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Investigating Paleodiet and Mobility throughout Stable Isotope Analysis at the Site of Tumilaca La Chimba, Moquegua, Peru

Breidy Ivan Quispe Vilcahuaman

INVESTIGATING PALEODIET AND MOBILITY THROUGHOUT STABLE ISOTOPE ANALYSIS AT THE SITE OF TUMILACA LA CHIMBA, MOQUEGUA, PERU

by

BREIDY I QUISPE VILCAHUAMAN

Under the Direction of Bethany L. Turner, PhD

ABSTRACT

The late manifestation of Tiwanaku affiliated culture in the upper Moquegua valley is known as Tumilaca which is associated with the terminal Middle Horizon (A.D. 950-1250). However, after A.D. 1250 radical changes in residential space, material culture and mortuary practices are associated with the Estuquiña phase. This thesis study analyzes diet in archaeological human remains through carbon ($\delta^{13}C_{collagen}$ & $\delta^{13}C_{carbonate}$), nitrogen ($\delta^{15}N_{collagen}$), and oxygen ($\delta^{18}O_{carbonate}$) isotopic values between Tumilaca and Estuquiña groups at the site of Tumilaca la Chimba in the upper Moquegua valley. Carbon ($\delta^{13}C_{carbonate}$) and Oxygen ($\delta^{18}O_{carbonate}$) isotopic values indicated high consumption of C_3 plants and same local water consumption in both Tumilaca and Estuquiña populations. Meanwhile, Carbon and nitrogen isotope values ($\delta^{13}C_{collagen}$ vs. $\delta^{15}N_{collagen}$) evidenced low consumption of C_4 plants (maize) but high local terrestrial C_3 plants and animal meat sources. The low evidence of maize consumption in the upper Moquegua valley could be linked to Tiwanaku collapse.

INDEX WORDS: Diet, Isotopes, Tiwanaku, Maize, Post-collapse, Moquegua

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BREIDY I. QUISPE VILCAHUAMAN

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BREIDY I. QUISPE VILCAHUAMAN

Committee Chair: Bethany L. Turner

Committee: Nicola O. Sharratt
Frank L. Williams

Electronic Version Approved:

Office of Graduate Studies

College of Arts and Sciences

Georgia State University

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DEDICATION

The following thesis is dedicated to my parents: Epifanio Quispe and Sorayda Vilcahuaman. This thesis is also dedicated to those people who believed in me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

During the Middle Horizon (A.D. 500-1000), the Tiwanaku culture represented one of the largest states in the South-Central Andes. Centered in the Altiplano basin, the Tiwanaku state occupied territories in eastern Bolivia (Anderson 2009), northern Chile (Torres-Rouff et al. 2013) and southern Peru (Goldstein 2005). The Tiwanaku state in the Lake Titicaca basin began disintegrating around AD 1000 and ended up collapsing around AD 1100 (Albarracin-Jordan and Mattews 1990). The collapse of Tiwanaku in the core and its peripheries has been studied by a number of scholars to analyze socio-political and economic changes in the Tiwanaku core and colonies (Stanish 1997, 2003; Arkush 2006; Lumbreras 1974, Goldstein 2005). According to Janusek (2004), the city of Tiwanaku was home to between 10,000 to 20,000 inhabitants by AD 800; however, population declined after collapse altering social organization and economic activity. Causes of collapse in the heartland include paleoenvironmental changes, disruption of hydraulic resources, and cultural revolution (Ortloff and Kolata 1993; Janusek 2004; Goldstein 2005; Williams 2002).

Collapse in the Moquegua valley was characterized by rejection of state authority, destruction of state towns such as Omo M10 and Chen Chen, and rebellion against authority (Goldstein 2005). In the upper Moquegua valley, including at the site of Tumilaca la Chimba, the late manifestation of Tiwanaku materials is known as the Tumilaca phase which is associated with the terminal Middle Horizon (A.D. 950-1250) (Sharratt and Williams 2008). The terminal Middle Horizon corresponds with centuries called the early Late Intermediate Period elsewhere in the Andes (Covey 2008; Sharratt n.d.). Investigation at Tumilaca sites indicates association with Tiwanaku manifestation throughout pottery, residential architecture, burial practices, and biological features (Bawden 1993; Sharratt 2010; Sharratt 2015; Sharratt 2016; Sharratt et al. 2012; Sutter and Sharratt

2010). Circa AD. 1250, scholars noted changes in cultural patterns suggesting a new occupation in the upper Moquegua valley. This new occupation is known as the Estuquiña which is associated with the second half of the Late Intermediate Period (A.D. 1250-1470). Estuquina sites are characterized by hilltop locations, protective walls around sites, single-room circular domestic structures grouped on terraces, while authority and economic activity were locally focused (Stanish 1989; 1991). The origin of the Estuquiña groups and its association with the Tumilaca is still unclear. Based on residential architecture, Stanish (1989 in Sharratt 2017), tested whether or not the Estuquiña populations represented the enclaves of *Lupaqa* migrants from the Titicaca basin, concluding that Estuquiña architectures shared little affinities with the altiplano.

Investigations demonstrated that Tumilaca populations had cultural and biological continuity with Tiwanaku (Bawden 1993; Goldstein 2005; Sutter and Sharratt 2010); meanwhile, Estuquiña population differs in cultural manifestations from Tumilaca. Hence, the primary research question in this thesis is: are there differences in stable isotope values between the pre-AD 1250 Tiwanaku-derived occupation (Tumilaca) and the post-AD 1250 occupation (Estuquiña) at the site of Tumilaca la Chimba? Currently, Sharratt and Spencer (personal communication) suggest three principal models (abandonment, displacement, or assimilation) to understand the collapse of Tumilaca and origin of Estuquiña population in the upper valley. The model of abandonment would be supported by demonstrated by differences in cultural identities between Tumilaca and Estuquiña populations. These differences could be manifested in ceramics production, domestic space, architecture, burial practices and diet. The model of displacement would be supported by differences in cultural identities and genetic ancestry but temporal overlap occupation between Tumilaca and Estuquiña populations. Finally, the model of assimilation would be supported by cultural similarities, temporal occupations, and similar genetic features between Tumilaca and Estuquiña populations.

This thesis analyze human remains throughout stable isotope values to estimate paleodiet between Tumilaca phase (AD. 950 - 1250) and Estuquiña phase (AD. 1250-1470) at the site of Tumilaca la Chimba in the upper Moquegua valley.

1.1 Expected Results

Archaeological and isotopic analysis suggested that maize was the main food resource among the Tiwanaku colonies in the middle Moquegua valley (Goldstein 2005; Somerville et al. 2015). During Tiwanaku collapse, populations migrated to the upper Moquegua valley maintaining cultural affiliations rooted in Tiwanaku heritage. Investigations suggested that the new refugees, also known as Tumilaca populations, had cultural and biological affiliation with Tiwanaku colonies in the middle Moquegua valley (Sharratt 2011; Goldstein 2005; Sutter and Sharratt 2010). Meanwhile, the Estuquiña population does not display evidence of Tiwanaku cultural continuity (Clark 1993; Williams 1990).The analysis of human remains at the site of Tumilaca la Chimba indicated higher osteological stress markers in Tumilaca populations rather than Estuquiña people (Lowman 2017). The high evidence of osteological stresses among Tumilaca people could be linked with political fragmentation and collapse during the terminal Middle Horizon.

Thus, this thesis expects to find differences in stable isotope values between Tumilaca and Estuquiña populations at the site of Tumilaca la Chimba. More specifically, I hypothesize that the Tumilaca population consumed C_4 plants, mainly maize because of the cultural affiliation with Tiwanaku colonies in the middle valley. In contrast, I hypothesize that the Estuquiña people had a more mixed diet based on C_3 and C_4 plants and consumption of local animals due to political stability and interaction with other population in the upper Moquegua valley.

2 CULTURAL BACKGROUND

2.1. The South-Central Andes: Environmental Context

The South-central Andes region is divided into five major sub-regions: the *valles occidentales*, the Titicaca basin, the *altiplano* meridional, the *circumpunena* and the *valluna,* which are characterized by ecological zones, pervasive aridity, and unpredictability in resources and food (Molina and Little 1981 in Aldenderfer 1989). The ecology and climate of the South-Central Andes are highly variable due to the latitude and altitude of the region's geography (Winterhalder and Thomas, 1978). Scholars such as Cabrera (1968), Dollfus (1981), and Nunez (1983) identify five different types of habitats along the South-Central Andes. Meanwhile, Pulgar Vidal (1981) classified the Andes in eight major environmental zones which represented one of the first efforts to understand the Peruvian Andes in different macro zones. The coastal or *chala* zone in Peru and northern Chile is located below 500 meters above sea level (m.a.s.l.), characterized by having hot temperatures between 25-35C during the day. The agriculture is based on production of beans (*Phaseolus vulgaris L.*), squashes (*cucurbita pepo*), maize (*zea mays*), peanuts (*arachis hypogaea*), cotton and sugar cane (*Saccharum officinarum*) (Knudson 2009). Moreover, the coast and littoral, interfluvial desert coast and low transverse valleys and basins are characterized by having marine and terrestrial resources such as shellfish, fish, birds, marine mammals, llamas, guanaco and plants. Meanwhile, high transverse valleys and basins are known for having animals and plants such as guanaco, deer, and prosopis.

The mid-altitude *yungas* in the Peruvian Andes is located between 500-2300 m.a.s.l. which is characterized by more raining season than the coast (Pulgar vidal 1981 in Kudson 2009). The agriculture is based on the production and cultivation of maize (*zea mays*), coca (*erythroxylum coca*), aji peppers, and some fruits such as guayaba (*psidium guajava*), cherimoya (*annona cherimola*), and lucuma (*Genus species*). The high-altitude quechua and *suni* zones is located between 2300-3500 m.a.s.l. The quechua zone is characterized by cold and dry temperatures and the agriculture zones are used to produce tubers such as potatoes, maca (*lepidium meyenii*), oca (*oxalis tuberosa*), mashua (*tropaeolum tuberosum*), quinoa (*chenopodium quinoa*) and animals such as llamas, alpacas and guinea pigs (*cuy*) are common in the zone.

The puna or Altiplano is the highest region in the South-Central Andes which is sub-divided into four subtypes, including wet, dry, salt and suni. Moreover, the Altiplano is extended in countries such as southern Peru, western Bolivia, and northern Chile and Argentina with the highest altitude above 3,800-4,00 m.a.s.l. and stretched around 800 km north-to-south. The seasonal period in the *Altiplano* is characterized by a rainy season from December through March and dry and cold temperatures running from April to November. Today, agriculture is based on cultivating native tubers such as potatoes (*solanum tuberosum*), mashua (*tropaeolum tuberosum*), oca (*oxalis tuberosa*), and olluco (*ullucus tuberosus*) and collecting wild vegetation such as *ch'iji*, and *ichu*. Besides the domestication of potatoes along the Andes, people from the *Altiplano* domesticated the Andean camelids such as llamas and alpacas (Janusek, 2008). In order to preserve food throughout the year, people from the *Altiplano* basin developed complex techniques to modify fresh food into storable food; for example, freeze-dried potatoes known as *chuno* and sun-dried and salted llama-alpaca meat or *charqui*. Aquatic resources are provided by the Titicaca Lake throughout its 8,500 square kilometers between modern territories of Peru and Bolivia. Such resources include aquatic plants (*algae, lima and totoras*), waterfowls (ducks, geese, gulls and wrens) and native fishes (Janusek 2008).

2.2. The Tiwanaku State: Overview

The Tiwanaku state was the earliest expansive state in the south central Andes, expanding its sociopolitical, cultural and religious influence from its altiplano core into territories such as eastern Bolivia (Anderson 2009), northern Chile (Torres-Rouff et al. 2013) and southern Peru (Goldstein 2005). In the following, I draw on the chronology presented by Janusek (2008) for the Lake Titicaca basin to review the origin, expansion and collapse of the Tiwanaku state. During the Early-Middle Formative period (1500-200 BC), the first permanent settlements in the Lake Titicaca Basin were established. Subsistence relied on hunting, foraging and fishing. Dietary patterns included domesticated plants and animals. During the Middle Formative period small but complex cultures developed in the Titicaca basin. Local populations in the Titicaca Basin began engaging in long-distance trades. In the Late Formative Period 1 (200 BC-AD 250) ritual-political centers emerged after the Qaluyu cultural complex collapsed. For instance, the site of Pukara implemented new ceramic styles and metal technology, and local communities increased farming, herding and trading along the valley. During the Late Formative 2 (AD 250-500), new ritual political centers such as Chachachipata in Ccapia, Lukurmata in Katary valley and KalaUyumi were established, expanding trade networks and increasing farming activities among local people.

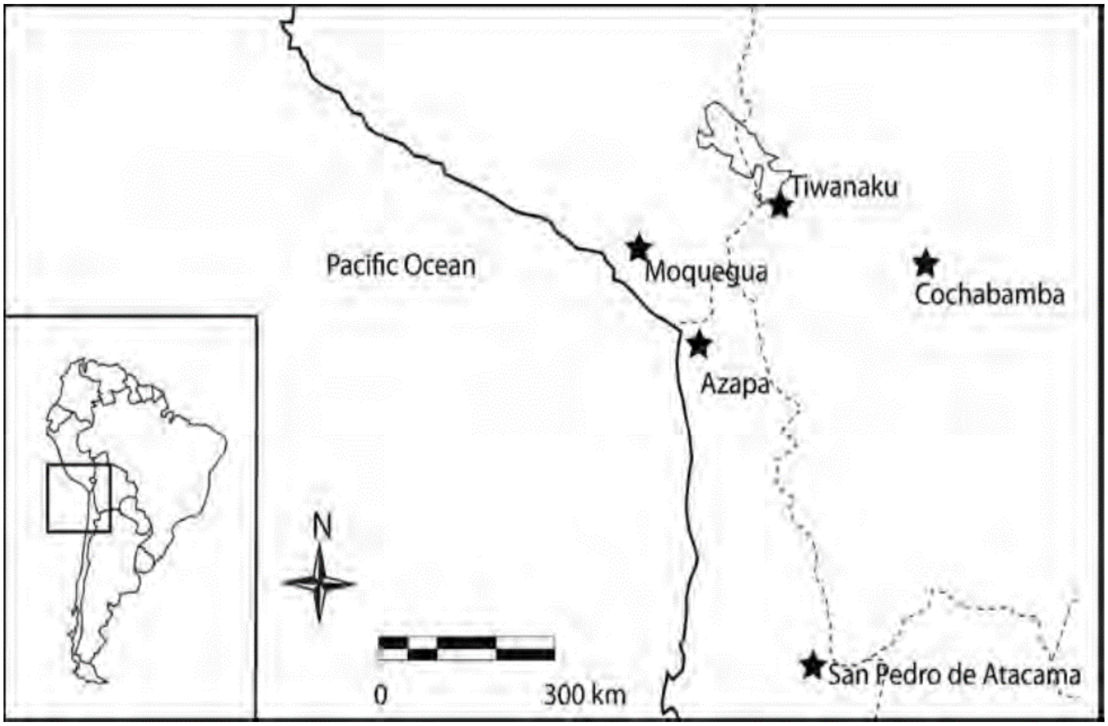


Figure 1. Map of the Tiwanaku core region and provinces (Sharratt 2016)

During the Middle Horizon (AD 500-1000), the Tiwanaku state dominated the Altiplano basin. State influence was based on cultural, political and ceremonial interactions among regions and communities, rather than military interventions. Famous for its architecture, stone sculptures and craft artifacts, the Tiwanaku state expanded into territories in the north of Bolivia (Anderson 2013), San Pedro de Atacama in Chile (Torres-Rouff 2008), and the Moquegua Valley in the southern Peruvian Andes (Goldstein 1989).

