From State to Empire:
Human Dietary Change on the Central Plains of China from 770 BC to 220 AD

by

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Abstract

This study is designed to investigate human dietary features on the Central Plains of China during the social transition from regional states to centralized empire, which occurred during the period from the Eastern Zhou to the Han Dynasty (770BC-220 AD). Human remains from four sites and animal remains from one site dated within this period were sampled for stable isotope analysis. The faunal isotope data reflect variable animal husbandry strategies, probably corresponding with the economic values of different species. The animal remains included pig, dog, cattle, and sheep, all of which were the possible meat resources for both the Zhou and Han people, while pigs and dogs were the most common ones. The human isotopic data reveal different dietary practices between the Eastern Zhou rural and urban areas. The urban diet featured limited meat and a significant amount of wheat, and it was further stratified by social status: poor individuals in the city consumed more wheat than the wealthy. In contrast, contemporary rural people ate millet as their staple food and included slightly more meat in their diet. This likely indicates that Eastern Zhou urban diets suffered from constant warfare and the concentration of population in the city, while those of the contemporary rural people remained stable and similar to traditional diets before this era. The Han Dynasty witnessed significant changes in human diet, reflected in a substantial increase in the dietary proportions of wheat and meat. The most apparent feature of human diet during this transforming period is that status-related differences were reflected in the amount of wheat rather than meat in the diet.

This change was the first significant human dietary transition on the Central Plains since Late Neolithic times, and had profound influences on human diet and health in the following dynasties.

Along with the investigation of dietary change, this study also discusses several topics that the literature has, thus far, debated or addressed insufficiently. Based on temporal comparisons of stable carbon and nitrogen isotope values, the "bottom-up model" (from low social class to upper class) of wheat's expansion in human diet on the plains is supported, and the long-held belief by many experts regarding soybeans as a staple food has been rejected. Additionally, the possibility of manuring effects on human collagen isotopic values on the plains has been excluded. A comparison in the context of published data has revealed a unidirectional dietary difference between males and females in agricultural societies of the Zhou and Han dynasties, probably related to sexual division of labour. Dietary isotopes' potential as preliminary indicators of human mobility in China have been evaluated for the first time and the results are exciting. They demonstrate that distinctive dietary features are not only able to reveal possible individual immigrants, but are also capable of identifying possible moving populations.

In conclusion, the drastic social changes from state to empire affected human diets significantly. However, suffering during these chaotic times triggered a significant dietary change, which eventually benefited both individuals and society in ancient China. This study demonstrates the value of expanding the research aspects of dietary isotopes by re-analyzing the published data. It reveals the considerable potential of historical stable isotope studies to illuminate details of human diets previously invisible to other methods.

Preface

This thesis is an original work by Ligang Zhou. No part of this thesis has been previously published. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Dietary study on ancient people living on the Central Plains of northern China from the eighth century BC to third century AD”, Study ID “Pro00042774”, September 20, 2013.

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Glossary of Terms Spelled in Chinese *pinyin* 拼音

Beiqian	北阡
Bencao gangmu	本草纲目
bo	伯
cai	菜
Chenjiagou	陈家沟
Chunqiu	春秋
dafu	大夫
Dahecun	大河村
Dahuting	打虎亭
ding	鼎
Dongheigou	东黑沟
Duogang	多岗
Erlitou	二里头
fan	饭
gong	公
Gouwan	沟湾
Gu'an	固岸
guo	椁
Han Dynasty	汉代
Han state	韩国
Haojing	镐京
Haozu	豪族
Heigouliang	黑沟梁
hou	侯
hu	斛
Huhewusu	呼和乌素
Hulaoguan	虎牢关
Jiahu	贾湖
Jinggouzi	井沟子
li	鬲
Li Ji	礼记
lieding zhidu	列鼎制度
Liuzhuang	刘庄
Luoyang	洛阳
Mian Chi	渑池
Nalintaohai	纳林套海
nan	男
Nanzhai	南寨
Qianzhangda	前掌大
qing	卿
Qinglongquan	青龙泉
Qinshihuang	秦始皇
Qiongkeke	穷科克
Quanrong	犬戎
Sandaowan & Bagou	三道湾& 叭沟
Sanyangzhuang	三杨庄
Shen Nong	神农
Shenmingpu	申明铺
shi	士
Shi Jing	诗经
shu	黍
su	粟
Tainli	天利
Tianyuandong	田园洞
Tuchengzi	土城子
Xindianzi	新店子
Xinzhai	新砦
Xinzheng	新郑
Xipo	西坡
Xishan	西山
Xuecun	薛村
Yan Tie Lun	盐铁论
Yangdi	阳翟
Yanshi	偃师
Yin Xu	殷墟
Yu Gong	禹贡
Yu Zhou	禹州
Zhenghan g cheng	郑韩故城
Zheng state	郑国
Zhou Li	周礼
zi	子

1. Introduction

As an essential requirement for human survival and development, food is of fundamental importance to both ancient and modern societies. Food and diet of past populations thus provide a unique window into ancient cultures, and have attracted increasing attention from historians and archaeologists during recent decades. Dietary features of ancient people were subject to both natural factors such as environment, climate, and resources, and cultural factors including food-procuring technology, social restraints on food access, and many other variables. The elements conditioning historical diets may leave visible archaeological traces in diverse and fragmentary forms that are hard to interpret, or they may leave nothing observable at all. Either way, there is a dearth of knowledge on paleodiet and a lack of reliable information. This dilemma has been improved greatly thanks to developments in archaeological science that enabled the application of stable isotope analysis (SIA) in paleodietary research. Rather than relying on diverse and fragmentary material remains or textual records, SIA has incorporated human and animal tissue values into the evidence pool as a major information source for paleodietary studies. It is now possible to uncover aspects of ancient human diet from perspectives that were invisible before.

Due to their lack of textual records, prehistoric periods have always been the traditional focus of paleodietary studies that use SIA. Topics such as subsistence changes, evolution of food-procuring technologies, origins of agriculture, the expansion of cultivated crops, animal domestication and husbandry strategies have been widely discussed in different parts of the world through SIA, contributing significantly to the understanding of prehistoric societies. Meanwhile, interest in the diets of historical populations, particularly those of imperial societies, is also growing. Fascinating discoveries have shed light on dietary patterns in different ancient empires. In Europe, research on the imperial period of Rome has revealed that urban and suburban diets differed, and that noticeable dietary heterogeneity existed in common people living during the first to the third centuries AD; this was consistent with related literary records (Killgrove and Tykot, 2013). As reflected by isotopic data for human remains from Dorset, the conquest of England by the Roman Empire brought about substantial social, cultural, and environmental changes, and influenced the diet of its people as well (Redfern et al., 2012). In the Americas, the Mayan elites' diets varied remarkably throughout time in terms of maize consumption and trophic level, while commoners' diets remained stable (Somerville et al., 2013). After its annexation by the Inca Empire, human diet and health changed little at Puruchuco-Huaquerones, Peru, despite the significant sociocultural changes that took place (Williams and Murphy, 2013). Both of the New World examples reflect distinct dietary features when compared with the European ones, illustrating the many unique dietary patterns and adaptive strategies possible in response to different natural and sociocultural circumstances. These discoveries have not only demonstrated the great potential of applying SIA in dietary studies of historical eras (complemented by more supplementary evidence than prehistoric times) but have also triggered curiosity about human diet in other ancient empires. China has been of particular interest: its first empire was established in the east during the third century BC, and its major accomplishments would endure for over two millennia.

Chinese culture is probably one of the most food-oriented in the world (Chang, 1977, p.11; Simoons, 1990, pp.13-15; Knechtges, 1986). There are numerous case studies illustrating different facets of China's relationship with food. The bronze tripod-vessel *ding,* a food container used in sacrificial banquets, was a prestigious status symbol of hierarchical status for nobles and also represented state sovereignty during the Zhou Dynasty (1045-256 BC) in ancient

China. It subsequently became a core representation in many social rituals (Zhang WJ, 2012). The Chinese also emphasize food in early written documents: the Warring States Period (480-221 BC) philosopher Gao Zi said "the appetites for food and sex are human nature" (Bloom trans., 2009, p.122). In 204 BC, the Han Dynasty politician Li Yiji remarked to the sovereign that "people are of unparalleled importance to the emperor, and food is of paramount importance to the people" (Ban, 1962, p.2108 [1st century AD]), a phrase now known to all Chinese people. With this context in mind, human diet would open an important window into ancient Chinese society and culture, as well as the interactions between people and socioeconomic fluctuations.

The era from the Spring and Autumn Period (770-481BC) to the end of the Warring States Period (480-221BC) in ancient China witnessed significant changes in politics, society, and scholarship (Qian, 2005, pp.3-5). Many territorial states were unified, and the first centralized empire was established in 221 BC. The transition from territorial states in conflict to a united empire was by no means peaceful. The number of recorded wars among different states between 770 and 221 BC varies from 614 to 762 in different studies (Editorial Board, 1985, p.3; Military Museum, 1994, pp.21-118; Wang and Qi, 2013); regardless, disagreements on specific numbers do not erase the high frequency of conflict. Constant military struggles inevitably resulted in long periods of instability and great human suffering. A series of reforms were implemented in different states in order to logistically support military competitions, and these consequently boosted regional economies. For example, land privatization led to higher efficiency for farmers, and lifting the ban on natural resources harvesting resulted in prosperity for handicraft industries and commerce, which promoted the emergence of metropolises (Qian, 2005, p.4). The complex scenario of instability and suffering coexisting with significant prosperity during this period raises the question of how it affected the daily lives of ordinary individuals. Some answers may be found in the contents of their diet.

Following unification, early imperial dynasties of the Qin (221-207BC) and Han (206BC-220AD) benefited greatly from the reforms and prosperity of the previous era. After the powerful but short-lived Qin, the Han soon developed into a flourishing and influential eastern empire, playing an important role in ancient world history. While benefiting greatly from the achievements of the previous era of territorial states, the early imperial period also displayed substantial differences: "Chinese culture during this period [the Qin and Han dynasties] is distinct from the societies that evolved out of it" (Lewis, 2007, p.1). This dissertation will investigate whether or not the significant differences between the era of territorial states and the early imperial period altered human diet.

These questions have rarely been considered before, despite the fact that Chinese scholarship has placed a high emphasis on ancient food and diet (likely resulting from the influence of the food-oriented culture). There are tremendous numbers of academic works falling under the category of dietary studies, and these are mainly descriptive works based on ancient texts or material remains discovered by archaeologists. However, the bias of historical documents and the fragmentary nature of archaeological remains have limited the depth of these studies, leaving much space unexplored, especially in the interaction between socioeconomic changes and human diet.

The current study is designed to fill in these gaps by investigating the dietary features of ancient Chinese people during the transformational period from 770BC to 220AD. In contrast to traditional works, this study mainly relies on SIA of skeletal remains. Stable isotope values of human and animal remains from the two different periods will serve as this paper's major evidence, while textual and archaeological information will be used to facilitate the interpretation of isotopic data. Considering the natural and cultural diversity within the vast territory of China, attempting to cover the whole country during a time span of nearly one millennium in a single study is obviously unwise. This study will therefore focus on the Central Plains of northern China, the main political centre that witnessed many of the major changes during the period in question. It seeks to find answers to the questions raised above and uncover new information about ancient Chinese diet.

Stable isotopic values from human and animal bones reveal the truth of how a complex social context affected human diet during the era of territorial states, and whether human diets from the prosperous imperial period differed from the previous era as did other aspects of culture. This study will shed light on the relationship between humans of different statuses and society in the context of this particular social transition.

This dissertation will be organized according to the following outline. The current chapter briefly introduces the study. Chapter 2 provides a basic introduction to the historical period and to the existing evidence gathered by previous studies. Chapter 3 introduces the methodological background. The archaeological background of selected human and faunal samples are presented in Chapter 4. Chapter 5 lists the results of stable isotope analysis of each site and presents site-level interpretations. Chapter 6 discusses the major questions targeted in this study through inter-site comparisons. Chapter 7 concludes the study.

2. Background

2.1 Brief History

The Zhou Dynasty (1045-256 BC) was the last Bronze Age regime in China, established by the *Ji* clan after the overthrow of the Shang in 1046 BC. The Zhou Dynasty was a royal state located in northern China, composed of regional political entities ruled by members of the Zhou king's clan or allies. Scholars formerly believed that the Zhou Dynasty ran a feudal system featuring a cluster of proto-independent powers under limited influence of the king (Li, 2013, pp.128-129). However, this has been corrected recently in light of new discoveries from bronze inscriptions demonstrating that the regional states were active participants in the political activities held by the Zhou royal court rather than independent kingdoms (Li, 2013, pp.129-132). The regional states respected royal sovereignty, paid tribute to the king and joined his sacrificial ceremonies regularly. Additionally, they also participated in military actions commanded by the king. This has demonstrated that the Zhou king played a powerful role as a common lord and the state was effectively controlled.

The year 771 BC was a noteworthy moment in Zhou history. The nomadic pastoralists from the northwest, referred to as *Quanrong,* broke into the capital city Haojing (in Xi'an city of Shaanxi Province) and killed the Zhou king. After this disaster, King Ping, who inherited the throne, decided to abandon the destroyed capital Haojing and move the royal court the next year to Luoyi (in Luoyang city of Henan Province) located in the eastern plains. It is clearly stated in historical documents that the relocation of the capital city was intended to avoid threat from the nomadic pastoralists (Sima, 1959, pp.149 [1st century BC]). The Zhou regime's waning was reflected in the fall of the capital and the following retreat. Its deterioration was not merely a sudden incident, but a consequence of generations of corruption and political struggles among royal family members and high-rank officials (Li, 2013, pp.160-161). Internal strife gradually undermined the authority of the king and exhausted the trust and respect of regional rulers.

A new era began in 770 BC with the relocation of the capital city to the east. The Zhou royal court was never able to restore its influence and the king, who still bore the title, nevertheless became a nominal figure. In this context, the aggressive and powerful regional states began to launch military competitions and annexations seeking hegemony; some of them threatened to overthrow the throne. In brief, the centuries following 770 BC can be characterized as “big fish eating small fish” (Li, 2013, pp.183). The number of regional powers shrank from several hundred to only seven in the first half of this new era, and eventually dropped to one after all the other six were gradually annihilated during the latter half.

Historians usually refer to the earlier phase of the Zhou Dynasty as the Western Zhou (1045 -771 BC) and the later as the Eastern Zhou (770 -256 BC) according to the geographical locations of the two capital cities. The former capital was in the northwest, while the latter was situated on the eastern plains. Based on variations in social and political circumstances, Eastern Zhou has been further divided into two eras. The first was the Spring and Autumn period (SAP, 770 -481 BC), named after the chronicle *Chun Qiu* (Spring and Autumn Annals). This text records the major historical events year by year from the fall of the Western Zhou in 771 BC to 481 BC. The second era is titled the Warring States period (WSP, 480-221 BC), named because of the frequent wars among the regional states during these years. There is no disagreement on dividing the Eastern Zhou into two periods, but opinions vary on the choice of a specific year to mark the division, a debate of which Falkenhausen (2006, pp.7-8) has presented a detailed review elsewhere.

