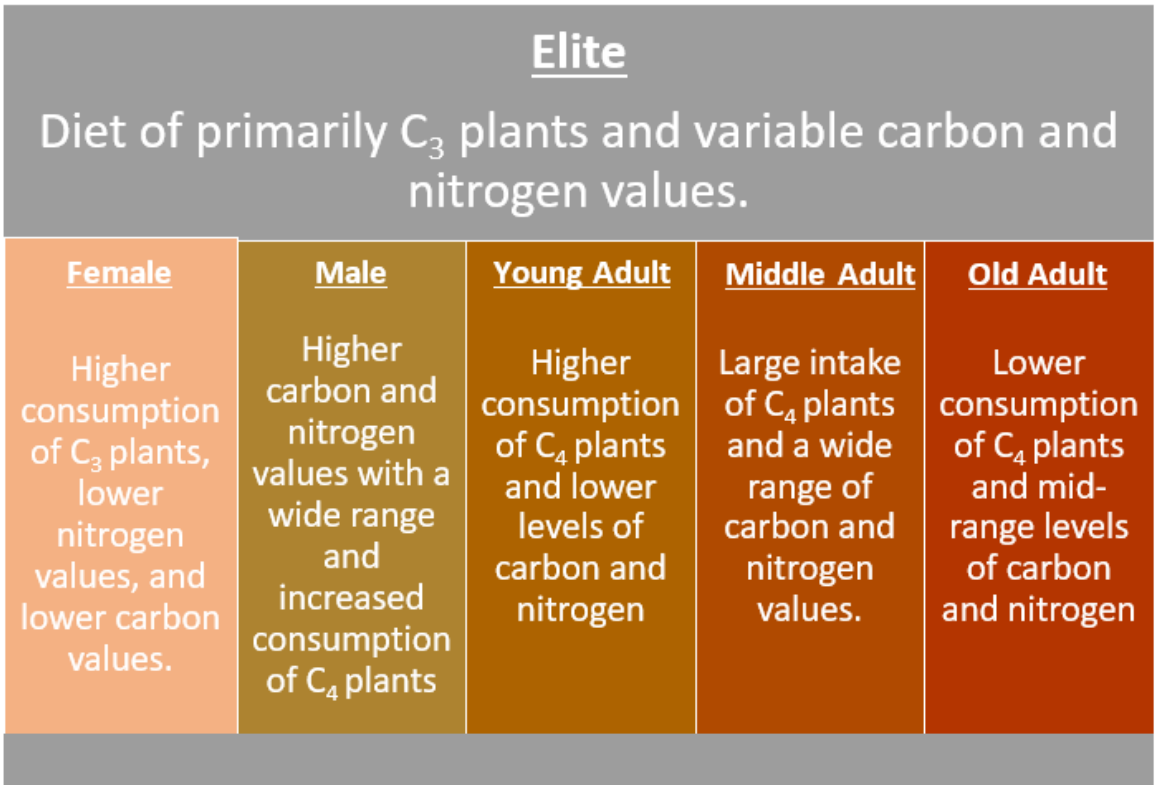

Figure 38: Chart summarizing the social identity profiles for each grouping.

Cultural Practice

Having discussed the general trends and addressing the ability to use social identity to isolate differences and subgroups within the elite population, the secondary goal of this project will be discussed. This is the ability to discern cultural practices from isotopic data. The results indicate that some interpretations may be made in relation to elite dietary practice.

From this assertion, three cultural practices can be inferred based on previous research regarding the dietary and socio-political makeup of elite Meroites. It should be noted that the

conclusions drawn here are not definitive, but merely reflect possible explanations rooted in cultural practice that could be accounted for by the isotope values of these individuals.

First, the elite class viewed bread made from wheat as a high-status food. The higher values of C_3 plants, which includes wheat, suggests that these individuals could have been consuming more of this high-status wheat bread, which is consistent with the status ascertained from their burials on Sai Island (Haaland, 2012; Haaland, 2014).

The second practice is related to C_3 plant consumption as well. Sudan has a long history of a beer culture that extends to the modern day (Haaland, 2012; Armelagos et al., 2001; Dirar, 1992). Typically, Sudanese beer is made of millet or sorghum, which are both C_4 plants (Dirar, 1992). The greater C_4 reliance seen in the males could be interpreted as an indicator of increased millet or sorghum beer consumption. However, many other food items were also made from millet and sorghum including sorghum bread and millet porridge (Dirar, 1992).