There is debate over the population size of Tiwanaku sites. For example, Parson (1968) suggested that the capital city of Tiwanaku was home to a population of 20,000 along 2.4 square kilometers; meanwhile, Ponce (1981 in Janusek 2004) argued that Tiwanaku reached a population of 9,750 – 46,800 per square kilometers. Janusek (2004) suggested that Tiwanaku housed between 10,000 to 20,000 inhabitants by AD 800, and recent demography studies suggested that the urban population in Tiwanaku was less than 7,700 people (Bandy 2013)

Building on earlier chronologies, Janusek (2008), divided the Tiwanaku period into two different phases: Tiwanaku 1 and Tiwanaku 2. Tiwanaku 1 (AD 500-800) was characterized by urban expansion and sociopolitical development. Local people begin making their own ceramic vessels for household use, farmers intensified agricultural production, domesticated animals such as llamas were used as transport, meat, wool and in ritual practices, and urban centers were distinguished with social status, occupation, and ethnicity. Tiwanaku 2 (AD 800-1100) saw consolidation of sociopolitical, economic, and ideological influence through the state's territory and peripheral regions. Expansion into the Moquegua valley was likely motivated by resource acquisition and the province produced and exported maize for consumption and for ritual practices in the Altiplano basin. At the state capital, elite residences such as Putuni were enlarged and converted into palaces and Lukurmata located in the Katari valley pampa was a raised-field farming state (Janusek 2008).

However, one of the most controversial processes in the South-Central Andes is the collapse of the Tiwanaku state in the core and peripheries around AD. 1000. Many hypotheses to explain why collapse occurred have been proposed based on environmental changes (Ortloff and Kolata 1993; Moseley 1997), ethnographic and linguistic studies (Torero 1987), competing polities (Williams 2002) and cultural revolution (Janusek 2004). For instance, Ortloff and Kolata (1993) propose that widespread drought undermined the state's agricultural productivity which ultimately led to its political failure. Goldstein (2005) argued that a crisis of civic faith was the cause of Tiwanaku political collapse in the Moquegua province. Bermann (1989:270) argued that the decline of the Tiwanaku state in the core and provinces was a long process which involved a gradual, but temporally and geographically uneven, decline in geo-political control throughout the heartland and peripheries. In fact, the Tiwanaku collapse in the core and provinces was a long-term process which involved political fragmentation, a crisis of civic faith between people and elites, rejection of selected iconographies in ceramics and textiles, reorganization of settlements, and new cultural manifestations.

In the next section I discuss the early evidence for human occupation in the Moquegua valley, the Formative period (1750 BC-AD 600), the Middle Horizon (A.D. 500-1000), the Tiwanaku colonies during the Middle Horizon and the Tiwanaku collapse (A.D. 1000)

2.3. The Moquegua Valley

The Osmore drainage, also known as the Moquegua valley, is located in the Peruvian South-Central Andes and covers a range of climates in its 3,480 square kilometers. Rice (1989 in Owen 2005) distinguished the Osmore valley into three different sub-valleys descending from the highlands toward the coastal area in the port of Ilo (Figure 2). The upper valley includes the Huaracane, Torata and Tumilaca rivers, from the puna to about 1600 m.a.s.l. with some agricultural limitations; the middle valley is broad and flat with warmer temperatures and larger concentrations of farmland including altitudinal zones of 1600 m.a.s.l. to about 900 m.a.s.l. there is about a 60 km long of the lower valley that is uninhabitable because the river goes underground. The coastal valley is about 25 km long and descends from around 325 m.a.s.l. to the ocean.

The Moquegua valley has been inhabited by people since the early Archaic period (800-1000 BC) when it was occupied by hunter-gather societies. There is evidence for early human settlement in the Moquegua valley at archaeological sites in the lower altitude coastal regions and the Moquegua highlands. On the coast, sites were established in places such as *Sitio Anillo* and *Quebrada Tacahuay*, where prehistoric populations consumed more marine foods, such as fishes and mollusks (Chacaltana 2014) than terrestrial resources. Meanwhile in the highlands, the earliest identified human settlement is at the site of Asana (Aldenderfer 1989).

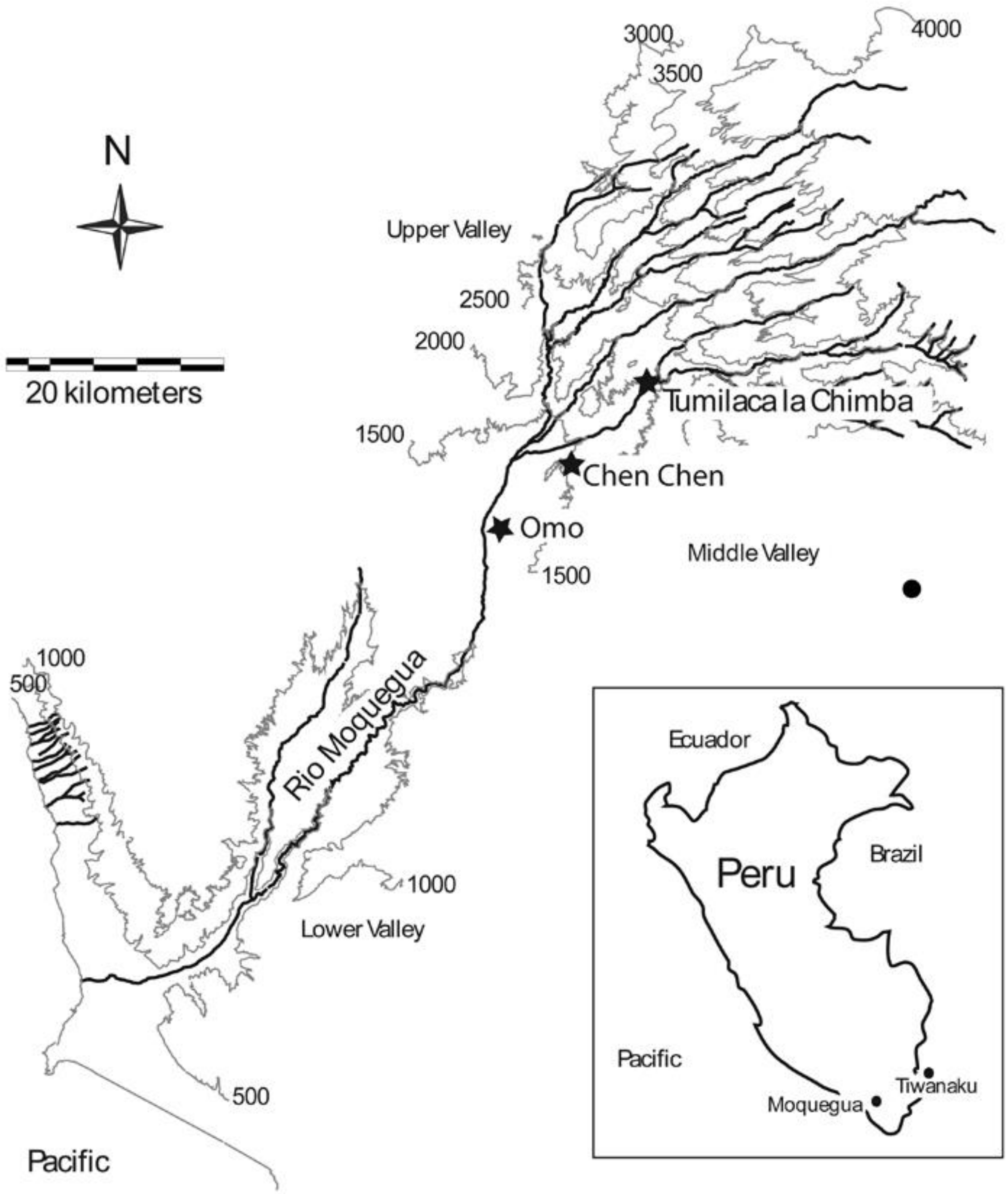


Figure 2. Map of the Moquegua Valley (after Sharratt 2012)

In the Formative period (1750 BC-AD 600), the Moquegua valley was inhabited by people who lived in small settlements with some evidence for agriculture, as well as for economic and cultural interactions with people from the Altiplano basin. The earliest evidence for agricultural settlements in the Moquegua Valley is at the Huaracane site, which was inhabited around 800 BC (Costion 2009; Goldstein 2005; Sutter & Sharratt 2010). According to Costion (2009), the Huaracane culture may have had some contact with the Wari state settled in the upper valley and with Tiwanaku communities located in the lower and middle valley of Moquegua. Owen (1993 in Sutter & Sharrat 2010) argued that Huaracane people were descended from an early formative culture who inhabited in the Moquegua valley.

During the Middle Horizon (A.D. 500-1000), the Moquegua valley is the only known place in the South-Central Andes where the southern highland Wari and the Altiplano Tiwanaku states both established outposts. The Wari state occupied the upper valley circa AD 550 for political and defensive purposes (Williams 2001; Costion 2009). The major Wari sites such as Cerro Baúl and Cerro Mejia were located in the upper valley connected by extensive water canal systems, unlike Cerro Trapiche located in the middle valley. According to Williams and Nash (2002), the Wari state occupied the upper Moquegua Valley in two different phases. The initial occupation was around AD 550-800 with no interaction with Tiwanaku colonies and the second phase dated to AD 800 to the early 13th century with evidence of interaction between Wari and Tiwanaku colonies (Williams 2012). According to Moseley and colleagues (2005), Cerro Baúl was abandoned by AD 1200 and involved violence and destruction of the main monuments.

Unlike the Wari influence in the upper Moquegua valley, the Tiwanaku State occupied the most productive maize-growing zone in the middle valley (Goldstein 2005). Early investigation into Tiwanaku occupation in the Moquegua valley suggested that the Tiwanaku occupied the Moquegua valley in two different immigration waves: the earliest Tiwanaku occupation known as the Omo phase (AD. 538 – AD. 648) and the Chen Chen phase (AD. 725 – AD. 950) characterized by more political and economic control from the Tiwanaku core (Goldstein 1989). However, new archaeological evidence suggests that both Omo and Chen Chen styles coexisted in the time period but with different manifestations (Goldstein 2005). For instance, Williams (2002) argued that the Omo site complex was characterized for being a politico-religious center and Chen Chen site for being demographic-economic center.

The Omo style settlements (M12, M13, M16) in the middle valley are located on top of bluffs which were associated with pastoralism. According to Goldstein (1989:231), most of the residential areas are wind deflated but houses at Omo style sites consisted of between two and eight rectangular rooms. The Omo-style ceramics consisted of utilitarian plainwares and two fine ware categories such as red-slipped and black polished fine serving wares (Goldstein 1989). According to Goldstein (2005), Omo-style black ware ceramics are more similar to those from Copacabana peninsula and Eastern slope of Bolivia. Other artifacts found at Omo style sites include narrow, stemmed, and triangular projectile points which are related to the Tiwanaku culture due to similarities in form and design. Archaeobotanical and faunal remains found at Omo style sites suggested a local diet based on maize, beans, pumpkins and squashes with less consumption of quinoa, tubers and hot peppers (Goldstein 2005).

The Chen Chen style was characterized by greater political and economic control from the Tiwanaku core. Investigations suggested that the Tiwanaku state established its colony in Moquegua due to the vast agricultural resources and connection with other cultures settled in the coastal site (Costion 2009). The Chen Chen settlements consisted of open patios, storage units and roofed rooms, which are characterized by having stone hoes and large rocker *batanes.* Moreover, the Chen Chen style settlements were characterized by extensive canal systems along the middle valley with large bustling towns of rectangular cane-walled houses (Goldstein 1989; 2005). Organic and botanical remains found in Chen Chen sites indicate an emphasis on agriculture in their economy. Macro-botanical remains found during excavation was primarily maize cobs, kernels, and husks. Moreover, household food consumption in the Chen Chen sites featureda high consumption of beans, gourds, pacae pods, *lucuma*, peanuts, *quinoa*, potato, *oca* and *chuno* (freeze-dried potatoes), camelid meat, cottonseed and different plant remains (Goldstein 2005:216). Meanwhile marine resource remains such as fish and shellfish indicate a contact and economic trade between Chen Chen populations and coastal cultures.

Chen Chen-style ceramics tend to exhibit standardized decoration characterized by lower firing temperatures, less surface burnishing, and lighter range of red surface slip color (Goldstein 2005). Moreover, the Chen Chen-style ceramic was similar to the Altiplano heartland though with differences in ceramic technology, form and decoration. Lechtman and Macfarlane (2005 in Stanish 2010) argued that Tiwanaku colonies in Moquegua replicated the ceramic style, household forms, and metal artifacts from the Altiplano heartland. Sharratt et al. (2015), analyzed state period and post-collapse Tiwanaku ceramics in the Moquegua valley throughout Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). The study noted largely local ceramic production during the state period but also noted that 10% of the analyzed sample was non-local.

Mortuary practices at Chen Chen site are well preserved and provide a better understanding of burials (Blom 1998; Blom 2000; Pari Flores 2002; Sharratt 2011; Vargas 1994). For instance, Chen Chen phase buried their people wearing sleeveless tunics of a fine to medium warp-face plainweave (Goldstein 1989:74). Furthermore, textiles at Chen Chen include camelid wool fabrics, fine plainweave cotton textile fragments, spun cotton yarn and unspun fibers including six colors such as green and blue. Other artifacts included flat handled wooden spoons, wooden *kero*, *tazones*, bone tubes and larger *batanes*.

2.4. Tiwanaku Collapse in Moquegua

Collapse in early complex societies is defined by Schwartz (2006) as the fragmentation of states into smaller political entities; the partial abandonment or complete desertion of urban centers, along with the loss or depletion of their centralizing functions; the breakdown of regional economic systems; and the failure of civilizational ideologies. In Moquegua, factors such as the control of water resources, social vulnerability, political instability and climate changes played a vital role in the political collapse of the Tiwanaku colony. Challenging the idea that widespread drought caused Tiwanaku political fragmentation, Williams (2002) argued that local factions mobilized against the core in response to the economic interdependence, mainly the exportation of maize toward the Altiplano. Meanwhile, Wari hydraulic practices played a fundamental role to decreased water availability in the middle Moquegua valley which undermined Tiwanaku agricultural production there (Williams 2002)

Moreover, several major characteristics marked the Tiwanaku collapse among their main colonies. For example, people rejected some selected Tiwanaku decorative motifs in ceramics, textiles and wooden objects (Ponce 1972 in Bermann et al.1989; Goldstein 1985; Owen 2005; Sharratt 2016). Additionally, the intensive productive agricultural system was replaced by hillside terrace systems, and the two major Tiwanaku settlements, Chen Chen and Omo M10, were largely abandoned and people dispersed and migrated to the lower middle valley and uninhabited upper regions causing a demographic decline (Sutter and Sharratt 2010).

In the Moquegua upper valley, the late manifestation of the Tiwanaku state has been termed Tumilaca which is associated with the Terminal Middle Horizon (A.D. 950-1250) (Owen 2005; Sharratt n.d.; Sharratt et al. 2008). Scholars describe the imitation of ceramics from Tiwanaku colonies in the Moquegua valley as “Tumilaca style”. Investigations into the Tumilaca phase demonstrate cultural affiliation with Chen Chen style (Bawden 1993; Bermann 1989; Goldstein 2005; Goldstein & Owen 2001; Owen 1994; Owen 2005; Owen & Goldstein 2001; Sharratt 2010; 2011; 2012; 2015; 2016a; 2016b).