The Eastern Zhou dynasty ended in 256 BC when the last king died without leaving any inheritor. However, the Warring States period lasted three more decades until the Qin state finally defeated its last military rival and established a united empire in 221 BC. Although powerful, the Qin Empire (221-207 BC) was rather short-lived due to its tyrannical style. It was overthrown by a peasants' revolt shortly after the death of its founding emperor *Qin Shihuang* (The First Emperor of Qin). Following this, a revolt leader named Liu Bang, established the second centralized empire in ancient China, known as the Han Dynasty (206 BC-220 AD).

The history of the Han Dynasty was divided into two phases by a short usurpation led by Wang Mang. Wang Mang was a high-ranking official serving the Han royal court. He seized the throne from the child-emperor in 9 AD and established the Xin Dynasty (9-24 AD). However, this replacement regime did not last long. Liu Xiu, a member of the royal lineage, soon restored the Han Empire. The period predating the Xin Dynasty is known as the Western Han (206BC-8AD) and the latter period started by Liu Xiu's rule is referred to as the Eastern Han (25-220 AD), following the same reasoning as used in the naming of the Western and Eastern Zhou. During its four centuries of rule, the Han Empire achieved significant success in economic development, military expansion, and cultural prosperity, and became one of the most influential empires in the world at the time.

Details of China's history from the Eastern Zhou to the Han Dynasty can be found elsewhere in both Chinese (e.g. Bai, 1994, pp.359-565; Bai, 1995, pp.173-449; Fan, 1995, vol.1: pp.105-275; Fan, 1995, vol.2: pp.3-205; Lu, 1992, pp.330-380) and English (e.g. Hsu, 1965; Loewe and Shaughnessy, 1999, pp.450-659; Twitchett and Loewe, 1986, pp.20-376; Li, 2013, pp.162-282). A basic chronology of this period is listed in Table 1.

The reign of the Qin Empire was too short to leave many identifiable remains on the Central Plains, and it is also doubtful that such a short regime would cast visible influence on people in terms of diet. So this study only focuses on remains predating and postdating the Qin, including the Eastern Zhou (both SAP and WSP) and the Han Dynasty.

Table 1 Brief Chronology of Chinese History from the Zhou Dynasty to the Han Dynasty[1]

Dynasty (Period)			**from**	**to**
Zhou	**Western Zhou**		1045 BC	771 BC
	Eastern Zhou	Spring and Autumn Period	770 BC	481 BC
		Warring States Period	480 BC	221 BC[2]
Qin			221 BC	207 BC
Han	**Western Han**		206 BC	8 AD
	Xin		9 AD	24 AD
	Eastern Han		25 AD[3]	220 AD

Note: 1. The chronology follows Li (2013).

2. The end of the Eastern Zhou was in 256 BC, and the Warring States Period ended in 221 BC

2.2 Social Structure and Archaeology

The era of transition from territorial states to empire witnessed numerous social changes in areas including politics, economy, and scholarship (Qian, 2005, pp.3-5). Most of these are out of the scope of the current study; however, the following sections will introduce the changes in social structures that were most likely to affect food access and subsequently shape human dietary features. This section also presents related archaeological findings as complementary data to enhance the understanding of social structural changes.

2.2.1 The Eastern Zhou: sumptuary rules and social hierarchy

Literary documents of the Zhou times, either passed down through later writers or excavated, are mostly oriented toward the noble class. Thus, they have provided insight into the sumptuary rules regulating people of the upper stratum and shed light on parts of the social structure of the time.

The Western Zhou maintained a rigidly stratified society with the king at the pinnacle of the hierarchical system. Officials in the court and regional lords made up different layers of the noble class, ruling the lesser nobles beneath them along with the majority of the population. Textual records suggest that there was a "Five Ranks" system applied to the Western Zhou nobles. Five titles including *gong* (duke), *hou* (marquis), *bo* (earl), *zi* (viscount), and *nan* (baron) were given to regional rulers and royal court officials to determine their status according to their kinship distance to the king. However, whether this system was successfully implemented is doubtful (Li, 2008). During the Eastern Zhou, the previous rank system was reshaped due to the wane of royal authority and the rise of regional nobles. Decline of royal influence allowed regional states to enjoy independence, and their former regional rulers were politically equal in status regardless of their inequality in power. The hierarchical system was then redefined within each terrestrial state. Regional rulers were at the top of the social hierarchy and were all referred to as *gong* (duke). Two grades of ministers referred to as *qing* (minister) and *dafu* (great officer) were found below the *gong* respectively, and the lowest level of nobles was called *shi* (knight) (Hsu, 1965, pp.5-7).

The differences in nobles' status were not only reflected in their titles; they also materialized in daily life. Ancient documents record the status-determined number of ritual bronzes each class of noble was entitled to, particularly the tripod-vessel *ding* used by the Eastern Zhou nobles in sacrificial banquets (see Yu and Gao, 1978a, 1978b, 1979 for a review). This differentiation has been supported by archaeological findings. Ritual bronzes were usually buried as funeral objects following their owner's death, and some of the inscribed bronzes reveal their possessor's identity to archaeologists. Excavated evidence indicates that the numbers of ritual bronze *ding* used by the upper three ranks (*gong, qing, dafu*) were nine, seven, and five respectively and the lowest rank *shi* could only use three or one on different occasions (Yu and Gao, 1978a, 1978b, 1979). Although exceptions do exist, most of the archaeological cases dated to the early half of the Eastern Zhou agree with this correlation (Zhang WJ, 2012). Therefore, the number of bronze *ding* has been a relatively reliable criterion to identify status of a SAP tomb's occupant when other forms of evidence are unavailable. The practice of representing noble status with the number of bronze *ding* is thus taken as one of the visible sumptuary rules in the SAP and referred to as *lieding zhidu* (a system using *ding* tripod as representation of status) by Chinese archaeologists. Two recent studies (Zheng, 2009; Zhang WJ, 2012) have reviewed this topic from the combined perspectives of textual records and archaeological discoveries, and offered detailed lists of references for further information.

Along with the number of ritual bronzes, a holistic analysis of unearthed materials has confirmed that the sumptuary rules of SAP society are also represented in tombs in many varying forms, including size of tomb, burial furniture, and other contents (Falkenhausen, 2006, pp.98-111). The sumptuary rules observed in a noble cemetery might only be applicable to the same lineage (Falkenhausen, 2006, p.100); this is probably why the numeric criterion introduced above does not work for all archaeological cases.

These sumptuary rules gradually faded during the latter half of the Eastern Zhou (WSP) when major changes took place and the kinship-based social structure was completely destroyed. Some high-ranking nobles might have been impoverished after losing their territories in military conflicts, while the lowest rank *shi* became more active on the historical stage because blood-lineage constraints were removed. Accordingly, shifts between formerly rigid social levels became common (Hsu, 1965, pp.24-39). A statistical analysis of the status background of historical figures (as recorded in known documents) has revealed that most of the influential individuals in the WSP were of obscure origin or without any connection to noble lineage (Hsu, 1965, pp.38-39). In this context, the ancient sumptuary rules might no longer have been effective and the archaeological practice of judging noble status by the number of unearthed bronze *ding* should be done with caution.

Below the ruling elements and noble class who were subject to sumptuary rules, Eastern Zhou society was made up of three other layers: peasants, merchants and artisans, servants and slaves (Hsu, 1965, pp.2-14). Similar to the situation in Greek and Rome where literary sources typically neglect the rural world by focusing on the elites (Morris, 1992, p.179), these people comprised the majority of the population and provided the necessities to sustain the society, but received the least literary attention in ancient China. However, their burial remains are archaeologically distinguishable from those of the nobles; they lacked luxury funerary objects such as bronze and jade, and their arrangements were always very simple. Further hierarchical classification among these three lower social layers and their temporal variations is currently impossible, though inequalities in their status might have existed.

The known archeological settlement remains of the Eastern Zhou have not provided much valuable information about social structure. Since the 1950s, excavated settlements of the Eastern Zhou have been mostly capital cities of different regional states. These sites demonstrate the prosperity of ancient Chinese metropolises and the luxurious life of the high-ranking nobles, as well as the highly developed handicraft industry (Wang, 1999). However, there is no clue as to how nobles of varying ranks differed in their residences or daily life. Unfortunately, little information about rural life is known either. Eastern Zhou rural settlements have long been archaeologically understudied (Wang, 1999), partly due to the bias of archaeologists' research interests toward the big cities, and partly because of the lack of literary clues to their locations. The hierarchies inside or between rural settlements suffer from neglect in literary documents and an imbalance in archaeological research, and thus remain ambiguous. Burial remains have so far been the only material source supporting the study of Eastern Zhou social structure.

2.2.2 The Han Dynasty: ranks and social structure

The Han Empire ran a highly centralized efficient government. Aside from a few wars caused by internal conflicts during early years, the empire's military actions were mostly concentrated in border areas, particularly in the north and northwest where they defended themselves against the powerful Xiongnu. Thus, the major imperial territory was free of warfare for centuries and people enjoyed a relatively peaceful life, in contrast to the Eastern Zhou's high frequency of warfare.

There were mainly three strata that comprised the Han society. The emperor, other royal members, and vassal kings (who enjoyed the honor of their titles but never took control of the fiefs they were granted) were at the top. Officials of different levels and other citizens inhabited the middle, and at the lowest stratum were commoners, slaves, and prisoners (Ch'ü, 1972, pp.63-151; Li, 2013, pp.288-294).

The hierarchical system of the Han Dynasty, known as the "Twenty Ranks System" and directly inherited from the Qin Empire, was mainly applied to the middle stratum of society. This system was much more complex and institutionalized than the "Five Ranks" of the Zhou. Notably, ranks in the Han system were bestowed to citizens to recognize their contributions to the country: they could be accumulated and altered. Zhou ranks, conversely, were only given to members of the king's lineage based on kinship orders and they were fixed at birth. In addition to being more meritocratic, Han ranks were also widely granted at a relatively high frequency to all citizens on occasions of national celebrations such as the new emperor's enthronement, the prince's capping ceremony, and other such events (Loewe, 1960; Zhao, 1997). This might seem to indicate that the ranks were only symbols of the benevolence and generosity of the Han emperor. However, the ranks were by no means nominal or empty; each of them conveyed material advantages and other privileges including granting of estates, reduction of legal punishment, and exemption from certain obligations (Loewe, 1960; Zhao, 1997). It is worth noting that the cumulative ranks and the high frequency of rank-granting events did not mean that every Han citizen was eligible to ascend from the lowest (the first) to the highest rank (the twentieth), which was just below vassal kings. Only the lowest eight ranks (the first to eighth) were granted to citizens without an official position in the government, while the other twelve (the ninth to twentieth) were reserved for officials only (Loewe, 1960; Zhao, 1997; Lewis, 2007, p.110). Evidently, the “Twenty Ranks System” was itself unequal; the middle layer of the society was further divided into different levels. In addition to the works cited here, there are a number of scholars that can be referred to for further information on this ranking system (e.g. Zhu, 1990; Ninshijima, 2004; Yang, 2012).

Unlike individuals in the middle social tier, people of the lowest strata were ineligible for higher ranking. They were slaves, prisoners, and non-rank commoners mostly composed of free peasants shouldering the burden of the empire by producing its necessities. Excavated Han legal statutes state that these different roles within the lowest social layer were also treated differently by law; for instance, slaves were clearly higher in status than prisoners (Li, 2013, pp.288-294).

Although complex, the Han ranking system and social hierarchy are clearly recorded thanks to abundant historical records and unearthed documents. However, social stratification is much less clear in archaeological contexts. Rarely was there any material representation of these ranks, and as a result it is currently impossible to differentiate them archaeologically. Among the thousands of Han tombs discovered during the past centuries, those of the top stratum were easily identified because of historical records on their locations or special burial objects (such as the well-known Jade Clothes Sewn with Golden Thread, exclusively used by royalty). Only a small number of tombs have been identified as belonging to high officials in the middle social layer. These identifications are based on occasionally unearthed seals carved with names or official titles, or other written evidence (Song, 1994, pp.140-162; Zhao and Gao, 2002, pp.33-101). For the majority of the middle layer tombs and all those of the lowest strata, it is still hard to tell the identity, status, or rank of their occupants.

There have, however, been attempts to differentiate the burial remains in terms of social ranks and correlate their owners with specific social classes. Zha (1990, p.233) divided Han tombs into seven groups and tentatively assigned their occupants' identity as: (1) the emperor and empress, (2) vassal kings and marquis (the twentieth rank), (3) officials from the prefecture to the county level, (4) lower officials and landlords, (5) rank holders without official position (first to the eighth rank), (6) non-rank holders, and (7) prisoners. Zha (1990, pp.233-274 and 319-366) identified several examples from each of the seven groups in Western and Eastern Han cemeteries respectively based on literary records, burial structure, and other forms of evidence. In another study using burial remains as indicators of social status, Western Han tombs below those of the emperors and empresses are assigned to five levels according to their occupants' status: (1) vassal kings and marquis (the twentieth rank), (2) the nineteenth to ninth rank, (3) the eighth to first rank, (4) peasants, and (5) poor peasants (Li, 1991, pp.245-247). However, social identities of the five levels of the Western Han tombs differed greatly from that of the Eastern Han in the same study. Vassal kings, marquis, generals and high civil officials were assigned to the top level in the Eastern Han; deputy prefecture governors and county magistrates were the second level; the third level included low officials, landlords, and rich peasants; and common peasants and poor peasants were assigned to the last two levels respectively (Li, 1991, pp.386-387). Discrepancies between the hierarchical systems employed by the two studies, as well as the differences and ambiguity of the standards applied in each work, have made it difficult to apply them in archeology. As such, archaeologists usually do not attempt to correlate the tombs with specific social groups by postulating the occupants' social rank or status, although variations in tomb scales and burial goods are still significant (Zha, 1990; Li, 1991; Song, 1994; Zhao and Gao, 2002).

It should be noted that economic capacity might be a stronger indicator of burial arrangements than social status in the Han Dynasty, and the two were often inconsistent. The situation of merchants can be taken as an example. They were commoners and politically discriminated against in the Han Dynasty. Simultaneously, they were economically superior to most commoners and even to some low-ranking officials (Ch'ü, 1972, pp.113-122). Some great merchants were as rich as high officials and lived very extravagant lives, as depicted in textual sources (Ch'ü, 1972, pp.114-116). As a result, lavish burials do not necessarily represent high status and vice versa, resulting in a complicated relationship between social hierarchy and its material representation.

In addition to burials, settlements dated to the Han Dynasty have provided another window into Han social life. Urban settlement remains of this period have been excavated and studied for centuries, demonstrating the skillful design of Han cities, as well as the prosperity of handicraft industries such as metallurgy, mining, and salt producing (for a review, see Liu, 1999; Zhou, 2001; Zhao and Gao, 2002, pp.34-54). Little was known about rural life until the discovery of the Sanyangzhuang site in 2003 (Liu et al., 2004; Liu and Zhang, 2008; Kidder et al., 2012). This is a large Han rural settlement composed of villages, courtyards, roads, and fields, which were all entirely preserved by the gentle alluviation of the Yellow River. For the first time, this offered material evidence with which to study the economy and social structure in rural Han areas. In Sanyangzhuang site, archaeologists have already located thirteen courtyards and excavated four of them (Liu and Zhang, 2008; Liu et al., 2010). Independent courtyards belonged to single families and were surrounded by trees and farmlands, with the distance between courtyards varying from 25 to 50 meters. All the discovered remains vividly illustrate a self-sufficient rural life prior to flooding (Liu and Zhang, 2008). However, as social stratification has not been well represented so far in either cities or rural settlements, further studies are still required.