Related to this practice, there have been other studies suggesting that beer was an important component of Meroitic culture and have suggested that it contains tetracycline, which has been identified as a modern antibiotic (Nelson et al., 2010; Armelagos et al., 2001). This was deduced based on the presence of yellow–green fluorophore deposition bands when bone was observed under a fluorescent microscope (Nelson et al., 2010; Armelagos et al., 2001). These studies have been previously critiqued on the basis that the observed tetracycline is a result of taphonomic changes in the depositional environment. However, this possibility was eliminated based on the presence of tetracycline patterning most similar to the tetracycline patterning seen in life (Armelagos et al., 2001). Considering these studies, it would

be interesting to pursue an analysis of the bones used in this research to determine if these individuals also have tetracycline present. This would be beneficial in further supporting the assertion that these individuals were consuming sorghum-based beer based. This is suggested because traditional Nubian methods for beer brewing involved fermenting sorghum, which produces *streptomycetes* causing tetracyclines to form (Armelagos et al., 2001). If tetracyclines were observed it could be inferred that these individuals were consuming beer made from fermented sorghum.

The last cultural practice that can be discussed based on these isotope values is the elite consumption of wine. Beer was consumed by all classes; however, wine was an elite beverage that was typically imported in an effort to mimic Roman traditions (Haaland, 2014). This is mentioned because grapes, which are typically used to make wine, are C_3 plants. The greater reliance on C_3 foods seen in the elite group could be explained by the greater consumption of imported wine in addition to the consumption of other C_3 foods. Interestingly, the reliance on C_3 plants appears to be greater among the females. It could be suggested that this indicates a higher consumption of elite status wine among these individuals. However, the consumption of other C_3 foods, including beer attributed to the lower classes, could also explain this increase in C_3 values among females.

CHAPTER SIX: CONCLUSION

The results of this research indicate that distinctions within the elite class can be made based on isotopic values. The primary distinction between the biological sexes was that females could possibly be viewed as lower elites based on their more homogeneous diet and their increased consumption of C_3 foods as compared to males. Some minor distinctions were also made between the various age groupings. These distinctions were used to create social identity profiles for the sub-groups identified within the elite class. The results of this study also provide some support for cultural practices, such as the potential consumption of millet/sorghum beer, wine, and bread, using isotope values. Lastly, the goal of acknowledging the ability of agency to impact the result presented here and the possibility of a non-binary experience was met. Future research aims to address some of the gaps of knowledge identified by this research. Overall, these data support the assertion that stable isotopes can be used to identify differences between biological sex and age categories for the purposes of constructing a social identity and identifying cultural practices. To return to the original questions posed in the introduction of this paper, a brief commentary will be provided on each question in addition to the holistic conclusions discussed above.

Can differences in life experiences between the biological sexes and within the elite class be inferred based on isotopic values?

The carbon and nitrogen isotope values of the males and females in the elite class display some differences. For example, males show a much greater range of $\delta^{13}C$ values, indicating a much more variable diet. This may have been the result of access, or perhaps

migration. Some differences, such as the possible lower elite status of females, can be discerned isotopically. This gives some insight into the variable ways elitism was experienced by males and females based on diet.

Are the differences in isotopic values between elite males and female's indicative of specific cultural practices?

The isotopic values of the males and females were useful in correlating diet with cultural practices such as beer culture, and elite consumption of known high status foods. However, isotopic values cannot provide a direct correlation between specific foods and a cultural practice because of the variety of plants within each grouping and the multiple possible explanations for these values. At this stage, only suggestions can be made regarding the interpretation of cultural practice from isotope values.

What are the implications of cultural practices on everyday life for elite males and females in ancient Nubia?

Because the cultural practices that could be linked with isotope values are not definitive, the interpretation of the implications of these practices on everyday life is difficult. In addition, the cultural practices identified are not readily linked to major implications on everyday life. For example, eating wheat bread does not provide any more information on an individual's daily life that could have significant implications on the way they experienced their life beyond that, in this sample, they were considered elite. Without further information this question cannot be fully addressed.

Can distinctions between elites be made in order to provide a deeper understanding of elite societal organization?

While many distinctions were not able to be made due to sample size and other limiting factors, one distinction was possible between the males and females. This difference is that females ate more C_3 plants, associated with lower status. This could indicate that females made up a lower portion of the elite class. If more research were conducted with a larger and more representative sample, more groups and differences could potentially be identified and additional distinctions could be made between males and females, or alternate groups, to delineate different strata within the elite class.

Limitations

There were a few major limitations to the research presented here. The first issue was sample size. After many individuals were eliminated due to poor preservation, the already small sample was decreased to only 36 individuals. It would be beneficial to have a larger sample to help establish a normal distribution of the population in this cemetery.