Tumilaca phase settlements are often in less accessible locations than earlier Tiwanaku sites, and some have boundary walls around them. Residential architecture largely replicates earlier Tiwanaku patterns (Bawden 1993; Sharratt 2015). In coastal Osmore areas, Tumilaca settlers (locally called Ilo-Tumilaca) maintained their cultural traditions, rather than only adopting new traditions from local people (Owen 1993). In the middle valley of Moquegua, Tumilaca settlements were characterized by building smaller, dispersed and defendable sites that lack the monumental architecture of the earlier Tiwanaku sites but maintained the same *quincha* cane construction as their predecessors for domestic architecture (Goldstein 2005). In the upper valley, the Tumilaca populations established new settlements at the Tumilaca la Chimba site, characterized by having protective walls around the residential areas. Non-residential architecture has been identified at one Tumilaca site in the upper valley (Sharratt 2016).

Tumilaca phase ceramic styles are similar in to Chen Chen styles. Specifically, they are characterized by similar vessel forms and many decorative elements but lack some elite affiliated motifs (Goldstein 1985; Goldstein 2005; Sharratt 2016). Goldstein (2005) identified at least three distinct geographic foci of ceramic production in the Moquegua valley. For instance, the upper valley shared similar ceramic styles, communities in the middle Moquegua valley tended to produce oversized *keros* with variability in base slips and the coastal Osmore valley tended to have nubbed-rim *keros* in different shapes.

Sharratt et al. (2012) report on the mortuary practices at the Tumilaca la Chimba site focusing on grave architecture, interment treatment and grave goods in order to compare the results with earlier colonies in Moquegua valley. The results indicated that mortuary practices at Tumilaca la Chimba were a combination of traditional Tiwanaku colonies and new mortuary behavior practices (Sharratt 2011). Regarding the interment treatment of individuals, Sharratt et al. (2012:201) noted that individuals were buried in a seated flexed position facing east, wrapped in similar textiles with the body held in place with fiber rope.

2.5. Late Intermediate Period in the Moquegua Valley

After three centuries of sociopolitical domination by the Tiwanaku state in the middle and upper Moquegua valley, followed by at least two centuries of cultural continuity in the wake of Tiwanaku collapse there are radical changes in the valley's archaeological record in residential space, material culture and mortuary practices. Local populations were differentiated by living on hilltops sites, with agglutinated rooms, adoption of above-ground *chullpa* burials, and wall protections (Goldstein 2005, Sharratt 2017, Stanish 2012). This new cultural presence in the upper Moquegua valley is called Estuquiña and is associated with the second half of the Late Intermediate Period (A.D. 1250-1500). Estuquiña settlements have also been identified in the middle valley but with less presence (Burgi 1989, Conrad 1993).

The origin of the Estuquiña group remains debated. Using residential architecture, Stanish (1989 in Sharratt 2017) tested whether or not the Estuquiña populations represented the enclaves of *Lupaqa* migrants from the Titicaca basin. The results indicated that Estuquiña architecture shared little affinities with LIP architecture in Titicaca basin. Other scholars highlight similarities in agricultural technology and ceramic forms similarity between Estuquiña and Wari state to argue that the Estuquiña group were descended from the Wari (Goldstein 2005, Williams 2002).

Estuquiña settlements are characterized by protective walls around sites and agglutinated domestic areas (Bawden 1993). Stanish (1989) argued that the Estuquiña phase emerged in the upper Osmore drainage with uniform settlement types characterized by protectable and fortified sites, extending toward the middle Moquegua valley and neighboring Tambo drainage. Chacaltana (2010) notes that the Estuquiña culture in the upper valley was characterized by separate houses located in upper valleys surrounded by protective walls. Whereas, Sharratt (2012) notes that at the site of Tumilaca la Chimba Estuquiña walls and residential structures are larger than in Tumilaca phase architecture.

The ceramics of the Estuquiña phase were first studied by Lozada (1987) drawing on an assemblage excavated from mortuary contexts at the Estuquiña type site in the middle Moquegua valley. Although the ceramics analyzed were from mortuary contexts, the analysis revealed low quality in the elaboration of the vessels, possibly suggesting lack of specialization in the manufacture of pottery by this Estuquiña population. Stanish (1989) notes the presence of Sillustani and Gentilar vessels at some Estuquiña sites; in this regard, Lozada (1987) indicated that the Estuquiña culture had cultural affiliation not only with contemporary coastal neighbors but also with the Inka culture. Bawden (1989) notes that Estuquiña ceramic assemblages are largely characterized by shallow bowls and boot-pots. They are also characterized by a general absence of decorated wares, the pastes of bowls are dark reddish gray and pink and the surface is burnished, red slipped and has a narrow black line (Stanish 1991).

Household activity and dietary patterns have received less attention during the Late Intermediate period in the upper Moquegua valley. Previous investigations indicated that during the Middle Horizon (A.D. 500-1000), Tiwanaku colonies had primarily a diet based on maize and its derivatives with complementary products such as beans, quinoa, gourds, tubers, pumpkins, squashes and peppers (Goldstein 2005:320). During the terminal Middle Horizon (A.D. 950-1250), the Tumilaca population consumed more local products due to the collapse of the economy and breakdown of trade with the Altiplano basin. Thus, the Tumilaca group could have had a more homogeneous and reduced diet based on the consumption of maize and higher frequency of guinea pig (cuy) but less access to foreign products such as shellfish, agricultural stones and llama remains (Goldstein 2005).

Parker and Sharratt (2017) analyzed microartifacts from Tumilaca and Estuquiña occupations to determine differences in household activities between the two populations. The results suggested that the Estuquiña population had more dietary diversity than Tumilaca populations. This suggests that Estuquiña populations had more access to marine and highland resources than Tumilaca population characterized by having a local and restricted domestic economy. The microartifact data also suggested that Estuquiña people consumed more guinea pigs (*cuy*) and maize beer (*Chicha*) than Tumilaca people. Finally, the data included *molle* seeds in Estuquiña domestic structures which could be evidence that *Chicha de molle* was brewed by the Estuquiña people. Chacaltana (2010) argued that Estuquiña populations developed a local and small economy cultivating maize, chilli pepper (*aji*), *quinoa* and consuming guinea pig (*cuy*) and camelids.

Excavations at the Estuquiña type site reveled differences in mortuary activities (Burgi 1989). For instance, Van Buren and colleagues (1989) studied the mortuary treatments of fifty-nine intact tombs among two hundred thirty-one tombs at the Estuquiña site, located in the middle Moquegua valley. The study concluded that the Estuquiña mortuary practices were structurally homogeneous with little difference in social status among the burials. Unlike the Tiwanaku colonies in Moquegua, the Estuquiña phase implemented above-ground mortuary towers or *Chullpas* which are common in cultures from the Late Intermediate Period. Moreover, excavations at the Estuquiña type site noted that human remains were found within and outside residential occupation rather than a designated cemetery as seen in Tiwanaku affiliated materials (Williams 1990).

2.6. Diet and Subsistence in the Moquegua Valley

The Moquegua valley was inhabited by the Huaracane tradition before the occupation of the Tiwanaku and Wari state (Costion 2013). Botanical and isotopic evidence related to diet and subsistence indicated the Huaracana people consumed more C_3 plants and marine resources rather than maize and C_4 plants (Sandness 1992). Goldstein (2005:311) argued that the first

Tiwanaku colonists in the Moquegua valley arrived as pastoralists, following a longer tradition of transhumance by highland camelid herders.

During the Middle Horizon (AD. 500-1000), a number of studies have focused on local subsistence, diet and understanding the complex association between the heartland in the Altiplano and the Tiwanaku colonies in Moquegua valley. Besides the cultivation, consumption and exportation of maize to the Altiplano highlands, paleonutrition among Tiwanaku colonies is still unclear. Based on botanical and faunal remains, Goldstein (2005) argued that Tiwanaku colonies consumed beans, quinoa, tubers, gourds, tubers, pumpkins, squashes, peppers, pacae, and peanuts with less evidence of camelids and limited access to marine resources. Sayre et al. (2012) used archaeological data and ethnographic material to analyze the role of *molle* beverage and its potential role at the site of Cerro Baul. The research found higher *molle* seeds in elite residential units which could be associated with status and identity among the Wari state.

Consumption of fermented beverage was also reported in Moseley et al. (2005). According to the authors, the consumption of *chicha molle*, prickly pear fruit, coca, and tobacco were exclusive to the Wari elite settled at Cerro Baúl. Moreover, based on zooarchaeological debris at the site of Cerro Baúl, Moseley et al. (2005) reported large and small camelids, guinea pigs, and other smalls animals remains such as vizcacha, deer, tinamous, doves, pigeons and bony fishes. Goldstein et al. (2008) argued that maize was not the primary product consumed at Cerro Baúl because corn remains, including a few cobs, represented less than 1% of the total ethnobotanical assemblage. Instead, *molle* tree played a significant role among people at Cerro Baúl. The substantial evidence of *molle* seeds in the site of Cerro Baúl would have indicated the importance of *molle* not only as a fermented beverage, but also as ethnic identity, cuisine, and social status (Goldstein et al. 2008).

In contrast, Tiwanaku colonies located in the middle Moquegua valley cultivated and exported maize as a principal product of subsistence (Goldstein 2005). During the Middle Horizon (AD. 500-1000), the middle Moquegua valley represented the main center of maize production and exportation toward the Altiplano. For example, Somerville et al. (2015) analyzed the Carbon and Nitrogen isotopic values at the sites of Rio Muerto and Omo in the middle Moquegua valley. The results indicated that Tiwanaku colonies were mainly terrestrial omnivores, consuming a mix of C_3 and C_4 plants, with a low frequency of marine resources.

During collapse (around A.D.1000), the leading Tiwanaku sites were destroyed, burials were looted, and Tiwanaku gods were rejected (Goldstein 2005). As a consequence of political fragmentation in the Moquegua valley, daily life was altered, and local people migrated to the upper valley establishing new settlements known as Tumilaca phase (AD. 950-1250) (Goldstein 2005; Sharratt 2011). According to Goldstein (2005), the economy of the Tumilaca population was disturbed, and people responded by increasing the consumption of local resources rather than exporting and importing products from the Altiplano. During Tumilaca occupation in the upper Moquegua valley, Goldstein (2005) noted higher frequency of guinea pig remains (*cuy*) but lower frequency of shellfish, agricultural grinding stones and llama remains. Meanwhile, Sharratt (2011) argued that refugee communities in the upper Moquegua valley maintained the same subsistence as Tiwanaku colonies with a reliance on maize and quinoa and some evidence of guinea pig and camelids.

Collapse and state fragmentation also impacted health status and nutrition in refugees. For instance, Starbird et al. 2010 (in Sharratt 2011) reported higher evidence of criba orbitaria, porotic hyperostosis, and skeletal lesions among Tumilaca people than Chen Chen populations. Additionally, Lowman (2017) reported higher incidence of criba orbitaria, trauma and endocranial lesions among Tumilaca populations, whereas linear hypoplasia, vertebral arthritis, and caries were higher in Estuquiña people.

Macrobotanical remains reported by Goldstein (in Sharratt 2011:579) also analyzed botanical data found at the site of Tumilaca la Chimba. For example, species of plants such as asteraceae, amaranthaceae, chenopodiaceae, mavaceae, poaceae, solanaceae and verbenaceae were found in the site of Tumilaca. Moreover, a few cultivated and domesticated plant remains such as arracacha, cotton, Guayaba and maize were recovered in very low numbers. Briefly, Chacaltana (2014) argued that the Estuquiña population cultivated products such as maize, chili pepper and quinoa. Likewise, the Tumilaca people consumed guinea pigs (cuy) and camelids such as llama and alpaca.

3 METHODS FOR RECONSTRUCTINIG DIET

Archaeology is a destructive science in which trained people have to use methods and techniques very carefully to recovery organic and inorganic material that will be useful to reconstruct not only socio-cultural patterns but also biological profiles. In bioarchaeology, the reconstruction of paleonutrition throughout the analysis of direct data has been improved using better macro and micro methods. Sutton and colleagues (2010) classified direct data in two categories: (1) the study of human remains (skeletal / dental pathological condition and biochemistry) and (2) the study of human paleofeces. Meanwhile, indirect data are those data that were available or utilized during food preparation.

3.1. Indirect Data

Indirect method is broadly classified as visible flora and fauna remains, chemical remains, technological remains, available resources (whether they were actually consumed or not), and evidence regarding the use of landscape (Sutton et al. 2010). Unlike direct methods, indirect data can only infer human consumption through the use of food, artifacts and other archaeological materials. Faunal remains, botanical remains, biomolecular remains, and inorganic remains including stable isotope analysis, trace element analysis, and soil chemistry analysis are examples of indirect data

3.1.1. Faunal Remains

The study of ancient animal remains is widely used to reconstruct human subsistence, paleoecology and biogeography (Sutton et al. 2010). Zooarchaeologists tend to focus mainly on animal remains and shell, but also soft tissues, blood, proteins, and chitin are important to estimate human paleonutrition. Moreover, animal remains may help to understand secondary questions such as division of labor (gender and age related), transportation, and ceremonies.

Ancient animals commonly found in archaeological sites are composed of vertebrate animals such as fish, amphibians, reptiles, birds and mammals which can be distinguished based on geographical origins and ecosystems (marine, terrestrial). Invertebrates animals uncommon in inland archaeological sites are also analyzed and can provide useful information regarding human paleodiet; for example, shellfish, crabs, lobsters, and shrimp can also provide information about paleodiet.

3.1.2. Botanical Remains

Human beings used plants mostly for consumption and subsistence but also secondary purposes including shelter, bedding, textiles, cordage, firewood, traditional medicine, and ritual practices (Sutton et al. 2010:73). In archaeology, botanical remains can be classified as macrobotanical remains which include tubers, seeds, and charcoal. Whereas, microbotanical remains are plants residuals seen only with the aid of technology. Pollen and phytoliths are mostly used by researchers, but preserved plant cuticles and starch grain analysis can also provide valuable information regarding paleodiet.

3.1.3. Skeletal and Dental Pathological Conditions

Bioarchaelogists have focus their studies in the analysis of human remains which include bones, teeth, soft tissues, hair and chemical remains depending on geographical conditions where the remains were buried. Most dental and pathological conditions seen in human remains are result of congenital malformation, disease, trauma, deformation and nutritional deficiencies (Sutton et al. 2010). However, the analysis of paleonutrition is focused mainly on nutritional deficiency which include porotic hyperostosis, criba orbitalia, scurvy, rickets, osteomalacia, growth stunting (linear enamel hypoplasias, harris lines). For instance, vitamin D in human bone is important to stimulate the absorption of calcium from the gut and prevent osteoporosis, fractures and osteomalacia. However, the lack of vitamin D may cause rickets in juvenile skeletons and osteomalacia in adults (Mays et al. 2006; Brickey et al. 2005).

Moreover, porotic hyperostosis and criba orbitalia are two of the most common pathological conditions seen in archaeological collections, frequently related to malnutrition, genetic traits and hereditary hemolytic anemia. Porotic hyperostosis and criba orbitalia are osseous responses to iron-deficiency anemia which is characterized by areas of pitting and porosity on the external surface of the cranial vault and orbital roofs (Walker et al. 2009). Goodman (2017:190), defines porotic hyperostosis as lesions on the cranium, the roof of the eye orbits and the ends of long bones. Anemia (without blood) is caused by blood loss, impaired erythropoiesis and increased hemolysis (Walker et al. 2009:110).