2.3 Background Information on Human Diet

2.3.1 General background

The special cultural emphasis on food in China is probably rooted in its long history of agriculture, which can be traced back 8000 years to Middle Neolithic times (An, 1988; Lu, 1999, pp.132-133; Ren, 2005). Chang (1977, pp.7-8) stated that at the base of the highly distinctive Chinese food culture is the division between *fan* (the staple food or grain food) and *cai* (the meat and vegetable dishes). The following section gives a general background on human diet in ancient China and uses Chang's *fan/cai* division.

Results of archaeological flotation studies suggest that several staple crops, including millet, rice, wheat, barley, sorghum, and soybean, have been grown in China since the Neolithic Age (An, 1988; Chen, 1990, pp.23-51; Kong et al., 2003; Zhao, 2011). Despite the ongoing debates on the origins of some species, cultivation of all these crops in the Zhou and Han Dynasties is unquestionable with the exception of sorghum, which should be excluded from the list based on the most recent evidence. Previous studies based on archaeological remains argued that sorghum had been grown in China since the Neolithic (Fan, 1997), or no later than the Western Han Dynasty according to a conservative opinion (Li, 1986). However, the sorghum remains dated from the Neolithic to the Tang Dynasty are now of questionable authenticity, given that they lack reliable supporting information such as measurement records or photographs (Liu et al., 2012). A re-analysis of the only proposed ancient sorghum remains with photographic records has revealed that these so-called earliest sorghum seeds, excavated from the Dahecun site in northern China, were in fact soybeans (Liu et al., 2012). Therefore, the cultivation of sorghum in the Zhou or Han Dynasties lacks reliable support. Genetic studies have recently clarified that Chinese sorghum is of African origin and likely spread into China via the Indian subcontinent (Zhang H et al., 2011; Billot et al., 2013); however, the exact time of this expansion still requires investigation.

The importance of each staple crop varied throughout time. From its onset, Chinese agriculture established two independent systems, the millet-based system in the north and the rice-based in the south, probably due to distinct environmental conditions. The borderline between the millet zone and the rice zone was not so clear; for example the well-known Jiahu site yielding 8000-year-old rice remains was located in northern China (Kong et al., 1996), demonstrating that rice had been grown in the north for a long time. More rice remains have been found from later sites in northern China, further confirming the existence of a blended zone growing both millet and rice (Wang and Xu, 2003; Liu and Xiang, 2005). Despite the blending of these two grains in some areas, the wetland crop (rice) could never be planted in the north on a large scale due to environmental constraints. Millet was the dominant northern grain: its role was established about 8000 years ago (Sun et al., 1981; Tong, 1984). However, the coexistence of millet and rice in the north was challenged after a new crop, wheat, was introduced into China around 4000 years ago, and spread quickly from the west to the east after its appearance (Jin, 2007; Dodson et al., 2013). This exotic grain finally overtook the dietary predominance of millet in northern China, but the exact timing of wheat's expansion into human diet of some areas is still not clear as reviewed by a recent study (Zhou and Garvie-Lok, 2015). This further suggests that wheat was still a minor grain compared to millet in the middle and lower reaches of the Yellow River during the sixth century AD based on published isotopic data.

Another important aspect of diet in China is non-grain dishes, including meat and vegetables. Ancient Chinese people procured meat from all the available aquatic and terrestrial resources by way of fishing, hunting, or animal domestication (Yuan, 1999). Fish is one of the earliest animal protein resources shown to have been exploited by anatomically modern humans in China (Gao, 1992; Yuan, 1999). Analysis of multiple stable isotopes has proved that fish consumption in China can be dated back to about 40000 years ago when the early modern humans in Tianyuandong Cave incorporated freshwater fish into their diet (Hu et al., 2009a). Fishing tools and skeletal remains of aquatic species are common in Neolithic sites from both the north and south (Wu, 1987), demonstrating the widespread nature of fishing and the importance of water resources in prehistoric human diets. Hunting wild animals was also a dependable way of acquiring meat and was widely practiced in Neolithic China as well (Yuan, 1999). Domestication of terrestrial animals appeared later than the former two practices but also provided the most stable meat supply; it took place in China postdating plant cultivation and pottery making (Yuan, 2001). Studies on archaeological animal remains have suggested that the earliest animal domestication in China was accomplished on dogs no later than 10000 years ago; following that were pigs (9000 years ago), sheep (5000 years ago), cattle (4000 years ago), horse and goat (3700 year ago), and chicken (3600 years ago) (Chen, 1990, pp.259-263; Yuan, 2001; Yuan, 2010). The majority of these livestock species in China had been domesticated mainly for the purpose of obtaining meat. Milk and dairy products, although highly appreciated by the upper strata in the Tang Dynasty (618 to 907 AD) (Chang, 1977, p.7), have not been widely accepted by the Chinese even in very recent times (for a review see Simoons, 1990, pp.458-460).

The extensive knowledge that Chinese people acquired about wild plant resources, which composed the majority of vegetable dishes, demonstrates the notable adaptability of Chinese diets (Chang, 1997, pp.7-9). Legend in China says that *Shen Nong* (The God of Agriculture) of far ancient times tasted hundreds of plants to determine their virtues for his people (He, 1998, p.1312). An ancient medical expert, Li Shizhen, documented over 1800 plants in the encyclopedic pharmaceutical book *Bencao Gangmu* compiled over 400 years ago. Each entry includes a statement of edibility. Such a large body of plant knowledge is attributed to generational accumulation in addition to the experiments and tests conducted by Li Shizhen himself. Both of these examples reflect China's long history of exploiting wild plant resources, partly as food resources. In addition to literary evidence, archaeobotanical studies lend support to the long history of plant usage in ancient China (Kong et al., 2003; Yu, 2011, pp.8-11). Exploitation of wild plants greatly enriched the list of vegetable dishes in Chinese diets, and some species could be identified through pollen, photoliths, carbonized seeds, kernels or other forms of floral remains. However, current knowledge on wild plants utilized for food in ancient times is still limited due to the huge number of potential choices and the paucity of archaeological evidence. Thus, an accurate list of these species incorporated into ancient diets is unavailable so far.

Alongside staple foods and dishes, the drinking of alcoholic beverages has also been of considerable significance in Chinese diets. This can be traced back to about 9000 years ago when Chinese people began to ferment beverages from rice, honey, and fruits (McGovern et al., 2004). Millet-based beverages have also been discovered in some later periods (McGovern et al., 2004). The remains of alcoholic beverages were only found occasionally in very unique preservation contexts, but drinking vessels made of clay or bronze displayed a high popularity in different archaeological sites (Li, 1993; McGovern et al., 2004; Huang et al., 2008), confirming that drinking had long been an important dietary component. There is not much evidence to pinpoint the raw materials used to ferment beverages consumed in historical periods because of the limited scale of archaeological samples. However, it can be assumed that the ingredients would not exceed the range of available grains and fruits in the associated eras.

The dietary styles formed in Neolithic times were preserved as basic dietary features through the following Bronze Age and succeeding historical dynasties. Details likely varied in different periods due to changing socioeconomic contexts, and it is thus necessary to further clarify the dietary situation in the Eastern Zhou and Han Dynasties respectively. The current study is focused primarily on northern China, and the following informational sections will thus also be centered on the north.

2.3.2 Food and diet in the Eastern Zhou

Information on human diet in the Zhou Dynasty is mainly obtained from textual sources, such as the folklore collection *Shi jing* (Book of Songs) and official documents including *Zhou Li* (The Rituals of the Zhou Dynasty) and *Li Ji* (Records on Rituals). However, literary sources do not agree with each other on the number of staple crops planted in this period. The variety of grains grown in the Zhou Dynasty is variously cited as "five grains", "six grains", "nine grains", or "hundreds grains" in different sources, though "five grains" is the best-known across China (Shinoda, 1987, pp.6-10; Yin, 1997; Song, 2002). The Japanese expert Shinoda (1987, pp.6-10) suggests that this renowned concept of "five grains" was likely derived from the philosophical theory of "five elements". While frequently referred to across a variety of literature, the species of the "five grains" change in many documents, sometimes include more than five types. Despite literary contradictions, experts have gradually come to agree that the main staple crops planted in the Zhou Dynasty did not vary significantly from those of the Neolithic age, and that the most common grains were millet, rice, wheat, barley, soybean, and hemp (Chang, 1977, pp.26-27; Wang, 2006; Chen WH, 2007; Yu, 2011, pp.42-46 etc.). The possibility of growing sorghum during this time period has already been excluded (see section 2.3.1).

As in the Neolithic age, these crops did not have equal importance. Millet was still the major grain in the north from the Western Zhou to the SAP, as reflected in historical documents (Qian, 2009; Hsu, 1984a). There were at least three species of millet grown in ancient China (Chang, 1977, p.26-27; Qian, 2009). The two main species were *su* (foxtail millet) and *shu* (broomcorn or common millet); they were frequently referred to vaguely as “grains” or “cereals” in some ancient texts (You, 1993; An et al., 2010). Their names and differences are still under debate; however, this will not be considered in the current study because they are similar in their isotopic signature. Finally, it is possible that millet was the only important grain grown before the SAP, and the flourishing of “five grains” or the spread of other minor grains appeared after the WSP (Qian, 2009).

Rice, although cultivated in some regions, was unlikely to have been very common in the north due to environmental constraints. Instead, rice was likely a luxury grain for the nobles in the Western Zhou and became available to commoners in the Eastern Zhou only at high prices (Hsu, 1984b). Yet another study proposes that rice was exclusively used for making wine in the Western Zhou and was not widely available for commoners, even in the Eastern Zhou (Qian, 2009). While these two opinions vary slightly, they agree that rice was an uncommon grain in the north and was not available to most people.

In documents of the time, wheat was not treated with great importance, and neither were barley or hemp. Archaeological evidence for these grains is sparse. Soybean's status, however, is more controversial. Some experts believe that it was a staple crop in the early Zhou period, though inferior to millet, because it was always listed among the "five grains" or "hundred grains" mentioned in different sources (Song, 1987; Gu, 1992; Yang, 2000). Soybean probably gained a status equal to millet during the WSP since it was then often mentioned together with millet, and there were warnings that the failure of millet and soybean would cause famine and endanger the state (Song, 1987; Yang, 2000). Others argue that soybean might only have served as a staple food in barren regions (Hsu, 1984a), or might have been actually eaten as a major vegetable supplementary to grains (Knechtges, 1997).

Most of our knowledge about meat consumption in the Zhou era comes from ancient texts about the noble lifestyle. For example, *Zhou Li* lists six beasts and six fowls as meats eaten on different occasions by the upper class. The species of these beasts and fowls vary in different interpretations of the *Zhou Li* as reviewed by Knechtges (1986), but it is clear that they were many. Potential species exploited for meat by the Zhou nobles included both domesticated animals (cattle, sheep, pig, and dog) and wild mammals (bear, deer, and rabbit), domesticated and wild fowls, and aquatic species such as fish and shellfish (Hsu, 1984b). Some of the species listed here have been identified in Zhou tombs from different areas (e.g. Cai et al., 1994; Song, 2011). The only animal that was not likely to be eaten is horse, because of its irreplaceable role in war and transportation.

Fish was of significant importance in the nobles' diet. On the personnel roster of the king's kitchen recorded in *Zhou Li*, there were 342 fish specialists out of the almost 4000 persons working on the diet of the king, outnumbering any other specialists in grains, meat, or sauces

(Chang, 1977, p.11). Documentary information also suggests a well-developed fishery industry in the Zhou Dynasty, and over 20 species of freshwater fish were farmed (Zhou, 1985). Freshwater species from rivers and inland lakes might have comprised the majority of aquatic meat resources. Literary clues on marine species are sparse, and marine skeletal remains discovered from northern inland areas are also few and far between. Currently, the only reported case of marine fish remains from these areas is from the Shang capital site, Yin Xu, located in Anyang of Henan Province (Wu, 1949). These has been no further cases reported from its contemporary sites or later excavations. However, marine shells were frequently found in Shang or later sites as personal adornments or representation of wealth (Li, 2007; Zhang TE, 1991), confirming communications between the inland areas and the coastal regions. Therefore, the possibility that some high ranking nobles consumed marine fish cannot be excluded.

Meat consumption appears to have also been subject to social status. In this highly stratified society, diet (mainly meat) was closely linked to rituals and social status (Shen, 2001). For example, the bronze *ding* -tripods of the Zhou Dynasty were used to contain meat in banquets; sumptuary rules assigned each rank a number of bronze vessels and specific meat species. The number of different types of meat decreased with descending ranks (Zhang WJ, 2012). The highest rank, represented by nine *ding*-tripods, was served with the richest meat dishes, including beef, mutton, pork, dried fish, dried meat (of other unknown species), intestines, tenderloin, fresh fish, and fresh meat (of other unknown species), while the lowest rank only had meat of suckling pig (Zhang WJ, 2012). This highly rigid dietary stratification had significant social effects. It is recorded that in the Eastern Zhou, several wars among the vassal states of Song, Zheng, Qi, and Wei were triggered during feasts where improper meat was served to aristocrats who felt insulted and looked for a chance to avenge themselves (Shen, 2001).

Zhou nobles valued fresh meat and fresh fish over dried meat or fish, as indicated by the rank-related variation in meat dishes. Additionally, archaeological findings of temperature controlled crypts or underground icehouses located inside or close to some capital cities appear to corroborate this assertion (Ma, 1986; An and Li, 1991). These underground facilities, accompanied with the variety of terrestrial and aquatic meat foods described in texts, seem to emphasize the luxury of the Zhou noble's diet. However, Hsu (1984b, p.248) suggests that such luxurious meals might only have been served on special events and were not for frequent consumption. The usual meat supply for those dukes who were of the nine-*ding*-tripod rank might be "no more than two chickens per day" (Hsu, 1984b, p.248). According to this interpretation, the most common meat resources in Zhou times are believed to have been pork, dog, fish, chicken (and eggs), and turtles (Hsu, 1984b; Knechtges, 1997). The potential discrepancies between the literary diet and actual diet has thus raised a question for further study.

Besides grains and meat dishes introduced above, a great variety of plants that were consumed as vegetables by the Zhou people are recorded in *Shi Jing* (Liu, 2008). Amongst the hundreds of plants documented in this book, there are about 30 species of edible wild vegetables, 18 species of wild fruits, and a few cultivated fruits (Liu, 2008; Pan and Lu, 2003, pp.10-11; Wang, 2006). As vegetables and fruits only played a supplementary role in the diet and are usually not the focus of isotopic studies, their species are not listed here in detail.

A significant proportion of discussion to this point has been spent on the nobles' diet, but that of the Zhou commoners remains obscure. The fragmentary information gleaned from folklore collected in *Shi Jing* indicates that in contrast to the luxurious diet of nobles, commoners frequently suffered from famines and had to rely on wild plants for survival (Liu, 2008). This noble-commoner dichotomy in diet is also evidenced in many other sources where the upper strata are always referred to as “meat-eaters” (Huang, 2012). This rhetoric likely conveys resentment from people of the exploited classes, but it also reflects that meat was likely regarded as a privileged food resource that was not available to commoners.