In addition to sample size, sample composition was also an issue. The sample consisted of a disproportionate number of males compared to females. The age distribution also favored middle aged to older adults. A more even distribution would be beneficial to make distinctions between age groups. It would also be prudent to obtain more categorical information for each individual to facilitate analysis based on more groups. This would aid in the creation of a social identity profile. Overall, a larger and more representative sample is needed.

Another limitation was the inability to construct a food web. This limited the analysis to plant consumption. The ability to construct a food web would be helpful in assessing higher status foods, like meat, associated with the burial feasting culture aforementioned (Haaland, 2012).

Lastly, there was no comparative data available for the assessment of nitrogen enrichment or isotope values that closely matched the sample used in this research. The availability of additional data would provide the opportunity to more definitively identify individuals with enriched nitrogen levels. Additionally, comparative data from other class groups could aid in delineating smaller sub-groups within the elite class. This could be evaluated by determining which individuals more closely resemble the isotope values of the middle class to define a lower elite subgroup.

Future Research

Future research on this elite population from Sai Island is necessary to fully develop the social identities of smaller groups within the elite class. Part of this research would include expanding the sample to be larger and more representative of all age groups and both biological sexes. This could potentially expand to include juveniles to assess the social identity of this elite sub-group. Another avenue of this research would include collecting more individual categorical data in an effort to expand the possible subgroups within the elite population. It would also be beneficial to complete strontium and oxygen stable isotope analysis to identify possible non-local individuals that could comprise another sub-group within the elite class. Lastly, the inclusion of animal data for this area would be beneficial in expanding

the food chain for the region. In addition, the aforementioned study of tetracyclines in the sample, would bolster the assertion that these individuals were consuming sorghum beer. This future research would allow for a greater range of interpretable data that could potentially lead to the ability to identify non-conforming individuals or non-binary experience in the past

APPENDIX: RAW DATA

Table 10: Table showing all individuals analyzed for this thesis. The line in yellow indicates samples removed due to poor preservation and the lines in blue indicate individuals that were run more than once.

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-001 Ind 5	Adult	Male	35-50 years	8.50	11.55	-17.34	15.59	41.68	2.67	3.12
To-004 Ind 1	Adult	Male	25 years	0.37	11.66	-17.20	12.45	34.2	2.75	3.20
To-004 Ind 2	Adult	Female	young adult	2.98	12.35	-15.94	15.4	42.19	2.74	3.20
To-005 Ind 1	Adult	Male	40 years	12.85	11.50	-17.53	15.84	43.74	2.76	3.22
To-005 Ind 2	Adult	Male	45 years	13.46	12.21	-16.57	16.13	44.07	2.73	3.19

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-005 Ind 3	Adult	Male	30 years	7.36	11.87	-15.40	15.50	41.98	2.71	3.16
To-017 Ind 2	Adult	Female	45-50 years	14.13	11.15	-16.72	15.06	40.65	2.70	3.15
To-017 Ind 3	Adult	Female	20 - 29 years	11.89	12.34	-16.67	16.18	43.68	2.70	3.15
To-017 Ind 4	Adult	Male	45 years	10.32	12.26	-13.84	15.44	42.37	2.74	3.20
To-017 Ind 5	Adult	Female	old adult	7.78	11.13	-17.33	12.61	35.01	2.78	3.24
To-018 Ind 1	Adult	Male	40 years	8.23	11.42	-13.67	15.41	42.37	2.75	3.21

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-018 Ind 2	Adult	Female	20 years	16.42	10.81	-17.92	16.76	45.06	2.69	3.14
To-018 Ind 3	Adult	Female	30 years	6.93	11.94	-17.67	15.12	41.87	2.77	3.23
To-024	Adult	Male	40 years	2.14	13.92	-14.49	3.69	11.49	3.11	3.63
To-024	Adult	Male	40 years	0.33	13.65	-16.76	0.81	9.67	11.96	13.96
To-026A	Adult	Female	35 Years	0.178	11.82	-17.31	6.42	24.09	3.76	4.38
To-026B	Adult	Male	18 years	4.87	11.35	-16.82	13.92	38.51	2.77	3.23
To-026C-2	Adult	Unknown	35 Years	1.6	13.12	-17.26	4.32	13.42	3.11	3.62