Early studies suggested that porotic hyperostosis and criba orbitalia are associated with maize consumption because maize is low in iron; besides, populations living in lower areas and closer to the ocean tend to have high prevalence of anemia because the high phosphoric content of marine food (Cybulski 1977 in Blom et at. 2005:164). However, Blom and colleagues (2005) studied anemia and childhood mortality along the Peruvian coast to analyze whether or not anemia was associated with maize and marine consumption among prehispanic Peruvians. Their results indicated that the distribution of criba orbitalia does not support the hypothesis that marine or maize-based diets are associated with childhood anemia.

Recent research (Rivera & Mirazon 2017) analyzed whether criba orbitalia and porotic hyperostosis tend to represent the same pathological conditions and result from the same type of anemia. They found that porotic hyperostosis tended to develop from a different type of anemia than criba orbitalia. Moreover, the study found that criba orbitalia may be associated with anemias that lead to diploic bone hypocellularity and hypoplasia; meanwhile, porotic hyperostosis could be linked to anemias that lead to bone marrow hypercellularity and hyperplasia. Therefore, criba orbitalia and porotic hyperostosis terminology have to be used based on the type of anemia.

Harris lines (HL) are an indicator of disease or malnutrition, particularly in juvenile remains, and reflect the nutritional stresses of childhood. HL are caused by bone-growth arrest forming thinner and denser bone mineralization as a reaction of nutritional stress and/or disease which is more common in long bones including the femur, tibia, and radius. HL are also more accurate in children than in adults because of the remodeling of bone; for example, Mays (1995 in Sutton et al. 2010) reported that Harris lines and other nutritional indicators were more accurate in medieval populations located in England.

Linear enamel hypoplasias (LEH) in teeth are another paleonutritional indicator widely investigated in biological anthropology. Suckling 1989 (in Goodman 2017:188) argued that LEH are a class of developmental enamel defects visibly recognizable as transverse or linear deficiencies in enamel thickness. The main causes of enamel defects are nutritional insufficiencies, drug toxicities and diseases that disturb the enamel's development. Whereas, Goodman and Armelagos (1985) argued that the main causes of LEH are localized trauma, heredity or systemic metabolic disruption during the growth of teeth. Moreover, researches have demonstrated that LEH is related to malnutrition, with higher rates in developing countries (Goodman 2017). Goodman and colleagues (1987 in Goodman 2017:189) found one or more hypoplasia on 46.7 % of the 300 children analyzed, which could be related to malnutrition and infectious diseases in weaning periods.

3.2. Direct Methods

Direct data represent those remains where no inference is necessary (Sutton et al. 2010). In bioarchaeology, dental indicators and stable isotope analysis are common methods to estimate paleodiet from ancient populations. In the next paragraph, I will discuss the application two of the most common methods to reconstruct paleodiet: (1) dental indicators and (2) biogeochemical analysis.

3.2.1. Paleodiet: Dental Indicators

Since the first publication in dental microwear (Dahlberg & Kinzey 1962 in Ungar et al., 2008), many biological anthropologists have used changes and modifications of the enamel and dentine due to food consumption and occupational wear to infer diet and nutritional subsistence patterns. Dental microwear is the study of microscopic patterns of use-wear on teeth which modify the surface of the enamel crown through physical features such as pits and scratches (Ungar et al. 2008). The main focus of the analysis of dental microwear are dental features left mainly in the molars caused by food consumption, the use of the tooth as a tool, and bruxism. The two main features analyzed in dental microwear are pits and scratches. Pits are identified as having circular indentations in the enamel; meanwhile, scratches are lineal features in the teeth enamel. According to Turner and Livengood (2017:168), pits are classified as large, small, or puncture, while scratches are classified as fine, coarse, or hypercoarse.

Currently, the standardization of methods applied in dental microwear analysis are being discussed and debated by bioanthropologists (Ungar et al. 2008). In the past, dental microwear analysis focused on hominids using low-magnification stereomicroscopy, whereas today bioarchaeologists are interested in inferring diet and nutritional status from dental microwear through new technologies and equipment such as the scanning electron microscopy (SEM) developed by Gordon (1988) and Teaford & Walker (1984). In bioarchaeology, dental microwear analysis has been used to infer how maize affects microwear features, support isotope studies, and distinguish between meat and plant consumption and food preparation techniques (Turner & Livengood 2017). For instance, Organ et al. (2005) analyzed dental microwear of occlusal surfaces of maxillary molars in the archaeological site of San Luis de Apalache, Florida. The results reveal that the frequency of pitting on the molar surface is higher than other populations, meaning that people from San Luis de Apalache had a different diet than other Native American people in Florida. However, dental microwear analysis is very limited in bioarchaeology; it has been most widely used to reconstruct the diet of living and extinct primates and fossil hominins (Turner & Livengood 2017:161).

3.2.2. Biogeochemical Approaches to Paleodiet

The application of stable isotopes in reconstructing paleodiet of prehistoric populations has played a very important role in bioarchaeology during the last 40 years. Biochemical analyses have been used to reconstruct the diet of ancient populations since the late 1970s. Anthropologists such as Vogel and van der Merwe (1977) and DeNiro and Epstein (1978) conducted stable isotope analyses of controlled feeding experiments in order to understand the isotopic values of foods eaten by animals and plants and their relationship with the environment. Currently, anthropologists reconstruct the diet of ancient populations not only to estimate paleodiet, but also to understand cultural processes such as instability, social upheaval, and violence (Turner et al. 2012).

Isotopes are variants of an element such as carbon, nitrogen, or oxygen with the same number of protons and electrons but different numbers of neutrons (Tykot 2004). Though ^{14}C

isotopes are unstable because of radioactive decay over time, isotopes such as ^{12}C and ^{13}C are stable and can be used to reconstruct the paleodiet in ancient populations.

The relationship between carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic values and diet can be interpreted as "you are what you eat," with some physiological exceptions (Tykot 2004; D'Ortenzio et al. 2015). Carbohydrates, proteins, and lipids are organic molecules metabolized by all organisms, and the molecular levels of these in wild and domestic animals vary according to their consumption of plants (marine vs. terrestrial) and other animals in different environmental conditions. As humans migrated, they consumed animals, fruits, and plants in different environmental conditions which were metabolized into their living tissues and preserved in their bones, teeth, and hair. This is why the use of biogeochemical isotopic values from prehistoric human tissues assists bioanthropologists in estimation and reconstruction of dietary patterns and subsistence, to understand not only paleodiet indicators, but also socioeconomic patterns among ancient populations.

3.2.2.1. Carbon Stable Isotope ($\delta^{13}C$)

The carbon cycle is an important process through which carbon moves through biotic systems. Carbon dioxide in the atmosphere is incorporated into terrestrial plants through photosynthesis ($6CO_2+6H_2O=C_2H_{12}O_6+6O_2$) along with water and solar energy, producing oxygen and glucose through a process called respiration. Through the extended network of food webs, different animals obtain and metabolize proteins, carbohydrates, and fats that then end up in human tissues such as bones, teeth, nails and hair. To understand stable carbon isotopes, it is important to understand the different photosynthetic pathways that occur in C_3, C_4 and Crassulacean Acid Metabolism (CAM) plants. For instance, $\delta^{13}C$ isotopic ratios in C_3 plants are more common in temperate areas with ranges of -33‰ to -23‰, which include plants such as wheat, rice, forest, wetland grasses, and most dicotyledonous plants such as root crops, legumes, vegetables, trees and shrubs (Lambert & Grupe 1993). C_4 plants are found in drier and warmer areas, which include plants such as grasses, sedges, and grains, and have $\delta^{13}C$ isotopic ratios between -16‰ to -9‰ (Price & Burton 2011). CAM plants vary between C_3 and C_4 ranges in different environmental conditions (Cadwallader et al. 2012).

In human remain analysis, bioanthropologists get paleodiet information through inorganic composition of the skeleton or bone minerals (Carbonate and phosphate) and organic composition of bone (collagen). Carbonate isotopic values ($\delta^{13}C_{carbonate}$) represent carbon drawn from all sources in the diet, including animals from terrestrial or marine sources and plants from different photosynthetic pathways (Turner et al. 2013; Turner et al. 2017). Meanwhile, collagen isotopic values ($\delta^{13}C_{collagen}$) represent the distribution of carbon found in dietary protein (Turner et al. 2017). Hence, the estimation of diet from bone carbonate can be reconstructed throughout the carbon isotopic values ($\delta^{13}C_{carbonate}$) minus 11‰ (Tomczak 2003) and the estimation diet from bone collagen is reconstructed using the carbon values ($\delta^{13}C_{collagen}$) minus 5‰.

In addition, $\delta^{13}C$ isotopic values can also distinguish whether or not human beings were eating marine or terrestrial foods. Oceanic and freshwater plants utilize dissolved bicarbonates rather than atmospheric carbon dioxide in photosynthesis, meaning that aquatic foodwebs can often have distinct $d^{13}C$ values distinct from terrestrial ones. However, $d^{13}C$ values can overlap significantly between aquatic and terrestrial foodwebs, making it hard to distinguish them using carbon isotopes alone (Williams et al. 2012). Consequently, most isotopic studies of paleodiet analyze not only carbon isotopes but nitrogen isotopes as well to estimate diet consumption.

3.2.2.2. Nitrogen Stable Isotope ($\delta^{15}N$)

In contrast to the carbon cycle, the nitrogen cycle begins with the introduction of nitrogen (N_2) in the atmosphere to the soil through the process of decomposition. Ground-dwelling bacteria and plant roots use nitrogen to build up proteins and DNA in different plants. Animals, including humans, eat those plants and other animals and thereby metabolize those nitrogen isotopes into their own tissues, with predictable shifts at each stage of a foodweb, known as fractionation effects (Price and Burton 2012). An understanding of the nitrogen cycle allows anthropologists to reconstruct dietary patterns through nitrogen isotopes ($\delta^{15}N$) preserved in animal and human tissues.

Archaeologically, nitrogen isotope values ($\delta^{15}N$) are found in the collagen of bone, tooth dentin and keratin of hair and nails, and reflect the type of proteins consumed by living organisms such as animals, vegetables, legumes, and whether they are from a terrestrial or marine source. Because oceanic foodwebs have more trophic levels compared to terrestrial and freshwater foodwebs, marine plants (seaweeds) tend to have higher $\delta^{15}N$ values than terrestrial plants (legumes) (Delwiche and Steyn 1970 in White et al. 2009:1529). In animals, $\delta^{15}N$ values represent trophic-level effects in protein consumption; for example, herbivores tend to have lower $\delta^{15}N$ values than carnivores due to their relative position on the food chain. Moreover, current studies have demonstrated that nitrogen isotope values ($\delta^{15}N$) may be disrupted due to the metabolic balance of individuals, as a consequence of climate, physiology and pathological conditions (Ambrose 1993 in White et al. 2009).

3.2.2.3. Oxygen Stable Isotope ($\delta^{18}O$)

In archaeology, oxygen isotope values ($\delta^{18}O_{carbonate}$) are used to estimate residential mobility and drinking water (Knudson 2009). During evaporation in the ocean, oxygen isotopic ratios (^{18}O) will decrease with precipitation, increasing altitude and latitude and decreasing temperature (Knudson 2009). Oxygen isotopic ratios (^{18}O) are incorporated into phosphate and carbonate in bone carbonate and enamel. Isotopic values of $^{18}O_{carbonate}$ are used to reconstruct paleoclimate, animal migration, residential mobility and water consumption (Balasse et al. 2006; Turner et al. 2012; Knudson 2009).

The presence of oxygen isotope values ($\delta^{18}O_{carbonate}$) in faunal remains is based on precipitation. In humans, oxygen isotope values are stored in bone carbonate through the consumption of water and food, inhalation and weaning. In the Andes, previous investigations in oxygen isotope values ($\delta^{18}O_{carbonate}$) were reported to analyze residential mobility, drinking water and food preparation (Tomczak 2002; Turner 2012; Slovak 2007; Knudson 2009). For instance, Knudson (2009) argued that the application of oxygen isotope analysis in archaeological Andean populations provide useful information about different environmental zones. However, it would be inappropriate to attempt to identify the environmental zone in which people live based only on oxygen isotopic values (Knudson 2009:185). When using oxygen isotope values, bioantropologists have to consider some biological and cultural factors that modify oxygen isotope signatures. For instance, oxygen isotopic values in dental enamel are enriched in oxygen (^{18}O) because of breastfeeding during childhood (Roberts et al. 1988 in Knudson 2009). Moreover, food preparation and drinking water have to be taken into account during the analysis of oxygen isotope values. During food preparation, oxygen (^{16}O) will evaporate and oxygen (^{18}O) will be enriched modifying the oxygen isotope signatures. Meanwhile, drinking water sources have to be considered because of the limited oxygen isotope data and the environmental variability in the Andes.

3.2.3. Other Isotope Studies Related to Paleodiet

Bioanthroplogists are trying to find new pathways and parameters in isotopic studies to reconstruct diet in addition to ^{13}C and ^{15}N isotopic values. Based on previous studies, Richards et al. (2003) suggested paleodiet could be studied by examining the composition of stable isotopic values of Sulphur ($\delta^{34}S$). Sulphur is found mostly in bedrocks, atmospheric deposition and microbial processes active in soils. Using $\delta^{34}S$ isotopic values, bioarchaeologists can potentially identify mobility and migration, as well as identifying consumption of freshwater resources and other dietary variables. However, the author indicated that $\delta^{34}S$ can only be used as a complementary isotopic source for paleodietary evidence with $\delta^{13}C$ and $\delta^{15}N$ isotopic values due to its inaccurate values in distinguishing marine sources. However, $\delta^{34}S$ isotopic values are still valuable because of their additional use in identifying migration and residential locality in archaeological population.

Knudson et al. (2010) used strontium isotopic values ($\delta\ ^{88/86}Sr$) to estimate paleodiet in the Moquegua valley, specifically at the Chiribaya cemetery, which dated to the Late Intermediate Period (AD. 1000-1300). While stable strontium analysis ($\delta\ ^{88/86}Sr$) can identify residential mobility, it can also be used to infer paleodiet in archaeology. Hence, Knudson and colleagues (2010) argued that people from Chiribaya Alta had a wider variability in diet from strontium sources (plants and animals) due to variation in $\delta\ ^{88/86}Sr$ values in addition to their findings of high mobility among the individuals analyzed at Chiribaya Alta.

Inorganic remains include the analysis of elements, minerals and components of water and carbon dioxide to estimate diet and nutrition in ancient populations (Sutton et al. 2010:86). Due to economic factors, training and equipment, the study of inorganic remains throughout stable isotope analysis, trace element analysis and soil chemical analysis are less frequently employed/ utilized in bioarchaeology.

Trace element analysis relies on the chemical elements incorporated into the mineral structure of bone throughout the consumption of food. Initially, Schoeninger (1979) analyzed the bone strontium level of individuals from the site of Chalcatzingo to estimate diet and social status. The results indicated that social status and diet based on meat consumption occurred among the groups analyzed. Based on some previous studies, the levels of Calcio (Ca), the ratios of strontium (Sr)/calcium (Ca), and the ratios of barium (Ba)/calcium (Ca) can be used to estimate paleodiet (Sillen et al. 1995; Burton and Price 1990). New advances in distinguishing meat vs. plants or terrestrial vs. marine food are possible due to the study of other elements such as zinc (Zn), copper (Cu), iron (Fe), and magnesium (Mg) (Burton and Price 2002). Besides the great contribution of trace elements to estimate diet and health, other social and behavioral questions could be inferred by anthropologists using trace elements. For example, social status (Aufderheide et al. 1981), ethnicity (Carlson 1996), aspects of pollution (Pyatt et al. 2000), and behavior related to toxicity (Keenleyside et al. 1996) can also be inferred using trace element analysis.