To draw a brief conclusion based on textual records and the rare archaeological findings, the Eastern Zhou people grew and ate all the staple crops inherited from their Neolithic ancestors, including millet, rice, wheat, barley, hemp, and soybean. The dietary predominance of millet is unquestionable; other grains were inferior to millet and their dietary roles are still open to discussion. Meat resources were composed of a large variety of terrestrial and aquatic animals, including both domesticated and wild species. Meat consumption was subject to social status, and this caused the key noble-commoner dichotomy in diet. The potential discrepancy in details of meat consumption between literary records and actuality is a notable topic for future research.

2.3.3 Food and diet in the Han Dynasty

Compared to the Zhou period, the evidence on diet in the Han dynasty is quite diverse. It includes tremendous volumes of textual records, diverse forms of funeral art recording different aspects of daily life, and some archaeological food remains from tombs. Consequently, there is no disagreement that the main crops planted in the Han times were similar to those of the Zhou, including millet, wheat, rice, barley, hemp, and soybean (Yin, 1997; Hsu, 2005, pp.77-84; Chen WH, 2007; Yu, 2011, pp.96-99). These are all among the names of grains painted on pottery barns discovered in Han tombs excavated in Luoyang, and some of these species have been identified from the carbonized remains inside the vessels buried with the dead (Luoyang, 1959, pp.154-159; Chen, 1961).

However, the dietary significance of different crops might have changed substantially; the predominance of millet in the north seems to have been challenged by wheat. Some experts believe that wheat was widely planted in Han times and elevated to a position equal to millet, which dominated the Zhou era and earlier times in northern China (e.g. Huang, 1982; Li, 1997, pp.8-10; Jin, 2007; Hsu, 2005, pp.79-81). Other voices are conservative, saying that although wheat agriculture in the Han Dynasty expanded, this grain was still less important than millet and it did not attain its predominance until the Tang Dynasty (618 to 907 AD) (Wang, 2000, pp.70-72; Zeng, 2005; An et al., 2013). Yu (1977) corroborates this assertion with an analysis of textual records. These conflicting arguments are all based on historical records from different sources, which contradict each other in different ways. For example, there are sources stating that the Han government had policies for promoting wheat agriculture (Hsu, 2005, pp.79-81). The success of this wheat promotion is doubtful, because there are also records indicating that wheat was still valued much less than millet, even during a time of great scarcity at the end of the Han Dynasty. In this great famine of 194 AD, cannibalism occurred and all grain prices rocketed, but the price of millet (500000 coins per *hu*) was 2.5 times that of wheat and soybean (200000 coins per *hu*) (Fan, 1965, p.376), indicating that wheat was still not viewed as equal to millet by people even in extremely hard times.

Other crops such as hemp and soybean were also grown in different proportions: the Han government promoted an integrated farming system and encouraged peasants to grow “five grains” including millet (two species), wheat, hemp, and soybean, so as to forestall potential crop failure due to natural disasters (Ban, 1962, p.1120 [1st century AD]). Some argue that soybeans were probably the main protein resource for commoners in ancient China, who had only limited access to meat (Zeng, 2012). It was also an important crop in Han times, but its actual role was still as obscure as in the Zhou Dynasty. The importance of soybean may have declined because it was considered less delicious than wheat, which was widely planted then (Hsu, 2005, p.82). Others argue that the importance of soybean was elevated, since utilization of millstones by the Han people increased soybean consumption by improving the taste of soy-based foods (Chen WH, 2007), and that soybean farming reached its peak in the Qin and Han periods (Yu, 2011, pp.98-99). Soybeans and water are recorded as the main survival foods of the poor (Ban, 1962, p.3682 [1st century AD]), and an agricultural book of the time recommends soybean as an important crop for famine resistance (Wan, 1957, p.129). The abundance of diverse evidence makes the exact dietary role of soybean more complicated.

Rice cultivation in northern China increased to some extent in the Han era (Li, 1997, pp.13-15; Hsu, 2005, pp.83-84)). However, it remained a minor grain due to environmental constraints: the region mainly practiced dry agriculture, and rice was not on the list of government-promoted "five grains."

While information about grains can be collected from textual records and enriched by archaeological finds, meat resources for the Han people are studied in different ways. Food remains in burials are an ideal source of information, but they are only available in very rare cases due to preservation conditions. Fortunately, other archaeological findings, particularly various forms of funeral art, are able to fill in the gaps by providing valuable details on meat foods likely consumed in the Han Dynasty.

Chinese of the Han times believed that dead people would continue their life in another world after death, and there were different beliefs about the afterlife mingled together (Loewe, 1982, pp.25-37). They were also convinced that in the afterlife, people would have similar requirements to those of the living, such as houses, barns, water wells, cooking stoves, livestock and poultry, and even servants, all of which were represented by pottery models or figurines interred into tombs. Furthermore, scenarios of daily life were vividly illustrated in mural paintings, stone reliefs, brick carvings, and other funeral art forms, either to record the life experiences of the dead, or to convey blessings for well-being in the afterlife from their beloved ones. These varying forms of funeral art have provided dietary information from a unique angle.

The kitchen scene is ubiquitous among funeral murals, and it reveals valuable information on dietary culture, particularly meat resources (Yang, 1991; Wei and Han, 1997). A few examples are given as follows. The meats hung on the racks laid out in the mural paintings from northeast China include pig head, leg and tripe of unknown animals, rabbits, pheasants, dried fish, and fresh fish (Li, 1955). These are also seen in painted scenes found in various tombs from Inner Mongolia in the north, which indicate that meats being prepared in the kitchens included pheasants, rabbits, fish, chickens, cattle, sheep, and some other unidentifiable animals (Luo, 1956; Inner Mongolia, 1974; Working Team, 1978, pp.20 &119-120). In a tomb from Shandong in the east, stone reliefs illustrate a fish lying on the chopping board of a kitchen; as well, a pig is being carried to the butcher on a pole with four feet tied together and a cow is being hit on the head by a mallet, which was probably the most effective method of butchering this large animal (Jiang and Li, 1954, figure 29). Another kitchen scene found from the same province displays turtle, fresh and dried fish, rabbit, pig head, pheasant, and intestines all hung on the rack; a cow, a sheep, and a pig are being butchered, and fish and chicken (or duck) are being processed (Ren, 1981). Similar thematic contents have also been found in central China. The kitchen scene in the Dahuting Han Tomb of Henan province illustrates two meat racks hanging unidentifiable terrestrial animals, fowls, and fishes (An and Wang, 1972). Although it is difficult to identify the particular species of animals hung on the racks, a cow's head and a leg can be seen on the ground just under the racks, and there is also a fish dish carried by a woman in the picture. No regional variation is discernible in the contents of these kitchen scenes. The abundant meat resources reflected by them can be divided into three main categories: terrestrial animals, fowls, and aquatic species. The identifiable terrestrial animals include pig, sheep/goat, cattle, dog, and rabbit. Horse was very rarely treated as food according to the figures (Yang, 1991). The most common fowl was a pheasant with a long tail, distinct from other domesticated or wild birds; following it are chicken and duck, then other unknown birds. Aquatic species mainly include fish and turtle, and a more specific identification of the species is unavailable.

In addition to the kitchen scene, the other commonly depicted content in Han mural paintings is the feast, which has also vividly informed our view of human diet in the era. By analyzing the feast scenes and descriptive literary records, Yu (1977) listed a number of the meat and vegetable dishes that were served in Han times. The raw materials of meat dishes depicted in feast scenes do not exceed the animal species reflected in kitchen scenes. However, feast scenes illustrate additional details on how they were served at table.

Besides paintings or stone carvings, pottery figurines of cattle, sheep/goat, dog, pig, chicken, duck, fish, turtle, and many other animals are frequently discovered in Han tombs (Jiang, 2011; Wei, 2014). This provides information on both animal husbandry and potential meat resources for the Han Dynasty. Molded or carved patterns on pottery models of cooking stoves also shed light on meat resources. There are fish, turtles, chickens, ducks, and sometimes heads of cattle and sheep molded or carved on the upper surface of the stoves (Zhou, 2009; Huang, 2011), indicating that these animals were commonly seen in the kitchen and were probably eaten frequently.

However, whether the contents of funeral art should be taken as a direct reflection of daily life or considered as blessings for the afterlife requires attention. Lavish funerals prevailed in the Han Dynasty (Zhang JF, 1995; Hao, 2007), and it is recorded that some people would treat their parents frugally when they were alive in order to save money for an elaborate funeral after their death (Fan, 1965, p.1315). This indicates that the funeral arrangements might sometimes have been exaggerated compared to real life. As such, depictions in funeral art should not be taken directly as evidence of a luxurious Han lifestyle. The variety of meat foods reflected in kitchen scenes, as introduced above, informs us that they were meats known to the people, perhaps eaten on special events, and unlikely to be served in high frequency in everyday life. The most common meat sources for the Han people might not have exceeded pig, dog, and chicken, which Han government policy promoted as good domestic species for every household (Ban, 1962, p.1120 [1st century AD]).

Meat resources seemed to have been widely available in Han times without any constraints or limitations. As the Han document *Yan Tie Lun* (Discourse on Salt and Iron) records, scholars complained that "in ancient times the nobles would not kill cattle, sheep, dogs, and pigs except for special events, but now there are butcheries everywhere and it is common to see people trading millet for meat", "on sacrificial events, the rich ones kill cattle, the middle class eat sheep and dogs, and even the poor have pigs and chickens to eat" (Wang, 1992, pp.351-352). This suggests that meat consumption increased, probably due to the prosperity of commerce and development of animal husbandry, and that economic status was likely to have been the only factor that affected access to meat resources.

In contrast to the abundant information on meat foods, vegetables were rarely portrayed in any form of funeral art, likely demonstrating their supplementary role in human diets. Vegetable species used in Han times did not differ much from those of the Zhou except that some central and western Asian species were added to the list after the expansion of trading (for a review see Anderson, 1988, pp.31-34). As all of them were served as complementary dishes, the added new species were unlikely to have caused significant effects on the main dietary components. Although these foods were crucial for vitamins, minerals, fibre and variety, they were low in protein and calories and it is accordingly difficult to detect them isotopically.

In brief, it can be seen that the main staple crops of the Han dynasty were similar to that of the Zhou, but the dietary significances of millet, wheat, and soybean might have changed substantially. Potential meat resources reflected in funeral art, including a variety of terrestrial and aquatic animals, were as abundant as those of the Zhou. However, pork, chicken, and dog were probably the most common meats for the Han people. In comparison to earlier eras, meat provisions may have increased in the market, and meat foods may have been more widely available. Finally, the dietary dichotomy between nobles and commoners or rich and poor was not frequently emphasized in literary sources, but this still requires further confirmation.

2.4 Questions Arising from Previous Works

The previous sections introduced the dietary background of the Zhou and Han Dynasties and listed the main features of human diet during these two periods. However, each scenario is still far from clear due to details either untouched or debated, usually because of the limitations of written documents and the paucity of useful archaeological information. Most importantly, the available information is not able to uncover the effects of social transition on human diet. This study therefore intends to seek answers for these unanswered questions in order to fill in gaps in the scholarly record and improve the understanding of human diet during social transition. The following are the specific questions arising from previous works that will be targeted in the current study:

(1) **What are the dietary roles of different grains during the two periods?**

Answers to this question drawn from previous text-based studies are ambiguous. Millet dominated the grains during the Zhou times and seemed to have been challenged by wheat in the Han Dynasty, but disagreements also exist. The importance of soybeans likely fluctuated from Zhou to Han, displaying either elevation or a downward shift as argued by different experts. The role of soybeans as a staple crop is also suspect. The dietary features of the transforming period will not be clear unless the debates on staple grains are settled with strong evidence.

(2) **What are the proportions of terrestrial and aquatic species in meat resources during these two periods?**

The dietary proportion of aquatic and terrestrial resources is another important factor characterizing the dietary practices of a population, and has not yet been discussed for the eras this paper covers. Although the Zhou capital was located in the inland area, ritual documents put a high emphasis on fish in the nobles' diet. The Han funeral art in different regions, either inland or coastal, also indicate that aquatic species (fish or turtles) were incorporated into people's meat resources, likely at a lesser rate than terrestrial species. However, to what extent the literary records or funeral art reflect the truth requires further investigation. In other words, the literary emphasis on aquatic resources in inland areas calls for attention, and it is necessary to evaluate the importance of aquatic resources in inland human diet of the two periods.

(3) Did meat consumption vary in different population groups?

Variations in meat consumption and their hierarchical implications may be the best way to approach social transition through human diets. However, researchers need to first test information on important topics such as the reality of luxury banquets depicted in texts or funeral art, the possible constraints on meat consumption in different periods, and the dietary dichotomy between nobles and commoners. Status-related comparisons of stable isotope values will evaluate the suggested dietary dichotomy between nobles and commoners and create reliable information on social structure. Additionally, comparison between males and females will tell us more about their social roles and diet in the imperial period, which is another topic not focused on in previous studies.

(4) Did human diet vary in urban and rural areas in the Eastern Zhou?

Prosperous commerce in the Eastern Zhou Dynasty helped develop many metropolises. New lifestyles would likely enrich and diversify food resources for urban populations as compared to rural ones. However, cities were always military targets during this period, and urban areas might have suffered more from the wars than their rural counterparts. The dietary features of these two areas may have varied subject to different social and economic contexts; and this assumption needs to be tested.

(5) Has the dramatic social change from territorial states to a unified empire affected human diet?

After the questions listed above are answered respectively for different periods, the study will be able to draw a clear picture of the human diet in each period from different perspectives, including staple grains, meat resources, overall level of meat consumption, and possible social constraints on food resources. This will allow any temporal changes to become clear, reflecting the possible effects of social change on human diet.

(6) **If there are changes in human diet during social transition, are they meaningful changes or just expected fluctuations?**

This paper will also conduct a long-term dietary comparison based on published isotopic data in the target area in order to observe the human dietary changes within a wider time scale. The long-term observation will be able to discern whether a dietary shift in a single site was just an expectable fluctuation or if it actually reflects meaningful temporal change. This is also the way to evaluate the historical influences of a dietary change on later periods.

2.5 Study Region: the Central Plains in Northern China

The 'Central Plains' has been used to refer to the middle and lower reaches of the Yellow River in some historical documents, a region that covers the whole of Henan Province and parts of many other nearby provinces along the river (Editorial Committee, 1996, p.133). However, the borderlines are ambiguous and hard to define. Nowadays this term is widely taken to refer mainly to the plains area of Henan Province, the territory of which roughly equals that of the *Yu Zhou* (Yu province) located in the centre of the nine provinces as recorded in the ancient document *Yu Gong* (Editorial Committee, 1996, p.133). To avoid any possible confusion, the use of the geographical term 'Central Plains' in this study follows its current meaning and refers to the plains of the current Henan Province only.