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-027	Adult	Female	25 - 30 years	0.422	14.57	-14.71	8.06	26.27	3.26	3.80
To-027 Ind 1	Adult	Female	25 - 30 years	4.76	11.28	-17.36	15.79	43.36	2.75	3.20
To-027 Ind 2	Adult	Female	28 - 34 years	2.28	11.12	-16.97	14.41	39.39	2.73	3.19
To-027 Ind 3	Adult	Female	19 years	2.91	8.62	-16.43	15.71	43.01	2.74	3.19
To-027 Ind 4	Adult	Male	35 - 44 years	1.47	11.50	-15.98	6.06	17.01	2.81	3.27
To-027 Ind 5	Adult	Male	35 years	4.63	13.65	-14.82	6.26	17.55	2.80	3.27

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-027 Ind 6	Adult	Unknown	25 - 28 years	2.29	12.22	-16.11	6.98	19.79	2.84	3.31
To-028 Ind 1	Adult	Male	38 years	10.839	12.13	-15.30	14.13	40.22	2.85	3.32
To-028 Ind 2	Adult	Male	38 years	8.965	14.59	-14.80	14.92	41.35	2.77	3.23
To-029	Adult	Female	30 - 34 years	0.27	13.30	-14.93	12.47	35.73	2.87	3.34
To-029A	Adult	Female	38 years	1.954	14.02	-13.78	12.64	35.40	2.80	3.27
To-030 Ind 1	Adult	Male	30 - 40 years	4.42	11.47	-16.95	15.1	41.22	2.73	3.18

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-030 Ind 3	Adult	Male	45 - 61 years	0.67	13.61	-13.25	12.53	34.28	2.74	3.19
To-031 Ind A	Adult	Unknown	Unknown	6.24	9.83	-17.07	14.67	41.14	2.80	3.27
To-034A Ind 1	Adult	Male	50 years	9.301	11.48	-15.82	10.80	31.41	2.91	3.39
To-034A Ind 2	Adult	Female	40 - 50 years	9.63	11.10	-17.51	15.27	42.89	2.81	3.28
To-034A Ind 3	Adult	Female	25 - 30 years	10.351	10.83	-17.08	15.24	42.20	2.77	3.23
To-035 Ind 1	Adult	Male	35 - 50 years	9.957	11.77	-16.63	15.40	43.18	2.80	3.27

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-035 Ind 2	Adult	Male	35 - 40 years	10.124	12.99	-15.20	14.85	41.37	2.79	3.25
To-036 Ind 1	Adult	Male	35 years	2.6	13.21	-14.92	13.03	35.61	2.73	3.19
To-038 Ind 2	Adult	Male	35 years	5.42	11.66	-15.60	14.61	39.59	2.71	3.16
To-040	Adult	Male	35 Years	6.38	11.64	-12.64	13.58	39.17	2.88	3.36
To-040	Adult	Male	25-35 years	6.38	11.57	-12.68	13.81	39.86	2.89	3.37
To-040 (Average)	Adult	Male	25-35 years	6.38	11.61	-12.66	13.69	39.51	2.89	3.37
To-041	Adult	Female	Unknown	8.1	11.37	-17.51	15.64	42.85	2.74	3.20

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-042 Ind 1A	Adult	Male	25 years	7.27	10.88	-15.28	13.94	41.51	2.98	3.47
To-042 Ind 1B	Adult	Male	25 years	10.99	11.23	-15.98	13.34	39.21	2.94	3.43
To-042 Ind 1A/1B (Average)	Adult	Male	25 years	9.13	11.05	-15.63	13.64	40.36	2.96	3.45
To-042 Ind 2A	Adult	Female	old adult	9.86	11.28	-15.35	14.95	41.89	2.80	3.27
To-042 Ind 2B	Adult	Female	old adult	11.6	11.61	-17.58	15.75	43.60	2.77	3.23

Sample ID	Adult/Juvenile	Sex	Age	%Collagen	$\delta^{15}N$ (‰, vs AIR)	$\delta^{13}C$ (‰, vs VPDB)	wt %N	wt %C	wt ratio C:N	atomic ratio C:N
To-042 Ind 2A/2B (Average)	Adult	Female	old adult	10.73	11.44	-16.46	15.35	42.75	2.79	3.25
To-043	Adult	Male	30 years	9.64	11.69	-18.05	15.72	42.75	2.72	3.17
To-043 Ind 1	Adult	Male	30 years	13.17	11.99	-15.71	15.11	42.62	2.82	3.29
To-043 Ind 2	Adult	Male	middle adult	10.36	12.12	-16.66	14.24	42.15	2.96	3.45
To-049 Ind 1	Adult	Male	30 years	0.93	15.25	-14.75	4.89	21.95	4.48	5.23

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