3.2.4. Limitation

Dental microware analysis has been useful in estimating broad paleodiet in living and extinct primates and fossil hominins but with limitations in archaeological populations (Turner and Livengood 2017). For instance, food consumption leaves different microwear features on the tooth enamel than food preparation. In addition, dental microwear has a “last supper” effect where only the last microwear features are left on the enamel to be analyzed. Therefore, interpretations of dietary patterns throughout dental microwear could be debatable because of food processing, seasonal, geographic and annual variation (Turner & Livengood 2017:173).

In stable isotope analysis, carbon (^{13}C) and nitrogen (^{15}N) isotopic ratios are the essential elements for estimating diet and food consumption in archaeological populations, with the incorporation of new chemical elements such as strontium and Sulphur to study dietary patterns. However, the analysis of stable isotope values in archaeological human remains has its limitations. Turner & Livengood (2017) argued that the analysis of isotope values cannot be used to estimate the "*absolute quality*" of variation in food consumption, but rather the relative proportions of diet. Furthermore, since some plants follow the same photosynthetic pathways (C_3- C_4 plants), it is difficult to estimate the specific foods. Finally, it is difficult to infer nutritional status from isotopic values because food may be imported from different areas and consumed by local populations (Turner & Livengood 2017:173-174).

3.2.5. The Application of Stable Isotope Analysis in the Andes

The first effort to get information about isotopic values from plants and animals in the Peruvian Andes was carried out by DeNiro and Hastorf (1985). The research concluded that most of the species analyzed belong to C_3 plants with exception C_4 plants (maize). Later, new isotopic data from identified native Peruvian flora and fauna remains were analyzed to understand the isotopic values of archaeological human remains (Tieszen and Chapman 1992; Turner et al. 2010; Cadwallader et al. 2012).

Having information about isotopic values from plants and animals in the Central Peruvian Andes, bioanthropologists have attempted to reconstruct diet throughout Carbon ($d^{13}C$) and Nitrogen ($d^{15}N$) stable isotope values. For example, one of the first paleodiet reconstructions using carbon and nitrogen isotopic values was carried out at the archaeological site of Chavin in the Peruvian highlands (Burger and Van der Merwe 1990). Later on, numerous investigations of paleodiet using Carbon ($d^{13}C$) and Nitrogen ($d^{15}N$) isotopic values were analyzed in the coastal, central and south Peruvian Andes (Knudson et al 2015, Tomczak 2003, Finucane 2007, Williams and Katzenberg, 2012). For instance, Knudson and Colleges (2015) conducted a study of carbon and nitrogen isotope analysis of fourteen individuals (n=14) in the *Wari Kayan* necropolis in Paracas. The results showed a mixed diet of C_3 and C_4 plants in isotopic values of carbon, whereas a diet rich in marine resources as a result in nitrogen isotopic values.

In the Osmore valley, Tomczac (2003) used carbon and nitrogen isotope values from bone collage and bone apatite at Chiribaya sites to analyze paleodiet. The study found local production of food resources and specializations among the Chiribaya groups such as farmers and fishermen. Somerville et al. (2015) analyzed $d^{13}C_{apatite}$, $d^{13}C_{collagen}$, and $d^{15}N_{collagen}$ from Tiwanaku colonies in the Moquegua valley. The results indicated high maize consumption among the Tiwanaku colonial sites and higher $d^{13}C_{collagen}$ values in males than females. Besides Carbon and Nitrogen isotopes analysis to reconstruct paleodiet, bioantropologists have used different isotopic elements such as oxygen ($d^{18}O$), strontium ($^{87}Sr/^{86}Sr$), lead ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$) and sulfur ($d^{34}S$) (Knudson 2009; Fernandez et al. 1999; Knudson et al. 2005; Turner et al. 2009).

4. RESEARCH DESIGN

4.1. Tumilaca la Chimba

The site of Tumilaca la Chimba is located in the upper Moquegua valley, fifteen km up valley from earlier Tiwanaku occupations in the middle valley. The site is at an altitude of approximately 1900 m.a.s.l. on a bluff above the Tumilaca River (Sharratt 2016). The earliest fieldwork at Tumilaca la Chimba was conducted by Romulo Pari (1980) with the excavation of fourteen intact tombs and a number of disturbed burials. In the early 1980s, the Programa Contisuyo distinguished two different occupations (a Tumilaca and an Estuquiña occupation) based on small test excavations (Bawden 1989; 1993). Since 2006, Sharratt's team has conducted four seasons of excavation in Terminal Middle Horizon and two seasons in Late Intermediate Period (2017).

The first occupation at the Tumilaca Chimba site is related to the terminal Middle Horizon or the Tumilaca phase which dates to AD. 950 and lasted until at least AD. 1250 (Sharratt n.d.). The Tumilaca phase is characterized by four spatially discrete cemeteries on the slopes of Cerro La Chimba which overlooks the residential sector. Domestic architecture consists of double-faced walls and constructed of small regular neatly aligned stones held together with mortar (Bawden 1993; Sharratt 2015). The first occupation at the Tumilaca la Chimba also includes a rustic collective ceremonial building and four cemeteries located above residential and public structures (Sharratt 2016). Various cultural and biological investigations suggested that the Tumilaca phase inhabitants were related to their Tiwanaku predecessors who had settled in the middle Moquegua valley during the Middle Horizon (Sharratt 2015, 2016). Non-metric dental analysis at four Tumilaca cemeteries found that Tiwanaku populations settled in the middle valley are biologically related with Tumilaca people (Sutter and Sharratt 2010).

The second occupation of the Tumilaca la Chimba site is related to the Late Intermediate period or Estuquiña phase which dates to circa AD. 1250-1470. The Estuquiña occupation consists of a central domestic area with one cemetery located in the eastern side of the site and is characterized by higher single-faced walls that define large trapezoidal and rectangular structures. Estuquiña architecture, cultural artifacts, burial practices, ceramics, and textiles at the site are different than their Tumilaca and Tiwanaku predecessors (Sharratt 2017). There are approximately 35 Estuquiña style rooms arranged in clusters around patio spaces which include a large plaza and defensible structures on hilltops.

4.2. Samples and Methods

This study includes individuals from the Tumilaca phase (AD. 950-1250) which were excavated during 2006-2007 field season and from the Estuquiña phase which were excavated in the 2015 and 2016 field seasons. For the purposes of this study, carbonate ($d^{18}O$ and $d^{13}C$) and collagen ($d^{13}C$ and $d^{15}N$) were extracted from bone samples. For bone carbonate isotope analysis ($d^{18}O_{carbonate}$ and $d^{13}C_{carbonate}$), the Tumilaca sample consists of thirteen individuals (n=13), six individuals (n=06) excavated in 2006 and seven individuals (n=07) excavated in 2007. The Estuquiña sample consists of fourteen individuals (n=14), six individuals (n=06) excavated in 2015 and eight individuals (n=08) in 2016. Most of the individuals have a biological age, sex and burial number. Most of the samples analyzed are adults with the exception of one sub-adult and two unidentified individuals. See table 1.

Table 1. Total Samples for d^{18}O$_{carbonate}$ and d^{13}C$_{carbonate}$ isotope analysis

Lab Code	Phase	Sex	Age	burial #
BQ02B	Tumilaca	Male	21-23	45-1
BQ03-B	Tumilaca	N/A	N/A	46
BQ04-B	Tumilaca	Male	25-29	46-4
BQ05-B	Tumilaca	Male	35-42	44-5
BQ06-B	Tumilaca	Male	35-45 y	46-10
BQ39-B	Tumilaca	Female	21-24 y	47-6
BQ40-B	Tumilaca	Sub-adult	10-15 y	47-27
BQ41-B	Tumilaca	Female	24-30 y	47-25
BQ42-B	Tumilaca	Female	18-24 y	47-22
BQ43-B	Tumilaca	Female	15-19 y	47-20
BQ45-B	Tumilaca	Male	23-29 y	47-4
BQ46-B	Tumilaca	Male	30-39 y	44-1
BQ48-B	Tumilaca	Male	35-39 y	46-3
BQ50-B	Estuquiña	Male	30-39 y	56-7
BQ51-B	Estuquiña	Female	25-34 y	56-4
BQ01-B	Estuquiña	N/A	N/A	56-6
BQ52-B	Estuquiña	Female	30-39 y	56-5
BQ53-B	Estuquiña	Female	35-39 y	56-2
BQ54-B	Estuquiña	Male	25-34 y	56-1
BQ56-B	Estuquiña	Male	20-29 y	56-13
BQ58-B	Estuquiña	Female	15-21 y	56-12
BQ59-B	Estuquiña	N/A	Adult	56-11
BQ60-B	Estuquiña	Male	30-35 y	56-20
BQ62-B	Estuquiña	Female	35-45 y	56-9
BQ64-B	Estuquiña	Female	25-34 y	56-13
BQ66-B	Estuquiña	Female	25-34 y	56-20
BQ67-B	Estuquiña	Male	21-35 y	56-18

For bone collagen isotope analysis ($d^{13}C_{collagen}$ and $d^{15}N_{collagen}$), the Tumilaca samples were reduced from fifteen (n=16) individuals to five (n=5) individuals. Meanwhile, the Estuquiña samples were reduced from twenty (n=20) individuals to three individuals (n=3). The Estuquiña and Tumilaca samples were recovered during fieldwork 2015-2016. Biological sex, age and burial number are included in table 2.

Table 2. Total Samples for $d^{15}N_{collagen}$ and $d^{13}C_{collagen}$ isotope analysis

Lab Code	Phase	Sex	Age	Burial #
BQ02B	Tumilaca	Male	21-23 y	45-1
BQ03-B	Tumilaca	N/A	N/A	46
BQ04-B	Tumilaca	Male	25-29 y	46-4
BQ05-B	Tumilaca	Male	35-42 y	44-5
BQ06-B	Tumilaca	male	35-45 y	46-10
BQ39-B	Tumilaca	Female	21-24 y	47-6
BQ40-B	Tumilaca	Sub-adult	10-15 y	47-27
BQ41-B	Tumilaca	Female	24-30 y	47-25
BQ42-B	Tumilaca	Female	18-24 y	47-22
BQ43-B	Tumilaca	Female	15-19 y	47-20
BQ45-B	Tumilaca	Male	23-29 y	47-4
BQ46-B	Tumilaca	Male	30-39 y	44-1
BQ48-B	Tumilaca	Male	35-39 y	46-3
BQ44-B	Tumilaca	Female	30-34 y	47-10
BQ47-B	Tumilaca	Female	20-25 y	46-14
BQ49-B	Tumilaca	Female	24-29 y	46-15
BQ50-B	Estuquiña	Male	30-39 y	56-7
BQ51-B	Estuquiña	Female	25-34 y	56-4
BQ01-B	Estuquiña	N/A	N/A	56-6
BQ52-B	Estuquiña	Female	30-39 y	56-5
BQ53-B	Estuquiña	Female	35-39 y	56-2
BQ54-B	Estuquiña	Male	25-34 y	56-1

BQ56-B	Estuquiña	Male	20-29 y	56-13
BQ58-B	Estuquiña	Female	15-21 y	56-12
BQ59-B	Estuquiña	N/A	Adult	56-11
BQ60-B	Estuquiña	Male	30-35 y	56-20
BQ62-B	Estuquiña	Female	35-45 y	56-9
BQ64-B	Estuquiña	Female	25-34 y	56-13
BQ66-B	Estuquiña	Female	25-34 y	56-20
BQ67-B	Estuquiña	Male	21-35 y	56-18
BQ65-B	Estuquiña	Male	30-39 y	56-14
BQ61-B	Estuquiña	N/A	30-39 y	56-25
BQ55-B	Estuquiña	Female	17-21 y	56-3
BQ57-B	Estuquiña	Female	15-20 y	56-24
BQ68-B	Estuquiña	N/A	Adult	56-16
BQ63-B	Estuquiña	Male	25-34 y	56-21

The bone samples from the Tumilaca and Estuquiña samples were divided into two groups to perform isotopic mass-spectrometric analysis. Firstly, the analysis of carbonate was carried out in the Bioarchaeology laboratory at Georgia State University. Bone preparation for carbonate isotope analysis was performed following established methods (Ambrose 1993; Garvie-Lok et al. 2014; Schoeninger et al. 1989) and adapted by Turner et al. (2009). From each sample, approximately 2 cm in length was cut in two pieces to remove trabecular layer and external surface was cleaned using a dental drill. The cut bones were placed in tubes with distilled water (ddH20) and sonicated using an ultrasonic cleaner to remove external dirt from the bones. The sonification process was repeated three to four times during five minutes for each sample. Then, bone samples were placed in the fume hood to let them dry overnight. Once the bone samples were dried, we used an agate mortar and pestle to crush the bones and obtain a fine powder which were deposited in tubes and socked for 24-72 hours in a 2% NaOCl (bleach)/ddH2O solution until degassing in the solution. The samples were centrifuged, rinsed to neutral level using distilled water (ddH20) and then soaked for 2–4 hours in a 0.2% acetic acid solution at 4 C to remove any exogenous carbonates and other diagenetic contaminants. Carbonate samples were centrifuged and rinsed with ddH2O, freeze-dried and sent to the Department of Geological Sciences at the University of Florida at Gainesville for VG prism mass spectrometer analysis. Isotopic values are expressed as per mil (&) relative to standard marine ocean water (SMOW). Mean d18O of NBS-19 analytical standard is 28.1& (vs. SMOW), with a standard deviation of 0.11& (Turner et al. 2009).

In order to obtain collagen, the samples of bone powder were flushed for four hours with a 10:5:1 solution of methanol, chloroform and distilled water (ddH20) in the fume hood to remove lipids from the bone. Then the samples were dried for 48 hours and placed in 15ml glass tubes with Teflon caps and added 0.5 M hydrochloric acid at 4°C to demineralize the bone. After demineralization, the samples were treated with 0.2% potassium hydroxide (KOH) solution for 48-72 hours to remove humid contaminants. Then samples were soaked in 0.5 M HCI for 48 hours at 4°C and then heated in a 0.5 M HCI solution at 95°C until samples was dissolved (approximately 8 hours). Gelatinized samples were filtered using 0.045 μm Millipore syringe tips into a 5 ml borosilicate tubes (Turner et al. 2010).

The samples were analyzed with Carlo Erba CNS interconnected with a mass spectrometer Micromass Prism Series II for isotopic values of $\delta^{13}C$ and $\delta^{15}N$. Finally, the isotopic values of collagen and Carbonate were analyzed using statistic software IBM-SPSS 23.0 and Microsoft Excel 2013.

5. RESULTS

5.1. Bone Carbonate Isotope Values ($\delta^{18}O$ and $\delta^{13}C$) from Tumilaca

Data for bone carbonate isotope values ($\delta^{18}O$ and $\delta^{13}C$) from the Tumilaca population are featured in table 3. The carbon stable isotope values ($\delta^{13}C$) of bone carbonate from the Tumilaca phase range between -7.34‰ to -13.59 ‰ with an average value of -9.43 ‰ and standard deviation of 1.58‰. The oxygen stable isotope values ($\delta^{18}O$) of bone carbonate from the Tumilaca phase range between 21.6‰ to 30.37‰ with an average value of 24.27‰ with standard deviation of 2.15‰.