Located in central China, Henan Province features a diverse landscape including both fertile floodplains and mountains, with the Yellow River running through from the west to the east (Figure 1). The plains area, which is the well-known Central Plains, covers the vast majority of the territory (31°23′-36°22′ N latitude; 110°21′-116°39′ E longitude). Climate on the plains is generally temperate and displays distinct seasonal fluctuations resulting from the East Asian monsoon effect in summer and the vast Siberian anticyclone influence in winter. Modest temperatures (annual average =10.5-16.7℃) and precipitation (annual average = 408-1296 mm) [1] greatly benefit the growth of crops on the fertile floodplains, turning this area into one of the most important agricultural centres in China. Moreover, the Central Plains' role as a transportation nexus has also been established with the construction of highway and high-speed railway networks in recent decades, created due to the advantageous geographical location.

Thus, the Central Plains' geographical advantages in agriculture and transportation have been realized from Neolithic to contemporary times. The region has always had an important role in China's politics, economics, and culture (Zhang KS, 2001; Yang and Sun, 2002; Liu, 2006; Wen et al., 2013). The abundance and continuity of the cultural remains left in this area enable a chronological reconstruction of ancient Chinese prehistory and history beginning from the Neolithic era, demonstrating that the Central Plains witnessed and experienced most of the significant events in the history of ancient China. Along with its core position in history, the Central Plains played an irreplaceable role in Chinese archaeology. It has significantly impacted both the development of archaeology in China and the prosperity of interdisciplinary research in

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[1] Specific information is cited from official website of the provincial government: http://www.henan.gov.cn/hngk/zrdl/

archaeology, on which Yang and Yuan (1997, pp.2-26) have presented a detailed review elsewhere. This paper will give a brief contextual overview, in the following section.

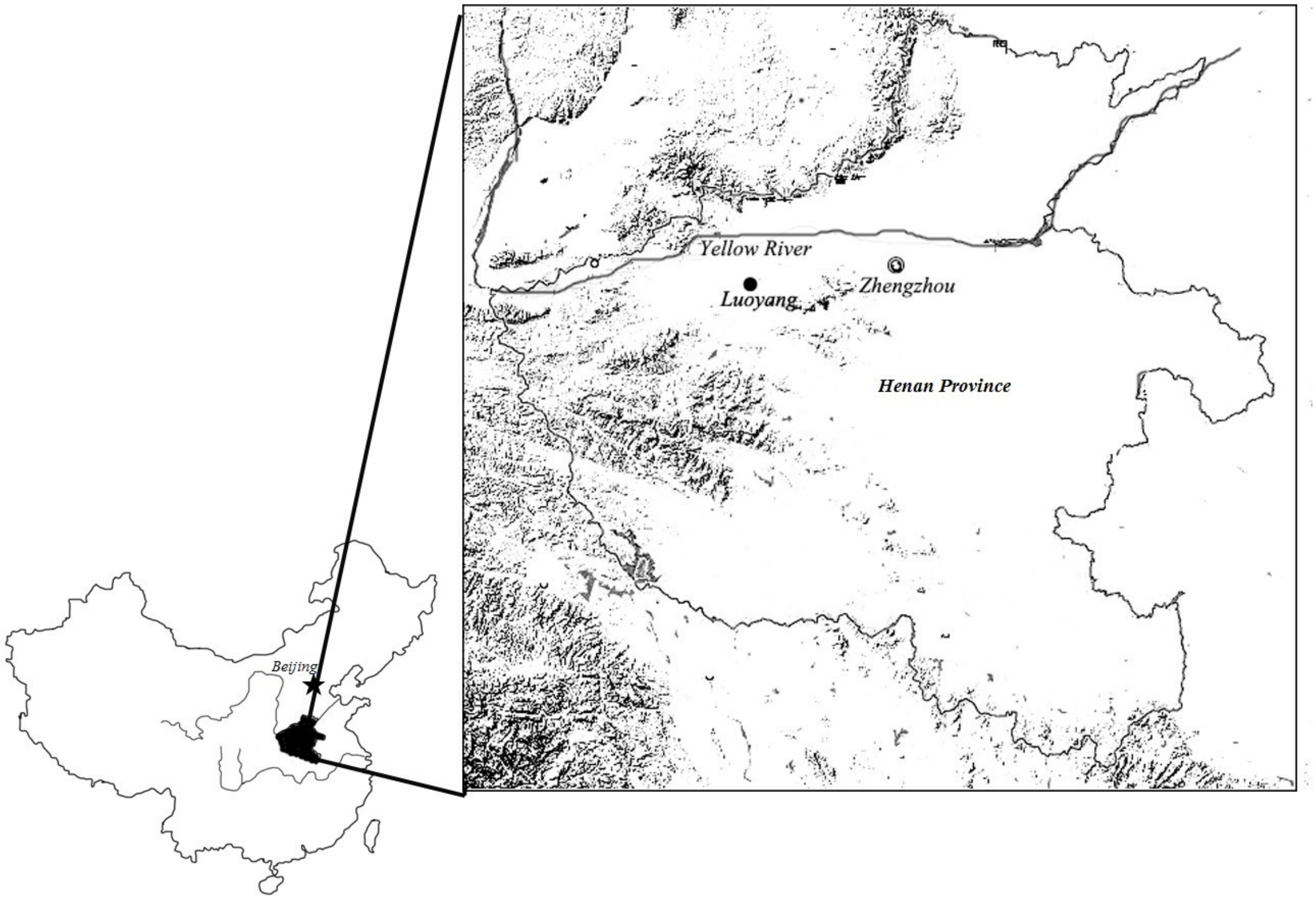

Figure 1. Location of the Central Plains in China

In the 1920s, the Central Plains witnessed the initiation of modern archaeology in China marked by two excavations in the area. The first one is the well-known Mianchi village excavation, conducted on a Neolithic site by Swedish scholar Johan Gunnar Anderson in 1921. Following the Mianchi excavation was the first independent excavation led by Chinese archaeologists on the Bronze Age palatial *Yin Xu* in 1928. Up until new China was established in 1949, most archaeological projects were practiced in this area, including investigations of a number of famous Neolithic and Bronze Age settlements and cemeteries. These early discoveries saw the birth of modern Chinese archaeology and fostered the first generation of Chinese archaeologists. After the 1950s, increasing construction projects brought about numerous new finds in this area. Excavations of a series of settlements and cemeteries in the plains, ranging from Paleolithic times to the imperial periods have established the framework of archaeological chronology in China, and also facilitated the development of theories and methods of Chinese archaeology (Yang and Yuan, 1997, pp.2-4). In this sense, the Central Plains area is the cradle of modern Chinese archaeology.

Modern archaeological sciences and interdisciplinary research in Chinese archaeology since the 1990s have been increasingly applied due to two national archaeological projects centered in the Central Plains: the “Xia-Shang-Zhou Chronology Project” and the “Project of Detecting the Origin of Chinese Civilization”. The chronology project saw the first attempt to establish historical chronology by radiocarbon dating (Guo et al., 2000). Afterwards, AMS radiocarbon data from three major ancient city ruins on the Central Plains solved the long-debated issue of dating the three Bronze Age dynasties (Yang, 2001). In addition to traditional research methods based on archaeological stratigraphy and typology, newer methods such as zooarchaeology, botanical archaeology, environmental archaeology, paleodietary analysis and many others have also been applied in the second project, yielding valuable information on the origins of early Chinese civilization (Fang, 2008; Wang, 2012). The Central Plains thus continue to play an influential role in Chinese archaeology.

The Central Plains have unquestionably been the key area for deciphering the historic transition from state to empire in the Eastern Zhou and Han Dynasties. This region was the political center of the Eastern Zhou after the relocation of the royal court to Luoyang city, erected in the west of the plains (Figure 1). The plains were controlled by over 50 regional states in different areas (Yang and Yuan, 1997, p.425). The royal court and regional states left hundreds of cities of varying scales on the plains, about 176 of which have been located by archaeologists and the rest of which are only seen in ancient documents but not yet discovered (Shang, 2007, p.5-6). Among these cities, the Eastern Zhou royal capital in Luoyang and the capital of the once powerful states Zheng and Han in Xinzheng have received intensive studies because of their historical importance and good preservation. In addition to city remains, the innumerable Eastern Zhou tombs ranging from the level of kings and dukes to commoners buried under the plains have also demonstrated the archaeological significance of the region (Yang and Yuan, 1997, pp.449-491).

The political center of the Han Dynasty was set in the northwest during the first half of its history, but was relocated back to the Central Plains when the Eastern Han founding emperor Liu Xiu decided to also settle his capital in Luoyang. The prosperity of the empire resulted in high population density on the plains and left an abundance of material remains buried underground. Besides the capital city, there are also a number of prefectural cities located in this area which are not well studied. In the 1950s, the first chronological framework of pottery typology and burial forms of the Han Dynasty was built based on the tombs discovered in the outskirts of the Eastern Han capital city Luoyang (Luoyang, 1959); this was a milestone in Han archaeology in China. In the following decades, thousands of Han burials, from the royal class to commoners, have been exposed in different parts of the plains by salvage excavations. Recently, the discovery of the well-preserved rural settlement Sanyangzhuang has for the first time shed light on the agriculture and rural life of the Han people (Liu et al., 2004; Liu and Zhang, 2008; Kidder et al., 2012). All of these findings have added weight to the role of the Central Plains in Han archaeology.

During the period from 770BC to 220AD, royal courts of the Eastern Zhou and Han were settled on the Central Plains for over seven centuries (770-256 BC, 25-220 AD). Thus, the plains were the most important political center of the time: they suffered from intense warfare amongst the regional states, witnessed the collapse of the Eastern Zhou, experienced the Qin Empire unification, and housed the prosperity of the Han Empire. The fluctuations of history have left a rich source of archaeological remains in this area to inform our contemporary reconstructions of the transition from state to empire. More importantly, human and animal skeletal remains are generally well preserved thanks to the modest precipitation on the plains, and are valuable materials for isotopic investigations on human diet in the context of social transition. On consideration of these historical and archaeological advantages, the Central Plains is the ideal place to delve into the questions concerning human diet and social changes from states to empire in ancient China.

3. Background to Stable Isotope Analysis

As introduced in section 2.4, prior research based on literary records or archaeological evidence has produced ambiguous or even conflicting results on many issues concerning human diet, and also overlooked several key points. In order to overcome these limitations and draw a clearer picture of human dietary features during this period of social transition, the current study applies stable isotope analysis (SIA) to address the many questions raised from previous studies.

3.1 Stable Isotope Analysis and the Study of Paleodiet

3.1.1 Essentials on stable isotopes

All the essentials on stable isotopes introduced in this section are taken from Sharp (2007). Isotope is the general name given to atoms of an element with the same number of protons but different number of neutrons. The isotopes of an element that never undergo radioactive decay due to their stable proportions of neutrons to protons are called stable isotopes. In stable isotopes, varying numbers of neutrons cause differences in nuclear mass, resulting in distinct thermodynamic and kinetic properties. Therefore during physical and biochemical processes, molecules composed of stable isotopes with different nuclear mass will undergo fractionation or partitioning depending on specific conditions. This means that some stable isotopes are excluded while others are concentrated when a process moves from one stage to another, eventually causing variable isotopic composition at different stages of the process.

Essentials on the stable isotopes of the two elements most commonly used in paleodietary analysis, carbon and nitrogen, are briefly introduced as follows. Carbon has one common and one rare stable isotope, ^{12}C and ^{13}C respectively, each of which is expressed by a superscript number standing for the total of protons and neutrons and an uppercase letter representing the element. The common stable carbon isotope ^{12}C has 6 protons and 6 neutrons, and the rare one ^{13}C has 6 protons and 7 neutrons. The stable carbon isotopic composition of a substance is represented by the ratio between the common and rare isotopes ($^{13}C/^{12}C$). For the convenience of comparative studies, stable carbon isotope ratios ($\delta^{13}C$) of different tested substances are all represented by the ‰ deviation of their $^{13}C/^{12}C$ from that of an international standard material (marine limestone PDB, now exhausted but still accepted as the standard) whose value is set as 0‰. The stable carbon isotope ratio ($\delta^{13}C$) of a tested sample is calculated following this equation: $\delta^{13}C = (R_{sample} / R_{standard} - 1) \times 1000‰$. In this equation, R_{sample} refers to $^{13}C/^{12}C$ of the tested sample, and $R_{standard}$ refers to $^{13}C/^{12}C$ of the standard material. A positive $\delta^{13}C$ value indicates that the analyzed sample is enriched in ^{13}C content compared to the standard, and a negative value indicates depleted ^{13}C content in the tested substance relative to the standard.

Nitrogen also has two stable isotopes ^{14}N and ^{15}N, both having 7 protons, but with 7 and 8 neutrons respectively. Calculation of the stable nitrogen isotope ratio ($\delta^{15}N$) follows similar principles as that of $\delta^{13}C$, but the international standard is the $^{15}N/^{14}N$ of atmospheric N_2 (Ambient Inhalable Reservoir, or AIR). In a similar way to $\delta^{13}C$, a positive $\delta^{15}N$ value indicates elevated ^{15}N content in the sample compared to air, and a negative value suggests depleted ^{15}N content in the substance compared to air.

The review contributed by Sharp (2007) can be referred to for more details on basic principles of stable isotopes.

3.1.2 Stable isotope analysis and paleodietary studies

The stable isotopes of the elements composing human and animal food also display variable reactions during the process of being digested and synthesized into the consumer's tissues. This is well understood for stable carbon isotopes, which undergo routine fractionation from primary producer plants to consumers' tissues as proved by early biochemical studies and controlled experiments (e.g. DeNiro and Epstein, 1976, 1978; Vogel, 1978; Van der Merwe and Vogel, 1978) and as detailed below. These early studies further suggested that the carbon isotopic composition of food components would be reflected in the consumer's tissues after a particular fractionation, and that it was thus possible to reconstruct this dietary information by analyzing body tissue isotopically. This is known as the concept of "you are what you eat" that laid the foundation of paleodietary reconstruction using stable isotope analysis (SIA) (DeNiro and Epstein, 1976; Kohn, 1999; Tykot, 2004).

The first application of SIA in a dietary study of an archaeological population was conducted in North America (Vogel and van der Merwe, 1977; van der Merwe and Vogel, 1978), provoking a re-examination of early complex society formation and the adoption and spread of maize cultivation in this area (Lee-Thorp, 2008). This is regarded as a striking example showing that archaeological science can be productively disruptive by rejecting a long-held idea, and therefore starting a new wave of studies seeking for alternative answers (Killick, 2015). Thereafter the great potentials of SIA in the study of ancient human diets has been gradually acknowledged by archaeologists and widely practiced (see Lee-Thorp, 2008 for a review). The increasing attention to archaeological bone SIA during the recent decades has been well reflected in the rising frequency of publications in top academic journals (Pestle et al., 2014), demonstrating that SIA has become one of the mainstays of modern archaeology (Makarewicz and Sealy, 2015).

Carbon, nitrogen, oxygen, sulphur, and hydrogen are all important light elements contributed by foods to consumers' tissues, and their stable isotopes can be used to reconstruct paleodiet following the principle of "you are what you eat" (Lee-Thorp, 2008). Among them, stable carbon and nitrogen isotopes are the most common ones used to study paleodiet, and related theories and techniques have been well developed and widely accepted. Only these two stable isotopes will be used in the current study, and the following review is confined to them.