Table 3. Carbonate Stable Isotope Values ($\delta^{18}O$ and $\delta^{13}C$) from Tumilaca population

Lab Code	**Phase**	**Sex**	**Age**	**burial #**	**$d^{13}C$ (‰, vs VPDB)**	**$d^{13}C$ Est. Diet**	**d18O (vSMOW)**
BQ02-B	Tumilaca	Male	21-23 y	45-1	-9.10	-20.10	30.37
BQ03-B	Tumilaca	N/A	N/A	46	-9.50	-20.50	23.17
BQ04-B	Tumilaca	Male	25-29 y	46-4	-9.31	-20.31	25.34
BQ05-B	Tumilaca	Male	35-42 y	44-5	-8.76	-19.76	23.78
BQ06-B	Tumilaca	male	35-45 y	46-10	-9.71	-20.71	24.21
BQ39-B	Tumilaca	Female	21-24 y	47-6	-8.06	-19.96	23.39
BQ40-B	Tumilaca	Sub-adult	10-15 y	47-27	-13.59	-24.59	23.32
BQ41-B	Tumilaca	Female	24-30 y	47-25	-7.34	-18.34	22.07
BQ42-B	Tumilaca	Female	18-24 y	47-22	-9.00	-20.00	24.30
BQ43-B	Tumilaca	Female	15-19 y	47-20	-8.00	-19.00	25.72
BQ45-B	Tumilaca	Male	23-29 y	47-4	-11.13	-22.13	21.61

BQ46-B	Tumilaca	Male	30-39 y	44-1	-10.09	-21.09	24.01
BQ48-B	Tumilaca	Male	35-39 y	46-3	-8.97	-19.97	24.29
AVERAGE					-9.43	-20.43	24.27
STDEV					1.58	1.58	2.15

5.2. Bone Carbonate Stable Isotope Values ($\delta^{18}O$ and $\delta^{13}C$) from Estuquiña

Data for Carbonate isotope values ($\delta^{18}O$ and $\delta^{13}C$) from the Estuquiña populations are featured in table 4. The carbon stable isotope values ($\delta^{13}C$) of bone carbonate from the Estuquiña phase range between -4.61 ‰ to -12.42 ‰ with an average value of -6.93 ‰ and standard deviation of 2.22‰. The oxygen stable isotope values ($\delta^{18}O$) of bone carbonate from the Estuquiña phase range between 12.86‰ to 25.65‰ with an average value of 23.35‰ and standard deviation of 3.13‰.

Table 4. Carbonate Stable Isotope Values ($\delta^{18}O$ and $\delta^{13}C$) from Estuquiña population

Lab Code	Phase	Sex	Age	Burial #	d^{13}C (‰, vs VPDB)	d^{13}C Est. Diet	d18O (vSMOW)
BQ50-B	Estuquiña	Male	30-39 y	56-7	-6.62	-17.62	23.67
BQ51-B	Estuquiña	Female	25-34 y	56-4	-12.42	-23.42	22.24
BQ01-B	Estuquiña	N/A	N/A	56-6	-6.13	-17.13	24.45
BQ52-B	Estuquiña	Female	30-39 y	56-5	-7.76	-18.76	23.79
BQ53-B	Estuquiña	Female	35-39 y	56-2	-6.67	-17.67	24.23
BQ54-B	Estuquiña	Male	25-34 y	56-1	-5.28	-16.28	24.59
BQ56-B	Estuquiña	Male	20-29 y	56-13	-6.31	-17.31	24.95
BQ58-B	Estuquiña	Female	15-21 y	56-12	-11.19	-22.19	12.86
BQ59-B	Estuquiña	N/A	Adult	56-11	-4.61	-15.61	24.51

BQ60-B	Estuquiña	Male	30-35 y	56-20	-6.01	-17.01	23.28
BQ62-B	Estuquiña	Female	35-45 y	56-9	-6.59	-17.59	24.43
BQ64-B	Estuquiña	Female	25-34 y	56-13	-5.88	-16.88	25.65
BQ66-B	Estuquiña	Female	25-34 y	56-20	-5.00	-16.00	24.59
BQ67-B	Estuquiña	Male	21-35 y	56-18	-6.53	-17.53	23.71
AVERAGE					-6.93	-17.93	23.35
STDEV					2.22	2.22	3.13

5.3. Bone Collagen Isotope Values ($\delta^{15}N$ and $\delta^{13}C$) from Tumilaca Population

Data for bone collagen isotope values ($\delta^{15}N$ and $\delta^{13}C$) from Tumilaca population are featured in table 5. The carbon stable isotope values ($\delta^{13}C$) of bone collagen from Tumilaca phase range between -16.7‰ to -30.2 ‰ with an average value of -20.8‰. The nitrogen stable isotope values ($\delta^{15}N$) of bone collagen from Tumilaca phase range between 4.9‰ to 7.4‰ with an average value of 6.5 ‰. Unfortunately, original samples were reduced from sixteen to five individuals because bone collagen was insufficient to run mass spectrometry analysis due to bad preservation of the human remains. The samples with enough collagen are highlighted below.

Table 5. Collagen Stable Isotope Values ($\delta^{15}N$ and $\delta^{13}C$) from Tumilaca Population

Lab Code	Phase	$d^{15}N$ (permil, vs AIR)	$d^{15}N$ Estimated Diet	$d^{13}C$ (permil, vs VPDB)	$d^{13}C$ Estimated Diet	wt %N	wt %C	C/N
BQ06-B	Tumilaca	13.23	9.73	-19.44	-24.44	1.15	4.86	4.23
BQ42-B	Tumilaca	12.13	8.63	-20.48	-25.48	0.42	2.42	5.76
BQ49-B	Tumilaca	6.15	2.65	-25.42	-30.42	0.32	4.35	13.59
BQ41-B	Tumilaca			-27.81	-32.81	0.14	1.81	12.93
BQ45-B	Tumilaca			-27.30	-32.30	0.14	1.77	12.64
BQ02-B	Tumilaca	21.59	18.09	-17.18	-22.18	1.14	7.48	6.56

BQ46-B	Tumilaca	13.86	10.36	-17.93	-22.93	0.91	4.34	4.77
BQ04-B	Tumilaca	18.12	14.64	-17.24	-22.24	0.89	4.50	5.06
BQ44-B	Tumilaca	10.91	7.41	-15.17	-30.17	0.79	2.89	3.66
BQ03-B	Tumilaca	10.65	7.15	-12.58	-17.58	10.94	30.54	2.79
BQ39-B	Tumilaca	9.13	5.63	-12.57	-17.57	8.61	24.47	2.84
BQ47-B	Tumilaca	10.89	7.39	-17.16	-22.16	8.19	22.67	2.77
BQ05-B	Tumilaca	8.35	4.85	-11.65	-16.65	9.81	27.66	2.82
BQ43-B	Tumilaca			0.12		0.09	0.65	7.22
BQ48-B	Tumilaca	-1.09	-4.59	-25.59	-30.59	0.49	4.76	9.71
BQ40-B	Tumilaca	1.34	-2.16	-25.93	-30.93	0.21	3.77	17.95
AVERAGE		14.9	6.5	-13.8	-20.8			
STDEV		1.2	1.2	2.3	5.6			

5.4. Bone Collagen Isotope Values ($\delta^{15}N$ and $\delta^{13}C$) from Estuquiña Population

Data for bone collagen isotope values ($\delta^{15}N$ and $\delta^{13}C$) from the Estuquiña population are featured in table 6. The carbon stable isotope values ($\delta^{13}C$) of bone collagen from the Estuquiña phase range between -16.3‰ to -23.4‰ with an average value of -19.0 ‰. The nitrogen stable isotope values ($\delta^{15}N$) of bone collagen from the Estuquiña phase range between 9.7‰ to 13.1‰ with an average value of 11.4‰. Original samples were reduced from twenty to three individuals because bone collagen was insufficient to run mass spectrometry analysis due to bad preservation of human remains. The samples with enough collagen are highlighted below.

Table 6. Collagen Stable Isotope Values ($\delta^{15}N$ and $\delta^{13}C$) from Estuquiña Population

Sample	Phase	$d^{15}N$ (permil, vs AIR)	$d^{15}N$ Estimated Diet	$d^{13}C$ (permil, vs VPDB)	$d^{13}C$ Estimated Diet	wt %N	wt %C	C/N
BQ65-B	Estuquiña	4.53	1.03	-22.27	-27.27	0.31	2.19	7.06
BQ62-B	Estuquiña			-25.33	-30.33	0.25	2.22	8.88
BQ61-B	Estuquiña			-27.22	-32.22	0.13	1.30	10.00
BQ64-B	Estuquiña			-24.22	-29.22	0.11	1.04	9.45
BQ56-B	Estuquiña			-26.34	-31.34	0.71	8.61	12.13
BQ55-B	Estuquiña	16.64	13.14	-12.30	-17.30	3.93	11.99	3.05
BQ53-B	Estuquiña			-26.50	-31.50	0.18	1.99	11.06
BQ50-B	Estuquiña	7.58	4.08	-23.90	-28.90	0.59	6.67	11.31
BQ66-B	Estuquiña	7.95	4.45	-22.34	-27.34	0.39	2.41	6.18
BQ58-B	Estuquiña			-26.11	-31.11	0.17	2.63	15.47
BQ67-B	Estuquiña	13.55	10.05	-20.60	-25.60	0.33	2.18	6.61
BQ52-B	Estuquiña			-25.72	-30.72	0.21	3.14	14.95
BQ57-B	Estuquiña			-23.41	-28.41	0.11	1.31	11.91
BQ68-B	Estuquiña			-26.54	-31.54	0.15	2.26	15.07
BQ59-B	Estuquiña	17.86	14.36	-21.15	-26.15	0.40	2.41	6.03
BQ63-B	Estuquiña	9.61	6.11	-18.54	-23.54	0.57	2.64	4.63
BQ01-B	Estuquiña	21.13	17.63	-15.27	-20.27	1.10	5.06	4.60
BQ54-B	Estuquiña	13.18	9.68	-16.51	-21.51	0.56	3.04	5.43
BQ51-B	Estuquiña	14.95	11.45	-18.35	-23.35	11.06	30.87	2.79
BQ60-B	Estuquiña	13.20	9.70	-11.32	-16.32	8.33	23.81	2.86
AVERAGE		14.9	11.4	-14.0	-19.0			
STDEV		1.7	1.7	3.8	3.8			

6. DISCUSSION

6.1. Bone Carbonate Isotope Values ($\delta^{13}C_{carbonate}$ vs $\delta^{18}O_{carbonate}$)

The inorganic component of bone provides very useful information to enhance understandings of paleodiet from archaeological human remains (Wright and Schwarcz 1998). Through the study of a mineral portion of bone such as carbon ($\delta^{13}C_{carbonate}$) and oxygen ($\delta^{18}O_{carbonate}$), scholars estimate paleodiet which could provide excellent isotopic information even when bone collagen is degraded. Isotopic values of carbon ($\delta^{13}C_{carbonate}$) in bone carbonate represent carbon drawn from all sources in the diet, including animals from terrestrial or marine sources and plants from different photosynthetic pathways (Turner et al. 2013:27). Meanwhile, isotopic values of oxygen ($\delta^{18}O_{carbonate}$) in apatite carbonate provide good information on residential mobility and water consumption (Knudson 2009).

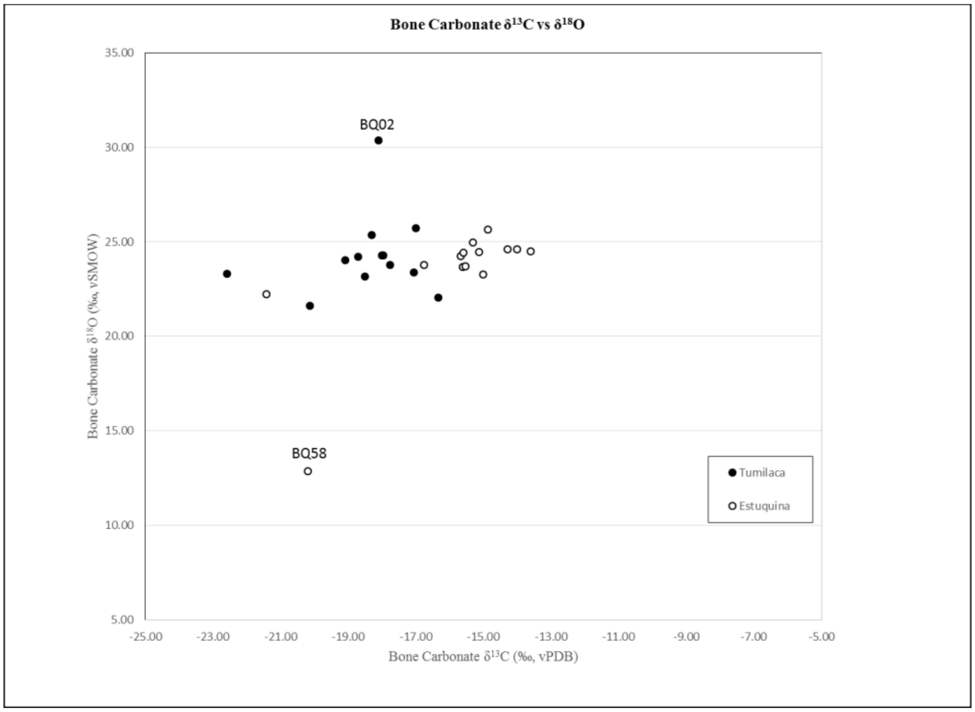
The estimation of diet in bone carbonate from isotopic values of carbon ($\delta^{13}C_{carbonate}$) indicates a small difference between Tumilaca and Estuquiña populations. The evidence indicates greater consumption of C_3 plants than C_4 plants in both populations. More specifically, the Estuquiña samples tend to have carbon isotopic values ($\delta^{13}C_{carbonate}$) between -13.61 ‰ to -21.42 ‰ which suggest a mixture of C_3 and C_4 terrestrial plants. In contrast, the Tumilaca population have fewer negative carbon isotopic values (between -16.34‰ to -22.59‰) which indicate more C_3 plants with less consumption of maize.

The isotopic values of Oxygen ($\delta^{18}O_{carbonate}$) indicate that both populations drank water from the same local spring because they have isotopic values between 21.61‰ to 25.72‰. However, there are two individuals with different Oxygen isotopic values. The individual BQ58 (Estuquiña) has more oxygen isotopic values associated with people from the Lake Titicaca basin as reported in Knudson (2009). Meanwhile, the individual BQ02 (Tumilaca) could be a local person who used and drank water from a different spring.

Typical mortuary treatment during Tumilaca phase indicated cultural inclusion of ceramics, corn cobs, chrysocolla beads, beads made of perforated seeds, fragmentary textile, and camelid bones (Sharratt 2011). Osteological information from the individual BQ58 is reported in Lowman (2017) as a female with biological age between 15-21 years old and possible enamel hypocalcification. In contrast, the individual BQ02 was a male with age between 21-23 years old. Information about mortuary treatment indicated the presence of textile, rope, lithic flakes and ceramics. The analysis of the skeletal remain indicated minor dental wear (Sharratt 2011).