3.1.2.1 Stable carbon isotope analysis and applications

Stable carbon isotopes in a consumer's tissues come ultimately from primary producers in the food web. Plants are the primary producers in terrestrial food webs and are divided into three groups according to their different photosynthetic pathways (Smith and Epstein, 1971; Vogel, 1980; O'Leary, 1981; Farquhar et al., 1989). The C3 group utilizes the Calvin-Benson photosynthetic pathway and displays strong discrimination against ^{13}C when fixing CO_2 into the tissue during the process, resulting in very low δ^{13}C values. In contrast, the C4 group of plants uses the Hatch-Slack pathway and incorporates more ^{13}C during the photosynthetic process, leading to higher δ^{13}C values in tissue compared to the C3 group. Plants of the C3 group have δ^{13}C values varying from -24‰ to -36‰ with a global mean of about -26.5‰, while C4 plants have a distinct global average δ^{13}C of -12.5‰ and less variation ranging from -9‰ to -16‰ (O'Leary, 1981; van der Merwe, 1982; Farquhar et al., 1989). Besides these two main groups, the third one, the CAM group, is capable of using both the C3 and C4 pathways, and its members display δ^{13}C values falling between those of the former two groups.

Most plants are of the C3 group, while C4 plants mainly include grasses growing in hot and arid environments (Vogel and van der Merwe, 1977). In human food resources, cultivars such as wheat, barley, oats and rice, as well as all root staples, are C3 plants, while the small number of economically important C4 plants includes millet, sorghum, maize and cane sugar (Lee-Thorp, 2008). CAM plants contribute very few items to human diets, only in some areas with special ecosystems, and thus are not focused on in most dietary studies.

In the aquatic ecosystems, marine primary producers (e.g., phytoplankton, algae) are enriched in ^{13}C compared to terrestrial C3 plants, and their mean $\delta^{13}C$ value is about -10‰ but varies on different occasions (Smith and Epstein, 1971). Carbon values of freshwater ecosystems organism are similar to terrestrial values, but these values are also highly variable (Fry, 1991; Richards et al., 2001).

Based on ecosystem values, early experts suspected that the $\delta^{13}C$ values of a consumer's body tissues reflect that of its diet, and proposed the well-known concept of "you are what you eat" (DeNiro and Epstein, 1976). Later DeNiro and Epstein demonstrated that the overall $\delta^{13}C$ of an animal's body was very similar to that of its diet except for an enrichment of about 1‰ from diet to body and variations among different tissues (DeNiro and Epstein, 1978). This confirmed that the $\delta^{13}C$ values of the biochemical components preserved in fossilized materials, including collagen, chitin, or organic components of invertebrate shells, were determined by the isotopic composition of diet (DeNiro and Epstein, 1978). These findings for the first time demonstrated the possibility of dietary reconstruction based on animal tissue $\delta^{13}C$, but the variable isotope fractionation from diet to different body tissues required further clarification.

A study on South African ungulates feeding exclusively on C3 plants found that their bone collagen $\delta^{13}C$ was enriched by about 5.3‰ compared to that of the food base (Vogel, 1978). A similar study was conducted on a North American archaeological population whose food components were mainly C3 crops, and the result suggested that human bone collagen $\delta^{13}C$ was enriched about 5.1‰ compared to that of their diet (Van der Merwe and Vogel, 1978). The enrichment of 5‰ in $\delta^{13}C$ from diet to bone collagen has also been supported by some later studies on free-ranging herbivores (e.g., Krueger and Sullivan, 1984; Sullivan and Krueger, 1981; Lee-Thorp *et al.,* 1989). Experimental feeding studies have reflected that bone collagen $\delta^{13}C$ primarily reflects dietary protein $\delta^{13}C$ because the amino acids in protein are required for collagen synthesis, and thus many of the carbon isotopes incorporated into collagen are derived from consumed protein (Hare et al., 1991; Ambrose and Norr, 1993; Tieszen and Fagre, 1993; Jim et al., 2004). These studies have also confirmed that when the diet is adequate in protein, collagen $\delta^{13}C$ is primarily determined by protein $\delta^{13}C$ and often enriched by 5‰, although the body is also capable of synthesizing some of the amino acids of collagen without protein, incorporating carbon from dietary carbohydrates and lipids into the final product. This approximation is mostly accurate when diets are monoisotopic (similar $\delta^{13}C$ values in both protein and carbohydrate components, such as a diet based on C3 grains and meat of animals feeding on C3 plants), which was the case for the initially cited two examples of C3-feeding ungulates in South Africa and C3-eating people from ancient North America (Vogel, 1978; Van der Merwe and Vogel, 1978).

Results of former studies suggest that the enrichment value of 5‰ between dietary protein $\delta^{13}C$ and human bone collagen $\delta^{13}C$ is reliable in most cases and can be applied in dietary studies of archaeological populations (e.g. Katzenberg, 2008; Lee-Thorp, 2008). Theoretically, a pure C3 diet (average $\delta^{13}C$ -26.5‰) would be reflected by bone collagen $\delta^{13}C$ of about -21.5‰, while a pure C4 diet (average $\delta^{13}C$ -12.5‰) would result in collagen $\delta^{13}C$ of about -7.5‰. It should also be kept in mind that the 5‰ value is a simplification that will be inaccurate for many mixed diets, and non-protein carbon clearly influenced collagen $\delta^{13}C$ values in some archaeological humans (e.g. Craig et al., 2013). This should be considered when archaeological human $\delta^{13}C$ values are interpreted.

Stable carbon isotopes are not only present in bone collagen, but also present in bone, dentine, and enamel mineral in the form of carbonate substitutions in the apatite crystal matrix (Le Geros, 1991). Controlled feeding studies have revealed that apatite $\delta^{13}C$ value is determined by that of the whole diet (see Kellner and Schoeninger, 2007 and Fernandes et al., 2012 for a review). But the fractionations of $\delta^{13}C$ from diet to apatite vary within and between species (e.g. DeNiro and Epstein, 1978; Ambrose and Norr, 1993; Tieszen and Fagre, 1993; Passey et al., 2005; Warinner and Tuross, 2009). There is no direct measurements on the value of diet-to-apatite fractionation in humans, and recent studies have used values for humans varying from 9.5‰ to 13‰ (e.g. Prowse et al., 2004; Keenleyside et al., 2006; Kosiba et al., 2007; Lanehart et al., 2011; Gil et al., 2014). This poses a challenge to the application of apatite analysis, and so do problems of diagenesis and treatment variation in bone mineral samples (Garvie-Lok et al., 2004; Loftus and Sealy, 2012). Nonetheless, apatite $\delta^{13}C$ has great potential for the study of grain consumption. Because whole-diet $\delta^{13}C$ responds to changes in grain consumption more readily than does dietary protein $\delta^{13}C$, it has been proved useful in detecting the initial introduction of isotopically distinctive grains into human diet (e.g. Harrison and Katzenberg, 2003; Gil et al., 2014). However, as there remain many uncertainties in fractionation value, sample quality evaluation, and laboratory treatment protocols in apatite $\delta^{13}C$ analysis, the current study will only analyze bone collagen, which is relatively well understood.

3.1.2.2 Stable nitrogen isotope analysis and applications

Nitrogen molecules originally come from the atmosphere and can only be broken down by certain bacteria in soil and water. After being broken down, they are absorbed by plant tissues, and then passed along the food chain on to consumers' tissues. During this process, stable nitrogen isotopes undergo variable reactions, which result in different stable nitrogen isotope ratios ($\delta^{15}N$ values) in different stages. The fractionation of stable nitrogen isotopes during this process is witnessed by ecosystem studies and has been further understood through experimental studies on animals, proving that $\delta^{15}N$ values display a stepwise enrichment of 3‰ to 5‰ from one trophic level to the upper next along the food chain (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984; Sealy et al., 1987; Bocherens and Drucker, 2003). A recent controlled dietary study on humans suggested that the diet-to-collagen enrichment, or trophic level enrichment, in $\delta^{15}N$ for humans ranges up to 6‰ (O'Connell et al., 2012). These results confirm that the $\delta^{15}N$ value of a consumer's tissue is determined by that of the diet, and also reveal the potential of stable nitrogen analysis for dietary reconstruction.

In the application of stable nitrogen isotope analysis in paleodietary studies, $\delta^{15}N$ values of humans and coexisting animals are compared to evaluate the trophic level position of human beings in the local food web, and determine the possible meat resources for humans. In addition, variation of $\delta^{15}N$ values among different populations or individuals might reflect their differences in trophic level and meat consumption, which can be further interpreted as differences in social status in human society. It is worth noting that this application is based on the diet-to-collagen fractionation of $\delta^{15}N$, the exact value of which varies from 3‰ to 6‰ in different studies as introduced above. Taking all of these former studies into account and considering that the potential traps of applying a low fractionation value (Hedges and Reynard, 2007), a mid-value of 4.5‰ seems to be acceptable and will be used as a reference value for the diet-to-collagen enrichment in $\delta^{15}N$ in the current study.

Stable nitrogen isotope ratios are also able to differentiate terrestrial-based diets from marine-based diets. The $\delta^{15}N$ values of aquatic animals, including marine and freshwater species, are highly enriched compared to that of terrestrial animals due to the longer food chains in aquatic ecosystems (Schoeninger and DeNiro, 1984). As a result, $\delta^{15}N$ values of people living on aquatic-based diets would differ significantly from those of populations living on terrestrial diets. However, this works better in detecting marine resources than in freshwater species because marine fishes are elevated in both $\delta^{15}N$ and $\delta^{13}C$, while the situation in the latter is more complex and not easy to determine (Hedges and Reynard, 2007).

In addition, stable nitrogen isotope analysis is also potentially capable of evaluating the use of legumes in human diet (DeNiro and Epstein, 1981). Based on their distinctive modes of nitrogen fixation, terrestrial plants fall into two groups, namely legumes and non-legumes (Hoering and Ford, 1960; Delwiche and Steyn, 1970). Legumes are able to fix nitrogen through symbiotic bacteria and usually have lower $\delta^{15}N$ values than non-legumes, which cannot fix molecular nitrogen at all. The $\delta^{15}N$ of legumes is usually close to 0‰, while values of other non-legume plants fall above this level and vary in different situations (DeNiro and Epstein, 1981). Therefore, heavy dietary reliance on legumes, which were important plant protein resources in some ancient societies, should result in very low $\delta^{15}N$ values in human body tissues. This research potential was realized very early, but archaeological examples of dietary reliance on legumes have only been identified in very rare cases (e.g. Varalli et al., 2015).

However, variations of $\delta^{15}N$ are also subject to many other factors that might affect the interpretation of data. These include external factors such as aridity (Heaton, 1987; Hartman, 2011), leaching and salinity (Handley and Raven, 1992), and manuring (Choi et al., 2002; Bogaard et al., 2007; Fraser et al., 2011). Internal factors should also be noticed, as it has been proved that special metabolic conditions such as illness and starvation can alter $\delta^{15}N$ values (Katzenberg and Krouse, 1989; Metoka et al., 2006), resulting in the observation that "you are not what you eat" under these special circumstances (Fuller et al., 2004). It should also be noticed that breastfeeding is also able to elevate $\delta^{15}N$ values for infants' body tissues in contrast to those for adults (Fogel et al., 1989; Fuller et al., 2006). These have complicated the use of stable nitrogen isotope analysis, but also greatly expanded its prospects in paleodietary investigations.

Although analysis of stable nitrogen isotopes was applied in paleodietary studies later than was stable carbon isotope analysis, considering a combination of the two elements always works more effectively than does either single one. This is partly because elemental concentrations of both carbon and nitrogen, represented by atomic C/N ratio provides an important criterion for evaluating the quality of collagen extracted from archaeological bones. The C/N ratios ranging from 2.9 to 3.6 obtained from fresh bones in experimental observations by DeNiro (1985) have been widely accepted as an indicator of reliable collagen quality. Later experiments suggested that the individual percentage concentrations of carbon and nitrogen in collagen are also capable of assessing its preservation (Ambrose, 1990). The combination of both elements is not only able to determine collagen preservation, but also able to reveal more detailed dietary information. For example, it has been suggested that a positive correlation between collagen $\delta^{13}C$ and $\delta^{15}N$ on a site might reflect incorporation of marine or freshwater resources into human diets (e.g. Ambrose et al., 1997; Weber et al., 2011).

3.1.2.3 Target tissues in SIA and paleodietary studies

Stable carbon and nitrogen isotopes are present in many tissues, including calcified tissues such as bone and teeth, and keratinous tissues such as hair and nails. These tissues are present in different biological structures and are subject to varying post-mortem alterations (for a review see Lee-Thorp, 2008). Bones and teeth are usually less affected by diagenesis and are more commonly found in archaeology than other tissues. Their organic components, in the form of bone and dentine collagen, archive both carbon and nitrogen isotopes, while their minerals components contain carbon only, in the form of carbonate substitutions in the apatite crystal matrix (LeGeros, 1991). It would be ideal to analyze both collagen and apatite from the same sample in paleodietary studies because the two fractions record isotopic signals from different dietary components. Bone collagen primarily reflects isotopic features of dietary protein, and apatite reflects that of the whole diet (see section 3.1.3). However, bone apatite analysis has not been as widely practiced in dietary studies because the tissue is vulnerable to diagenesis and there are many related uncertainties in the application (see section 3.1.3). In contrast, collagen is a tough structural protein with a survival rate much higher than that of non-collagenous tissues in ancient bones (Smith, 2005), and it is also a very robust biomolecule that can survive for up to 200,000 years under optimal conditions (Jones et al., 2001). Therefore bone collagen has been the most common target tissue in paleodietary studies using SIA and the related methodological issues have been well resolved during decades of development (Lee-Thorp, 2008).

Bone is a living tissue that remodels at varying rates depending on bone types and ages (Valentin, 2002, pp.185-188). During the process of bone turnover, dietary information recorded in old bone tissue is erased and new dietary information is archived in the newly deposited bone. The period of life represented by the stable isotope values of bone collagen depends on the bone types analyzed (Bell et al., 2001; Hedges et al., 2007). Bones with a fast turnover rate may reflect dietary features of the most recent years before death, because old tissue archiving early years' isotopic signals has been quickly replaced by newly deposited tissue recording the most recent intake of stable isotopes from the diet. Incremental tissues such as dentine, hair, and nail, however, are able to record the dietary signal in chronological order during the period of growth, and they should also be analyzed to observe the temporal change of diet within a certain period if the appropriate materials are available (e.g. Henderson et al., 2014; O'Connell and Hedges, 1999; Webb et al., 2013; Buchardt et al., 2007). Unfortunately, archaeological hair and fingernails are only preserved in very rare occasions, so dentine has been the most commonly analyzed incremental tissue (for a review see Burt and Garvie-Lok, 2013).

While the majority of dietary studies are focusing on bulk bone or tooth collagen, some recent studies have also displayed interest in stable isotopes of bone collagen amino acids, suggesting that the isotopic composition of amino acids is able to reflect more refined dietary information than bulk collagen (Honch et al., 2012; Naito et al., 2013; Styring et al., 2015).

3.2 SIA and Paleodietary Studies in China

It was not long after the initial application of SIA in dietary studies in North America that the theory and method were introduced into China. The first study in China was presented in 1984, introducing the essentials of SIA and paleodietary study and providing $\delta^{13}C$ data for 20 human samples from 10 archaeological sites (Cai and Qiu, 1984). Although most of the data were by-products of a C14 dating project and the number of samples was limited, they demonstrated the great potential of SIA in Chinese archaeology for the first time by revealing variable dietary patterns in different sites. This did not attract too much attention, however, and no further development in this field was seen in the following years except a translation of a Japanese SIA study in 1998 (Qi and Yuan, 1998).