Oxygen isotopic values ($\delta^{18}O_{carbonate}$) from bone carbonate storage in our organism come from consumed food, inhalation, and especially imbibed water (Knudson 2009). Drinking water is obtained via different sources such as rainwater, river water, glacial meltwater, and groundwater. In the South-Central Andes, food and drink preparations could affect oxygen isotope ratios found in bone carbonate. For example, boiled beverages such as *molle* and maize beer will be enriched in oxygen (^{18}O) because ^{16}O will evaporate during boiling (Wilson et al. 2007; Knudson 2009). Thus, the individuals BQ02 appear to have been unique or distinct compared to the rest of the assemblage. BQ02 may have consumed more *molle* beer (*chicha de molle*) which could be associated with ethnic identity and social status (Sayre et al. 2012; Moseley et al. 2005). BQ58, on the other hand, appears to have been drinking all of Lake Titicaca. In fact, oxygen isotope values ($\delta^{18}O_{carbonate}$) indicate local water consumption in both Estuquiña and Tumilaca population. See table 3.

Figure 3: Carbonate Isotope values from $\delta^{13}C_{carbonate}$ and $\delta^{18}O_{carbonate}$



Using the Mann-Whitney U test, the carbon isotopic values ($\delta^{13}C_{carbonate}$) from Tumilaca and Estuquiña populations are statistically different ($P < 0.001$). Meanwhile, oxygen isotope values ($\delta^{18}O_{carbonate}$) indicated no differences between those populations ($P < 0.409$). See table 7.

Table 07. Mann-Whitney U test for Bone Carbonate

	$d^{13}C$ Est. diet	$d^{18}O$ SMW
Mann-Whitney U	25.000	74.000
Wilcoxon W	116.000	165.000
Z	-3.203	-.825
Asymp. Sig. (2-tailed)	.001	.409
Exact Sig. [2*(1-tailed Sig.)]	.001[b]	.430[b]

6.2. Bone Collagen Isotope Values ($\delta^{13}C_{collagen}$ vs $\delta^{15}N_{collagen}$)

In carbon isotopic values ($\delta^{13}C_{collagen}$), human tissues will reflect the $\delta^{13}C$ values of plants and the animals that eat them (Turner et al. 2012; Lamb 2016). Traditionally, scholars argued that C_3 plants are more common in temperate areas with isotopic values of -33‰ to -23‰, which include plants such as wheat, rice, forest, wetland grasses, and most dicotyledonous plants such as root crops, legumes, vegetables, trees and shrubs (Lambert & Grupe 1993). Meanwhile, C_4 plants are found in drier and warmer areas, which include plants such as grasses, sedges, and grains, and have $\delta^{13}C$ isotopic ratios between -16‰ to -9‰ (Price & Burton 2011).

In the Andes, C_3 plants include beans, squash and potatoes with carbon isotopic values between -22‰ to -29‰ (Tieszen and Chapman 1992). C_4 plants are mostly represented by maize and kiwicha (DeNiro and Hastorf 1985; Turner et al. 2010). Currently, Cadwallader et al. (2012) added new carbon isotopic data of wild plants from the Peruvian South coast which include mostly C_3 plants such as *molle* (-26.77‰), *olluco* (-23‰), *maca* (-25.88‰), *oca* (24.80‰), *mashua* (-25.10‰), etc. Similar to $\delta^{13}C_{collagen}$, the isotopic values of nitrogen ($\delta^{15}N_{collagen}$) reflect the trophic level of the ecosystem with low nitrogen values in plants and higher values in omnivores.

Samples from Estuquiña (n=3) and Tumilaca (n=5) were reduced because of poor preservation and diagenetic contamination of human remains (see Table 7). Hence, the estimation of diet from carbon and nitrogen isotope values ($\delta^{13}C_{collagen}$ vs $\delta^{15}N_{collagen}$) indicate a high consumption of terrestrial C_3 plants in both the Tumilaca and Estuquiña samples. However, the carbon and nitrogen isotope values ($\delta^{13}C_{collagen}$ vs $\delta^{15}N_{collagen}$), indicated that Tumilaca populations had a diet based on C_3 plants. Meanwhile, the Estuquiña population had more access to a mixed diet of terrestrial C_3 plants and local animals. Moreover, there is a possibility that those individuals consumed *chicha de Molle* (δ ^{13}C -26.77‰) because of previous ethnobotanical and macrobotanical investigations at Cerro Baul (Sayre et al 2012; Moseley et al 2005; Goldstein et al. 2008).

Table 8. Reduced Collagen Isotope Values (δ^{13}C vs δ^{15}N) from Tumilaca and Estuquiña with biological age, sex and pathology

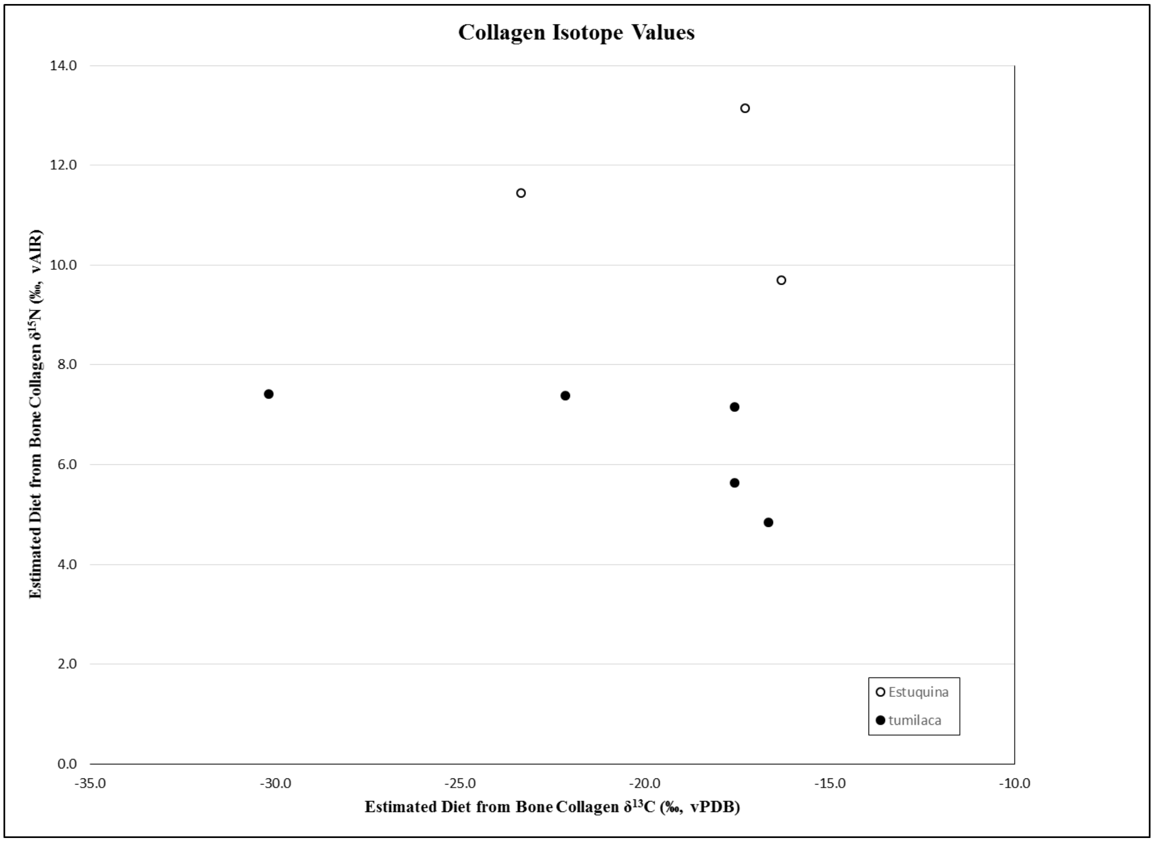
Period	Sample	d^{15}N Est Diet	d^{13}C Est Diet	Age	Sex	Pathology (Lowman 2017)
Estuquiña	BQ55-B	13.1	-17.3	17-21	Female	Dental caries
Estuquiña	BQ51-B	11.5	-23.4	25-35	Female	Dental resorption, abscess and caries
Estuquiña	BQ60-B	9.7	-16.3	30-35	Male	Vertebral arthritis, endocranial lesions, cranial porosity, dental resorption and caries
AVERAGE		11.4	-19.0			
STDEV		1.7	3.8			
Tumilaca	BQ44-B	7.4	-30.2	30-34	Female	Lesion on posterior manubrium, vertebral pitting and two fused thoracic vertebrae
Tumilaca	BQ03-B	7.2	-17.6	1-2	N/A	No visible pathology
Tumilaca	BQ39-B	5.6	-17.6	N/A	N/A	No visible pathology
Tumilaca	BQ47-B	7.4	-22.2	20-24	Female	No visible pathology
Tumilaca	BQ05-B	4.9	-16.7	N/A	N/A	No visible pathology
AVERAGE		6.5	-20.8			
STDEV		1.2	5.6			

Furthermore, δ^{13}C$_{collagen}$ vs δ^{15}N$_{collagen}$ values suggest low consumption of maize in both populations. Previous macrobotanical investigations at Cerro Baul found a minimal amount of corn remains in the burials which represented less than 1% of the total ethnobotanical assemblage (Goldstein 2008). Moreover, whole cobs found at Cerro Baul, mostly in elite Baul contexts, would indicate social status rather than every day consumption of maize. Nicola Sharratt (personal communication) noted the presence of maize, *quinoa*, and remains of guinea pigs (*cuy*) and camelids at Tumilaca tombs.

Unlike earlier $\delta^{13}C_{collagen}$ vs $\delta^{15}N_{collagen}$ isotopic investigations in Tiwanaku colonies and Wari occupation (Somerville et al. 2015; Finucane et al. 2006), populations from Tumilaca and Estuquiña tend to have lower isotopic values of C_4 plants which could be associated with lower consumption of maize or ritual practices linked to elite persons. The low maize consumption among Tumilaca population could be related to the Tiwanaku collapse in the middle Moquegua valley where Tiwanaku refugees consumed more local food resources rather than incorporate food from the highlands and the coast (Goldstein 2005).

Moreover, $\delta^{13}C_{collagen}$ vs $\delta^{15}N_{collagen}$ values indicated the low presence of marine food in Tumilaca and Estuquiña populations. In Tumilaca people, the lack of marine resources could be associated with the collapse of trade with the highlands and distance from the middle and coastal valleys to obtain fish and marine products. The Estuquiña people have more positive nitrogen isotopic values ($\delta^{15}N_{collagen}$) which could indicate more access to river resources and lake fish. See Figure 4.

Figure 4. Collagen Isotope values from $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$



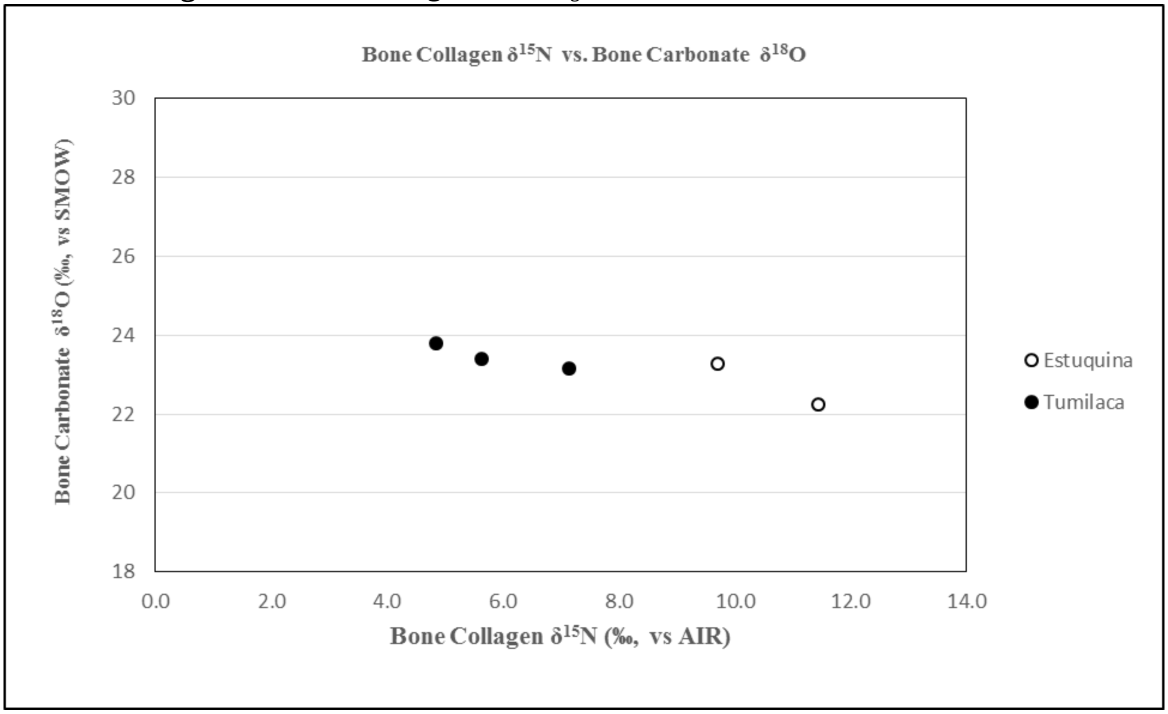
6.3. Nitrogen Isotope Values ($\delta^{15}N_{collagen}$) vs Oxygen Isotope Values ($\delta^{18}N_{carbonate}$)

Nitrogen isotopic values ($\delta^{15}N_{collagen}$) from Tumilaca are lower than in Estuquiña people. The $\delta^{15}N_{collagen}$ values showed differences in trophic levels between early occupation (Tumilaca) and later occupation (Estuquiña). As a mentioned before, Tumilaca people are linked with higher consume of C_3 plants and perhaps limited access to local meat such as camelids, guinea pigs (*cuy*), deer, viscacha, doves, and pigeons. In contrast, Estuquiña people have higher nitrogen isotopic values ($\delta^{15}N_{collagen}$) which indicate access not only to C_3 plants but also to local animals.

Oxygen isotopic values ($\delta^{18}O_{carbonate}$) suggest similar local consumption of water in both populations. Besides the differences of time periods between Tumilaca (AD. 950-1200) and

Estuquiña (AD. 1250-1470), the oxygen isotopic values ($\delta^{18}O_{carbonate}$) demonstrated that both populations consumed the same water resources. See Figure 5.

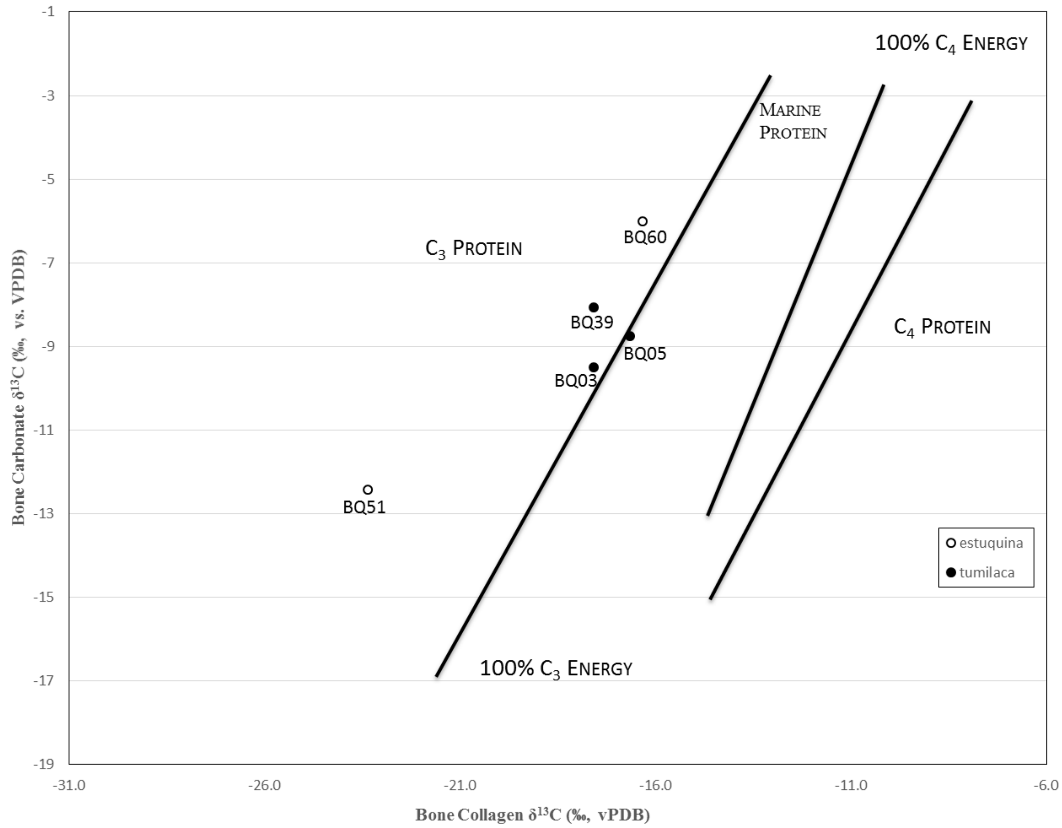
Figure 5. Bone Collagen $\delta^{15}N_{collagen}$ vs. Bone Carbonate $\delta^{18}O_{carbonate}$



6.4. Carbon Isotope values ($\delta^{13}C_{carbonate}$) vs Carbon Isotope values ($\delta^{13}C_{collagen}$)

A new analytical model to estimate the whole diet from $\delta^{13}C_{carbonate}$ and diet protein from $\delta^{13}C_{collagen}$ was proposed by Kellner and Schoeninger (2007). As shown in Figure 6, individuals from Tumilaca and Estuquiña were plotted along the three regression lines to analyze with more detail proteins and energy from C_3 and C_4 plants and marine proteins. Overall, Tumilaca and Estuquiña individuals had more access to proteins from C_3 plants and animals. The three individuals from Tumilaca (BQ03, BQ39, and BQ05) had a diet mainly from C_3 plants. In contrast, the two individuals from Estuquiña (BQ60 and BQ51) had a mixed food composed of proteins from C_3 plants, C_3 energy (fat and carbohydrates) and perhaps lake fish. Moreover, there isn't evidence of C_4 plants in the Tumilaca and Estuquiña individuals analyzed. See Figure 6.

Figure 6. Plot of $\delta^{13}C_{collagen}$ vs. $\delta^{13}C_{collagen}$ with regression lines for dietary estimation. Kellner and Schoeninger (2007)



6.5. Carbon ($\delta^{13}C_{collagen}$) vs. Nitrogen ($\delta^{15}N_{collagen}$) in the South-Central Andes

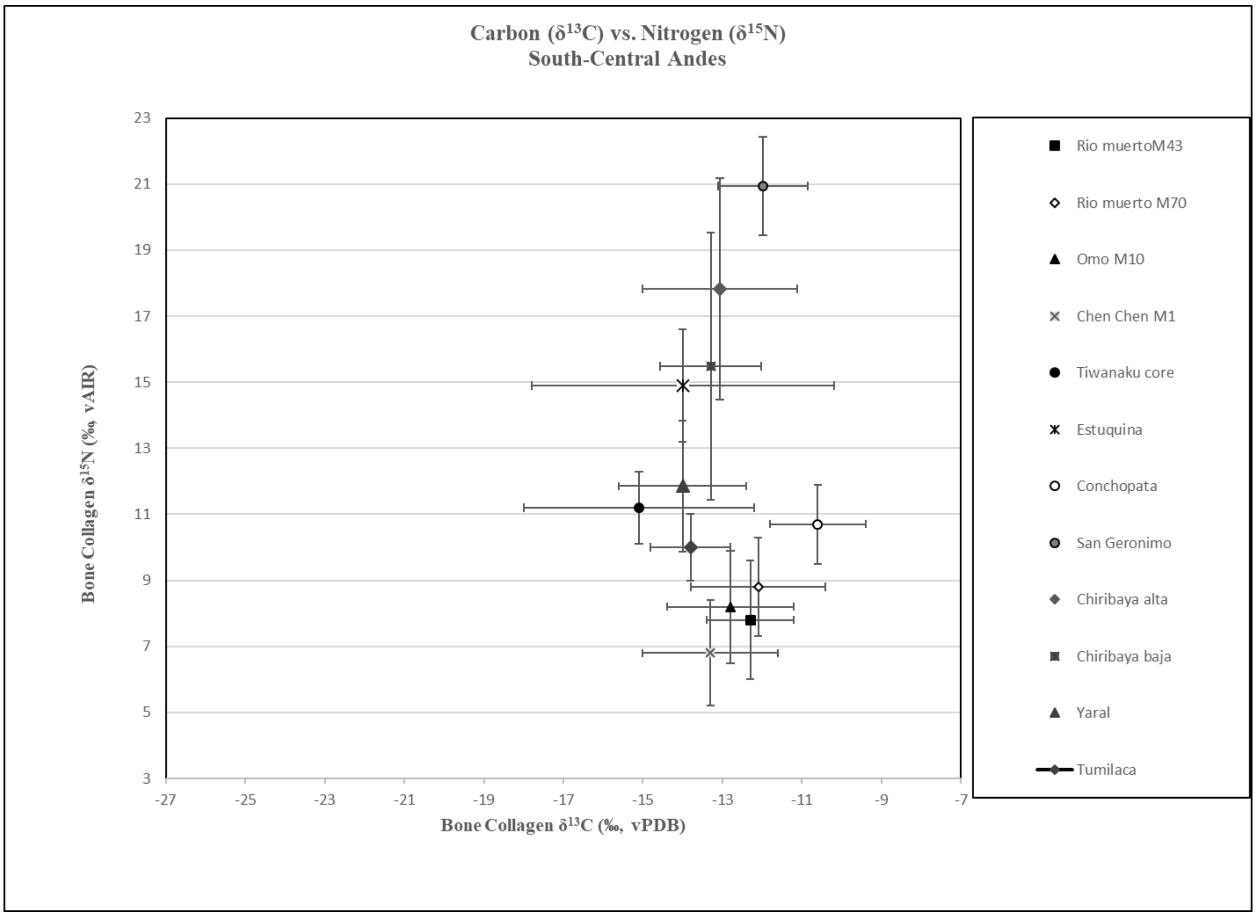
Overall, the average carbon ($\delta^{13}C_{collagen}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope ratios at Tumilaca la Chimba suggest that both Tumilaca (AD. 950-1200) and Estuquiña (AD. 1250-1470) populations had a rich diet based on C_3 plants with very low consumption of C_4 plants (maize) and limited access to terrestrial meat and fish. In comparison with a few isotope analyses in the region, Tiwanaku colonies (A.D. 500-1000) have more positive carbon isotope values ($\delta^{13}C_{collagen}$) than people who inhabited the upper Moquegua valley after the collapse. The average of carbon isotopic values ($\delta^{13}C_{collagen}$) in Tiwanaku colonies (Omo and Chen Chen) suggest that Tiwanaku residents had a rich diet in C_4 plants associated with maize consumption, supporting previous macrobotanical data in the Moquegua valley (Goldstein 2005). Moreover, carbon ($\delta^{13}C_{collagen}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope ratios reported by Berryman (2010) indicated differences in food consumption among populations from the Moquegua valley and the Lake Titicaca basin. Meanwhile, the average carbon ($\delta^{13}C_{collagen}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope ratios at Conchopata site (A.D. 500-1000) indicated a significant consumption of maize as the primary food in the highlands of Ayacucho. Meanwhile, Chiribaya sites, located in the coastal areas of Moquegua, have higher evidence of marine food with the exception of the site of Yaral. See Table 9.

Table 9. Stable isotope summary statistics from South-Central Andes

Author	N	Site	Mean $d^{13}C$	STDEV	Mean $d^{15}N$	STDEV
Somerville et al. 2010	13	Rio muerto M43	-12.3	1.1	7.8	1.8
Somerville et al. 2010	20	Rio muerto m70	-12.1	1.7	8.8	1.5
Sandness 1992	10	Omo M 10	-12.8	1.6	8.2	1.7
Tomczak 2001	14	Chen Chen M1	-13.3	1.7	6.8	1.6
Berryman 2010	57	Tiwanaku core	-15.1	2.9	11.2	1.1
Quispe 2018	3	Estuquina	-19	3.8	11.4	1.7
Quispe 2018	5	Tumilaca	-20.8	5.6	6.5	1.2
Tomczak 2003	22	San Geronimo	-11.98	1.13	20.94	1.48
Tomczak 2003	85	Chiribaya alta	-13.06	1.95	17.83	3.36
Tomczak 2003	17	Chiribaya baja	-13.29	1.27	15.48	4.05
Tomczak 2003	27	Yaral	-14	1.61	11.85	1.99
Finucane et al.2006	21	Conchopata	-10.6	1.2	10.7	1.2
Kellner and Schoeninger2008	26	Nazca	-12.9	0.7	8.8	1.2

The differences in dietary patterns between Tiwanaku colonies and Tiwanaku refugees could be linked to the Tiwanaku collapse in the Moquegua valley. During collapse people rejected Tiwanaku iconographies, textiles and wooden objects (Ponce 1972 in Bermann et al.1989), the two major Tiwanaku settlements, Chen Chen and Omo, were partially abandoned and people dispersed and migrated to the lower middle valley and uninhabited upper regions (Sutter and Sharratt 2010), and the intensive productive agricultural system was replaced by hillside terrace systems (Sutter and Sharratt 2010; Kolata 1985). Notably, the collapse in the middle Moquegua valley could have impacted the agrarian production of maize among Tumilaca populations which is revealed in osteological diseases reported by (Lowman 2017) and carbon ($\delta^{13}C_{collagen}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope ratios reported in this thesis. See Figure 7.

Figure 7. Plot of the carbon ($\delta^{13}C_{collagen}$) and nitrogen ($\delta^{15}N_{collagen}$) isotope average South-Central Andes



Using the Mann-Whitney U test, the nitrogen isotopic values ($\delta^{15}N_{collagen}$) from Tumilaca and Estuquiña populations are statistically different ($P< 0.024$). Meanwhile, carbon isotopic values ($\delta^{13}C_{collagen}$) indicated no differences between those populations ($P< 0.453$). See table 10.

Table 10. Mann-Whitney U test for Bone Collagen

	$d^{15}N$ Est. diet	$d^{13}C$ Est. diet
Mann-Whitney U	.000	5.000
Wilcoxon W	15.000	20.000
Z	-2.249	-.750
Asymp. Sig. (2-tailed)	.024	.453
Exact Sig. [2*(1-tailed Sig.)]	.036[b]	.571[b]

7 CONCLUSIONS

The site of Tumilaca la Chimba, located in the upper Moquegua valley, was inhabited in two different periods. The first occupation has been termed Tumilaca phase which is associated with the Terminal Middle Horizon or Tiwanaku collapse (A.D. 950-1250). Meanwhile, the second occupation is also known as the Estuquiña phase and associated with the Late Intermediate Period (A.D. 1250-1500). Investigations in Tumilaca sites demonstrated that cultural and biological affiliation existed between Tiwanaku colonies and Tumilaca populations. Whereas, the origin of Estuquiña population is unclear. Hence, this thesis study analyzes human remains throughout carbon ($\delta^{13}C_{collagen}$), nitrogen ($\delta^{15}N_{collagen}$), carbon ($\delta^{13}C_{carbonate}$) and Oxygen ($\delta^{18}O_{carbonate}$) isotopic values to estimate diet between Tumilaca and Estuquiña populations.

As mentioned before, I hypothesized that the Tumilaca population consumed mainly maize because of the cultural affiliation with Tiwanaku colonies. In contrast, I hypothesized that the Estuquiña occupation had a mixed diet based on C_3 and C_4 plants. Hence, I partially reject my hypothesis because Tumilaca people consumed more C_3 plants with low access to animal meat and fish. In contrast, Estuquiña populations had more varied diet in C_3 plants, and C_4 plants with more consumption of animal meat and perhaps access to lake fish.

Carbon ($\delta^{13}C_{carbonate}$) isotopic values from Tumilaca and Estuquiña populations indicated a small dietary difference between Tumilaca and Estuquiña populations. They both consumed high C_3 plants and low evidence of C_4 plants. Oxygen ($\delta^{18}O_{carbonate}$) isotopic values from Tumilaca and Estuquiña populations indicate that both populations drank water from the same local spring except two individuals (BQ58 and BQ02). The individual BQ58 (Estuquiña) has low oxygen isotopic values associated with people from the Lake Titicaca. Meanwhile, the individual BQ02 (Tumilaca) could be a local person who used and drank water from a different regional spring. However, the high oxygen ($\delta^{18}O_{carbonate}$) isotopic values associated with the individual BQ02 could be also associated with storage and preparation of water. More specifically, *chicha* preparation may affect the oxygen isotopic values of water during boiling (Knudson 2009).

Carbon and nitrogen isotope values ($\delta^{13}C_{collagen}$ vs. $\delta^{15}N_{collagen}$) from Tumilaca and Estuquiña populations indicated a high consumption of terrestrial C_3 plants, but low consume of C_4 plants. The moderate consumption of maize among Tumilaca population could be related to the political and cultural fragmentation between Tiwanaku colonies in the middle Moquegua valley and the heartland in the Altiplano basin. Meanwhile, Estuquiña population may have grown maize locally with low consumption in comparison with other populations.

The average of carbon and nitrogen isotope values ($\delta^{13}C_{collagen}$ vs. $\delta^{15}N_{collagen}$) among Middle Horizon populations (Rio Muerto M43, M70, Omo 10, Chen Chen M1, Titicaca Lake, San Geronimo, Chiribaya alta, Chribaya baja, yaral, Nazca and Conchopata) and Late Intermediate Period (Tumilaca and Estuquiña) also evidenced higher consume of maize before the collapse. The low evidence of maize consumption in the upper Moquegua valley could be linked to political fragmentation and later on with ritual practices. In contrast, macrobotanical evidence of *molle* seeds in Tumilaca and Estuquiña burials could be associated with cultural traditions, specifically with the production and consumption of fermented molle beverages.

Based on previous isotopic analysis in the middle Moquegua valley (Somervillet et al. 2015; Sandness 1992; Tomczak 2001), this study of collagen ($\delta^{13}C_{collagen}$ vs. $\delta^{15}N_{collagen}$) and carbonate ($\delta^{13}C_{carbonate}$ vs. $\delta^{18}O_{carbonate}$) isotope analysis represent the first attempt in reconstructing paleodiet and mobility among Tumilaca and Estuquiña occupations at the site of Tumilaca la Chimba in the upper Moquegua valley. Moreover, this thesis will contribute to understand and have a better panorama about post-collapse occupation, cultural interactions, and subsistence in the site of Tumilaca la Chimba.

Issues such as population sampling and diagenetic contamination of human remains have to be taken into account in future studies of stable isotopes analysis at the site of Tumilaca la Chimba. Enamel and dentin samples represent a better option to investigate diet and mobility among Tumilaca and Estuquiña populations. Moreover, different direct and indirect data have to be analyzed to reconstruct diet among Tumilaca and Estuquiña populations. Macro flora and faunal data and microbotanical remains have to be compared with isotope data available for archaeological populations in the upper Moquegua valley.

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