The early years of the 21st century marked the beginning of a new era for SIA and dietary studies in China. A series of studies were released starting in the year 2000; these systematically introduced the theory and methods in this field, and analyzed several sites dating from middle Neolithic times to historical times, yielding valuable information on diet and subsistence patterns of ancient Chinese people (e.g. Hu et al., 2000; Cai, 2001; Hu, 2002; Zhang XL et al., 2003; Zhang XL, 2003). For example, analysis of human remains from the Middle Neolithic site Jiahu has revealed the subsistence change from hunting and gathering to rice agriculture, and shed light on the origin of agriculture in China (Hu, 2002; Hu and Wang, 2005). Later studies have demonstrated the distinctive dietary features of southern and northern China, and confirmed the long coexistence of rice-based agriculture in the south and millet-based agriculture in the north (Zhang XL et al., 2003; Zhang XL, 2006).

SIA and paleodietary studies in China have been presented internationally since 2005 when the first collaborative project led by American experts to reconstruct Neolithic subsistence in northern China was published in English (Pechenkina et al., 2005). In the next year, the study on Jiahu human diets directed by Chinese experts also was published in English (Hu et al., 2006). Thereafter, SIA and paleodietary studies in China have attracted increasing attention, and human and animal remains from over 70 sites ranging from 40000 years ago (Hu et al., 2009a) to about 900-1000 years ago (Zhang QC, 2006) have been analyzed.

These studies have revealed the dietary diversity in different regions of ancient China. In the coastal area of the east and south, people began to exploit marine resources in Neolithic times as reflected by the high $\delta^{15}N$ of bone collagen (Wang et al., 2012; Hu et al., 2010). In the northwest, pastoral populations also displayed highly elevated $\delta^{15}N$ compared to peasants in agricultural zones, which was interpreted as an indication of a large amount of meat consumption (e.g. Zhang QC et al., 2009; Zhang QC and Zhu, 2011). Although northern China had established millet-based agriculture ever since Neolithic times (Pechenkina et al., 2005; Zhang XL et al., 2010), influences of the C3 crops rice from the south and wheat from the west have also been evidenced in different sub-regions as well. In the east of northern China, rice took a significant role in the diet of the Neolithic population from Liangchengzhen (Lanehart et al., 2011), while wheat contributed significantly to the diet of people dwelling in the northwest from about 3800 years ago (see Zhou and Garvie-Lok, 2015 for review). When some northerners displayed a certain interest in the wetland crop rice from the south, people in the south also probably grew and ate a certain amount of the northern grain millet (Guo et al., 2011), indicating that the division between the rice zone and millet zone was not so clear and that overlapping of the two zones was common in ancient times.

In addition to the focus on agriculture and subsistence, SIA studies in China have also displayed their potentials in zooarchaeology. Stable isotope values have revealed distinct dietary features between domesticated pigs and wild species, and this has enabled the application of SIA in understanding the process of pig domestication (Guan et al., 2007; Hu et al., 2009b). Isotopic analyses of animal remains have also demonstrated varying patterns of animal husbandry strategies adaptive to different species as well as different levels of agricultural intensification (Chen et al., 2012; Chen et al., 2014).

Despite these significant achievements obtained so far, temporal and spatial imbalance in the focus of current SIA and dietary studies in China should also be noted. Reading the sources cited in the three paragraphs above, it can be seen that most of the current studies focus on prehistoric sites and only a few of them concentrate on or partly relate to historical remains. Among the very few intensively studied historical sites, the majority are located in the border areas including

Xinjiang and Inner Mongolia, while some other areas show an obvious lack of attention. The temporal emphasis on prehistoric remains is at least partly related to the prevailing concept that this time period is likely to raise more intriguing questions due to the lack of literary records. On the other hand, the disproportional spatial distribution of current SIA studies is probably caused by the lack of practitioners. Such an awkward situation reflects the adolescence of SIA studies in China, as well as the bright future of this field.

The Central Plains targeted in the current study are among the understudied areas, although the two earliest SIA case studies were both based on remains from this place (Hu, 2002; Pechenkina et al., 2005). Besides these two projects, only four later studies were designed to focus on the core area of the plains (Wu et al., 2007; Pan et al., 2009; Zhang XL et al., 2010; Hou et al., 2013), and two on the southwest mountainous area (Fu et al., 2010; Hou et al., 2012). As for the specific period of social transition focused on in this study, no human remains on the plains dated to this period have been analyzed. There is one study investigating human dietary change during this transforming period in the same province as the Central Plains (Hou et al., 2012), but the targeted site is located in the southwest mountainous area. The mountainous environment of the analyzed site and its close proximity to the south have determined a dietary character differing significantly from that of the plains, as will be discussed later.

In brief, on consideration of the Central Plains' importance in Chinese archaeology and the abundance of archaeological remains, this area deserves more emphases in SIA and paleodietary studies. Particularly the historical remains that have obviously been overlooked in the past require more attention. This is also part of the motivation of the current study, not only intending to investigate the dietary change during a major social transition, but also attempting to demonstrate the great potentials of SIA and paleodietary studies in historical contexts.

3.3 SIA and the Research Questions

As introduced in section 2, the main crops in the Eastern Zhou and Han dynasties include millet, wheat, barley, rice, hemp, and soybean. Among them, millet belongs to the C4 plant group, while wheat, barley, rice, hemp, and soybean are all C3 plants. The variety of C3 grains seems to challenge the application of SIA, because current methods in stable isotope analysis are not capable of differentiating different C3 plants in human diets. This issue needs to be clarified to show the proper context for applying SIA in the current study.

Remains of barley have occasionally been discovered together with wheat in northern China starting in Neolithic times, but at a very low frequency (Jin, 2007, Liu and Chen, 2012, p.94). The very low frequency of archaeological and literary records of barley in comparison to wheat indicate that it was of much less importance than the latter; this is still true in modern society as reflected by a village survey in the 1920s (Simoons, 1990, P.74). As for rice, although it was grown sporadically in northern China since Neolithic times (Wang and Xu, 2003; Liu and Xiang, 2005), environmental constraints prevent the large-scale cultivation of this wetland crop in the north (Qian, 2009). Hemp (or cannabis), the seeds of which can be eaten or used to extract oil and the fibre of which can be woven into cloth, is always mentioned as an important grain as well. But it is more likely that this crop mainly served as an important economic plant producing fibre rather than a staple grain in ancient China (Li, 1974; Keng, 1974; Lu and Clark, 1995). All three of these species of C3 grains might be consumed only as minor grains and had very limited effect on human diet. If there is an isotopic signal suggesting a potential C3 dietary component in northern diets, the most likely choices would be wheat or soybean, which could be further differentiated by stable nitrogen isotope values. As for the C4 crop millet, there were at least three species cultivated in ancient China (Chang, 1977, pp.26-27; Qian, 2009). The two main ones were foxtail millet and broomcorn millet, which were referred to as *su* and *shu* respectively in ancient texts (You, 1993; An et al., 2010). Although these two species might have differed from each other in importance or taste as suggested by Qian (2009), they have been proven to be isotopically similar by a recent study (An et al., 2010). Moreover, they were similar in geographical distribution, growing conditions, and methods of preparation and consumption (You, 1993). Thus, including the two of them into the general category 'millet' by ignoring their slight internal differences is reasonable and would not affect the results. In this context, the discussions on main grains in the Zhou and Han times will mainly deal with millet, wheat, and soybean, which are isotopically distinct from each other, enabling the possibility of evaluating their dietary significance in this period of northern China using SIA.

Isotopic analyses on millet grains of both modern samples and archaeological remains have revealed that $\delta^{13}C$ of millet in ancient China ranged from -10.3‰ (Pechenkina et al., 2005) to -11‰ (An et al., 2010), confirming that this crop was a typical C4 plant with $\delta^{13}C$ values consistent with the global average value of modern C4 plants (-12.5‰). The predominance of this crop in human diets of northern China was established in Neolithic times, which was reflected in high $\delta^{13}C$ values of human bone collagen (e.g. Zhang XL et al., 2010; Peckenkina et al., 2005). In this context, incorporation of significant amount of C3 staples, either wheat or soybean, into the millet-based diet would cause a visible decline in collagen $\delta^{13}C$ compared with previous data. If soybean had been consumed as a staple grain as claimed by textual records, both low $\delta^{13}C$ and $\delta^{15}N$ values should be expected, at least in the poor people who were said to have relied heavily on soybeans for survival. Thus, comparisons of $\delta^{13}C$ and $\delta^{15}N$ values would be able to reveal the dietary roles of different grains and answer question No.1 raised in section 2.4.

Stable nitrogen isotopes analysis would be able to reveal whether the nobles consumed terrestrial meat or aquatic resources, and whether marine food had been incorporated into people's diets in large amounts, providing an answer to question No.2 in section 2.4. It is also capable of answering question No.3 by testing the dietary dichotomy between nobles and commoners, which is represented by differences in meat consumption according to literary evidence. If the historical documents have recorded the truth rather than rhetoric, there should be a significant discrepancy of $\delta^{15}N$ values between nobles and commoners for the reason that their protein resources, one of which was animal meat and the other was soybeans, were significantly distinctive in $\delta^{15}N$.

Questions No. 4, No. 5, and No.6 can be addressed by combination of both $\delta^{13}C$ and $\delta^{15}N$ values and statistical comparisons, which should allow the evaluation of dietary differences between urban and rural populations, and between the Eastern Zhou people and the Han people, and between former periods and the two periods targeted in this study. These results will be interpreted under specific social contexts, providing details on human diet during the period of transition.

The current achievements in SIA and paleodietary studies lend this study strong theoretical and methodological support. Moreover, the lack of previous focus on historical remains from the Central Plains calls for a focused dietary study in this area, and the agricultural features of northern China during the period to be studied provide a proper background for this investigation.

4. Materials and Methods

4.1 Human Samples and Archaeological Background

In order to study human diet on the Central Plains of northern China during the transforming period from 770BC to 220AD, human remains from four sites, including one urban and two rural sites dated to the Eastern Zhou Dynasty and one site dated to the Han Dynasty, were selected for stable isotope analysis. These sites are all located on the core area of the plains, their close proximity to each other indicating similar climatic, geographical, and environmental conditions (Figure 2). In addition, animal remains from a fifth site dating to the Eastern Zhou were also sampled so as to provide comparative data for potential meat resources for humans.

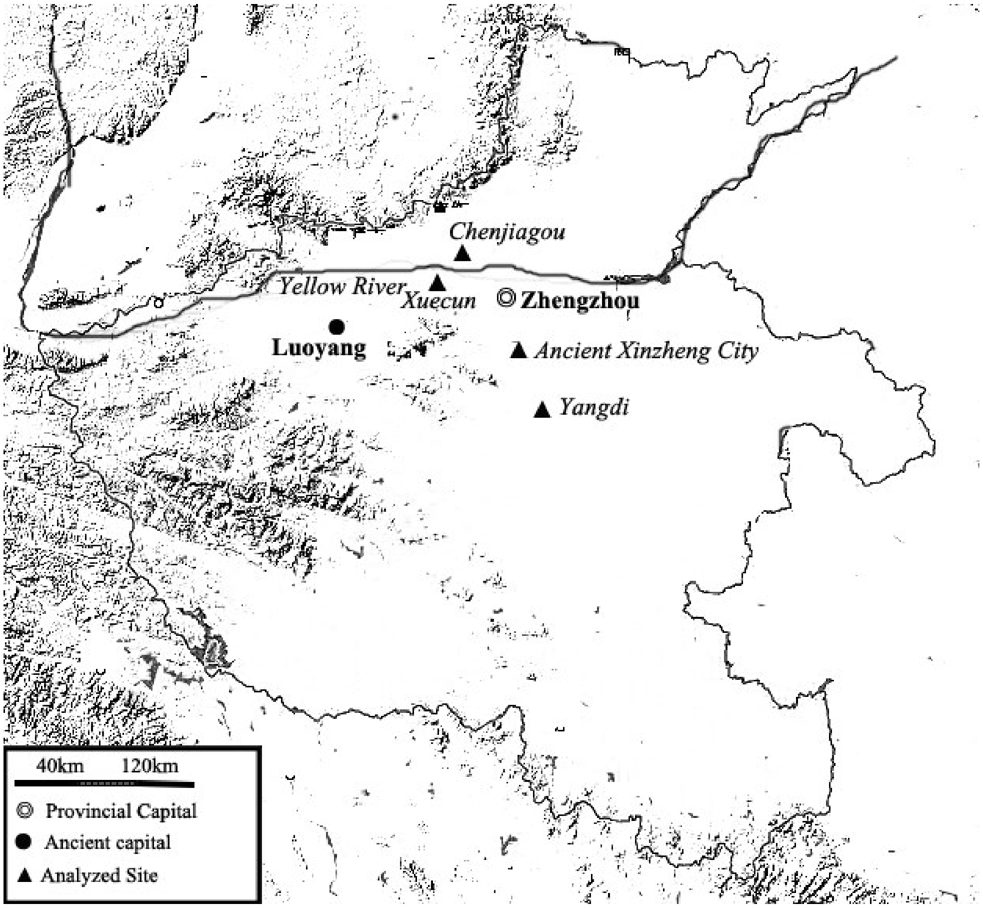

Figure 2 Location of the analyzed sites on the Central Plains

4.1.1 Yangdi site

Eight of the twenty human skeletons discovered from Yangdi site were analyzed for this study (for details of the samples see Table 2). Yangdi site is located in close proximity to the south of Baliying village, Yuzhou city of central Henan Province. Part of this site was occupied by the Water Transfer Project from southern to northern China, so that salvage excavation on this site was conducted by the team from the Department of Archaeology, Wuhan University, from 2006 to 2008 to mitigate the effects before the project.

This site was was named after ancient Yangdi city, because the surveyors who had located it before the excavation regarded it as the remains of this ancient city, which was a famous metropolis during the Eastern Zhou and had once been the capital city of the Han state from 408 to 375 BC. However, the 2006-2008 field work revealed that the main deposits of Yangdi site were settlement remains dated after the 12th century AD, except for 21 earthen pit human burials that were exposed at the bottom layer and dated to late Western Zhou or early Eastern Zhou according to burial custom and pottery morphology (personal communication with the field director, Dr. Xu Chengtai of Wuhan University). It is obvious that the excavated evidence lends no support to the existence of an ancient city of Eastern Zhou times, and neither does the follow-up survey in close proximity. There is an earlier study suggesting that ancient Yangdi city was probably located in the urban district of the current Yuzhou city (Liu, 1991), which is about six kilometers to the south of the excavated Yangdi site. As the urban area of Yuzhou city is occupied by modern structures and no systematic ground survey or excavation has been conducted, this suggestion can only be regarded as one of the probabilities. Although the exact location of the ancient city is still unknown, current information obviously indicates no relationship between it and the excavated Yangdi site, which was definitely a rural site of the Eastern Zhou period.

Features of the 21 burials excavated from the site also confirm that their occupants were commoners of very low status. There are no distinct differences within this group of people buried in Yangdi site, either in burial furniture or in funerary objects. Every individual was buried in a supine position in an earthen pit with a single wooden coffin or no burial furniture at all. Their funerary objects were no more than several pieces of shells contained in the mouth or worn around the neck or wrist; a very few daily use ceramics were seen only in two burials (one with two and the other with three items). Although it is suggested that shells, which had been used as the earliest form of currency in China, were still functional as money and were taken as a representation of wealth in the Eastern Zhou when metal currency was already in use (Zhang TE, 1991), this seems not to be applicable in Yangdi site where the shells were all associated with small and simple burials. Placing shells in the mouth was also a common burial custom in the Eastern Zhou, seen in different areas (Li, 2007), and the placement of shells around the neck or wrist seen in this site apparently indicates that they were used as body adornments rather than indicator of wealth or status.

4.1.2 Chenjiagou site

Over fifty burials from Chenjiagou site were dated to the Eastern Zhou according to preliminary examination of pottery typology and burial customs (personal communication with project director, Mr. Yang Shugang from HPICHA), and forty-one of them yielding human skeletal remains were selected for the dietary study (for details of the samples see Table 2).

Chenjiagou site is located on the northern bank of the Yellow River, within the territory of Wenxian county, Henan Province. This site was excavated by the Henan Provincial Institute of Cultural Heritage and Archaeology (HPICHA) from 2005 to 2006 to mitigate the impact of the construction work of the Water Transfer Project. The excavation covered an area of about 7950 m^2 and exposed a large number of pits, burials, kilns, houses and other remains dated from Neolithic times to the Song Dynasty (960-1279 AD). Some of the burials dated to the Western Zhou were reported in 2007 (Yang and Guo, 2007), but studies on most of the unearthed materials are still ongoing.

This site is located in an area once within the territory of the Zheng and Han states, successively, before the unification (Li, 2005), but is about 80 km to the north of the capital city. There is no evidence supporting any linkage between people buried in this site and the noble class based on the absence of status-informing bronze ritual objects in their burials. Therefore, Chenjiagou site was evidently a rural site occupied by commoners during the Zhou times.

All of the selected burials were single burials in earthen pits, with thirty-seven of their occupants lying in supine position and the other four on the side or in prone position. Their burial arrangements vary in both burial furniture and funerary objects. Burial furniture included double-layered coffins and single-layered coffins, and funerary objects could also be divided into two categories: daily use ceramics (twenty-one cases) and small items of jade or stone objects (six cases). It is worth noting that jade objects found in the six burials should not be mistaken as an indicator of wealth or high status, because they were no more than a few beads or fragments of other jade objects, which were distinct from the fine jade ornaments seen in noble graves. There are also a number of burials without any burial furniture and/or funerary objects.

Multiple-layered coffins in the Zhou Dynasty have always been taken as a mark of noble status (Zhao, 1998; Falkenhausen, 2006, pp.137-139), and it is suggested that the multi-layered coffin system was as important as the display of *ding*-tripod ritual vessel in the Zhou rituals (Zhao, 1998). According to the ritual rules, double-layered coffins were supposed to be used by the lowest rank of noble called *shi* (knight) (Zhao, 1998). However, at Chenjiagou, the very few daily use ceramics or even the complete lack of funerary objects in the graves featuring double-layered coffins obviously does not support the identification of their occupants as low-rank nobles; neither does the lack of apparent linkage between this site and any city. This is not unexpected, because cases of nobles violating the sumptuary rules are frequently reported (Zhao, 1998; Zhang WJ, 2012); thus, an imitation of noble burial furniture by some well-off commoners in the countryside would also be possible.

During the data analysis in the following chapter, variation in burial furniture will be considered and human individuals will be divided into three levels (double-layered coffin; single layer coffin; no coffin) for status comparisons. Individuals with different funerary objects (pottery and jade or jade only; pottery only; none) will also be compared. Variations in burial furniture and funerary objects might have reflected differences in economic capacities rather than social status. This has offered an opportunity to study the internal structure of the low-class population, who were ignored by literary records and sumptuary rules.

4.1.3 Ancient Xinzheng city

Seventy-six human samples from ancient Xinzheng city were analyzed in this study (for details of the samples see Table 2). This site, located inside the urban area of the current Xinzheng city, Henan province, was the capital of the Zheng and Han states, successively, during the Eastern Zhou. This site is normally referred to as *Zhenghan Gucheng* (ancient capital city of Zheng and

Han States) in China, which is shortened as ancient Xinzheng city in this study. Little was known about this city before the Zheng state, whose territory and capital were previously in northwest China, moved to the plains in 770 BC. As one of the most influential states of the time, the Zheng state soon annexed several small states on the plains after escorting the west-east relocation of the Zhou royal court, and built a new capital city in the current location. The city was taken over by the Han state after annihilating the Zheng in 375 BC, and continued to be Han's capital till 230 BC when the state was wiped out by the Qin. In total, this city served as capital of the Zheng for 394 years and that of the Han for the next 145 years, making it the most important Eastern Zhou city besides the royal capital in Luoyang. Details on the history of this city can be found elsewhere (Ma, 1978; Shi, 1998; Li, 2005; Tao, 2008).

Both the Zheng and Han states were powerful and influential in their time, and their capital city was also a prosperous metropolis during the Eastern Zhou. This is demonstrated by the variety of excavated handicraft workshops for iron smithing, bronze casting, jade manufacturing, bone tool production and pottery making inside the city, as well as literary evidence from different sources (see Tao, 2008, pp.26-35 for a detailed introduction). Obviously the prosperity of commerce and handicraft industry in this city greatly benefited from the geographical advantage of the plains, which, however, also caused suffering during time of war. With almost every powerful state casting a greedy eye on the fertile plains, the Zheng and Han states who successively controlled this area had always been in a strategically vulnerable position. It is said that in the SAP there was no state that suffered more wars than did the Zheng state, which was attacked about 80 times under its 394 year regime (Song, 1996). There were twelve battles directly related to the capital city, nine of which occurred just outside the city gates and the other three of which broke into the city (Shi, 1998). Frequent attacks were also targeted at the Han state after it took over Zheng's capital and territory in 375 BC. Thereafter, the Han state suffered about 23 attacks from different rivals (based on the records from Editoral Board, 1985, pp.27-35; Military Museum, 1994, pp.90-118) until it was finally annihilated in 230 BC. Although not every war was directly targeted at the capital, it can be assumed that the capital would not have been very peaceful when other areas of the state were suffering from constant warfare.

The ancient city ruins have almost been entirely overlaid by structures and facilities of the current city, except that some parts of the city wall made of rammed earth are still preserved above the ground. Remains of palace structures, handicraft workshops, granaries, sacrificial pits, and burials of both nobles and commoners have been discovered in different parts of the city, telling of both its prosperity and decline in ancient times. On account of its archaeological importance, the HPICHA has operated a permanent working station in this ancient city since the 1960s to focus on the excavation, protection, and research of the remains. Besides the findings of palatial and industrial remains during the past half-century's systematic surveys and excavations, archaeologists have also located several cemeteries for high-rank nobles, low-rank nobles and commoners. Parts of them have been excavated to mitigate the effects of expanding infrastructure constructions in and around the city, yielding thousands of human burials of different classes (for a review of this archaeological work, see Chen QL, 2007).

The human remains chosen for the current study are from two cemeteries exposed during the 2003-2005 salvage excavations inside the city. These two cemeteries were different parts of a large cemetery containing both low-rank nobles and commoners, and are referred to as Xinghong Garden cemetery (XH cemetery) and the Thermal Power Plant cemetery (TP cemetery) respectively, after the related construction projects. Because of their close proximity to each other inside the city (Figure 3), the two cemeteries, composed of 214 burials in total (151 from the XH cemetery and 63 from the TP cemetery), were numbered separately but discussed together in the field report published in 2007 (Fan and Xu, 2007), so that all of them will also be analyzed and referred to together as the Xinzheng burials in this study.

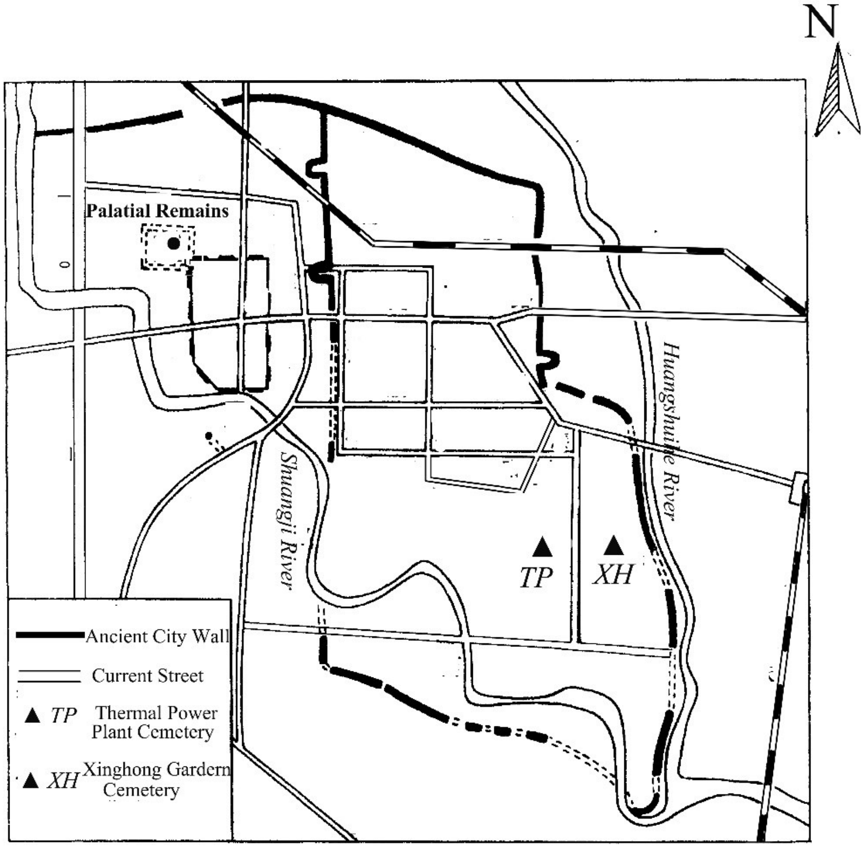

Figure 3 Location of the Xinghong Garden (XH) cemetery and Thermal Power Plant (TP) cemetery inside ancient Xinzheng city

Typological features of funerary objects from these burials suggest that the earliest ones of them might be slightly earlier than 770BC and the latest ones would not postdate the unification in 221 BC (Fan and Xu, 2007, pp.136-140), perfectly covering the whole period of the Eastern Zhou. These burials were further divided into nine temporal phases during this period according to the pottery typology and artifact assemblages (Fan and Xu, 2007, pp.136-140). All of them are single burials in earthen pits with skeletons mostly laid in supine position, but burial furniture varies from triple-layered coffins to single-layered coffins. Funerary objects from these burials differ remarkably as well, including bronze and pottery ritual vessels, jade ritual vessels, personal ornaments, daily use ceramics, and weapons. There are also a number of small burials with neither funerary objects nor burial furniture. These features demonstrate significant variation in social status of the burial occupants. It is not unexpected to see that they included some low-rank nobles, whose status is attested by their bronze or pottery ritual vessels and multi-layered coffins, because the cemetery was located inside the core area of the state. It is also obvious that there were poor people who could not afford any burial furniture or funerary objects buried in the same cemetery.

The authors of the field report on the site considered that grave size might better reflect the differences in social status and thus divided these people into three levels based on the length of their tomb openings (Fan and Xu, 2007, pp. 146-147). The tombs above three meters in length were attributed to the top status level, and those between three and two meters and the ones below two meters were attributed to the middle and the lowest level respectively. These three levels were suggested to represent the low-rank noble *shi*, commoners, and poor commoners in terms of social status based on their burial size and funerary objects (Fan and Xu, 2007, pp.146-147). However, although grave size can be taken as an indicator of social status, it is difficult to use in archaeological cases because of the lack of reliable standards. It has been suggested that besides tomb size, burial furniture and funerary objects, particularly ritual vessels, can also differentiate the owner's status in this period (Falkenhausen, 2006, p.100). In contrast to the method applied in the field report cited above, burial furniture and funerary goods might sometimes work more effectively because their differences are easy to identify. Some of the funerary goods were not in their original settings due to looting and thus could not serve as a reliable standard. Fortunately, though, burial furniture in both cemeteries is well preserved due to the special soil texture, with major features (e.g. coffin layers and size) still identifiable in the form of wood residue even after being looted. Ancient documents indicate that the presence of an outer coffin (*guo*, also translated as burial chamber) in the burial furniture serves as a mark of the ranked nobles; this has been attested to archaeologically in several cases (Zhao, 1998; Falkenhausen, 2006, pp.137-139). Therefore burial furniture would be the most suitable indicator of social status of the people interred inside the capital city. On this consideration, the sampled human individuals will be divided into three levels according to their burial furniture (multiple-layered coffin, including triple- and double-layered; single-layered coffin; no coffin) during analysis in the following chapter. The results of status division based on burial furniture are generally consistent with that based on grave size. These individuals might also include some warriors whose identity could be informed by weapons found in their graves.

Suffering from lootings or natural post-mortem alterations, only 65 skeleton-yielding burials from the XH cemetery and 11 from the TP cemetery were able to be analyzed. If these 76 burials were assigned to the nine temporal phases proposed by the field report (Fan and Xu, 2007, pp.136-140), the number of individuals in each phase would be limited and statistical meaning would inevitably be weak. Therefore, these burials were re-organized into three new phases for the current study, based on their original chronological sequence proposed in the report. Phase one includes the original first and second phases and dates to late Western Zhou (Early Eighth Century BC); phase two covers the third to sixth phases in the report and dates to the SAP, and phase three includes the seventh to ninth phase assigned by the report authors and dates to the WSP.

4.1.4 Xuecun site

The 287 burials dated to the Han Dynasty unearthed in Xuecun site have yielded only 164 human skeletons with variable conditions of preservation. Among them, 58 individuals from 47 burials (including multiple burials) were chosen for this study because of their relatively well-preserved human skeletal remains and intact archaeological context (for details of the samples see Table 2).

The site is located on the southern bank of the Yellow River within the territory of Xingyang city, Henan Province, facing Chenjiagou site across the water (Figure 4). This site was excavated between 2005 and 2007 by HPICHA to make way for the Water Transfer Project whose construction would destroy the majority of the remains. Over 10000 m^2 of the site has been excavated, and the exposed deposits include settlement remains dating to late Neolithic Age through early Bronze Age and over 500 burials dating to the Han Dynasty through late imperial times (the 19th century), some of which have been reported elsewhere (Chu et al., 2007, 2010). Most of the unearthed materials are still being studied, and a few results have been published by scholars of different fields (e.g. Xia et al., 2009; Zhou and Chu, 2009; Sun et al., 2013).

Among the large number of excavated human burials, there are 287 dated to the Han Dynasty based on coins and pottery typology. Burials of the Han Dynasty have been systematically studied from the aspects of both archaeology and physical anthropology (Zhou, 2008; Sun, 2013), providing a detailed and reliable background for the dietary study. They were further arranged into a chronological sequence including five phases ranging from Late Western Han to Late Eastern Han (or 141 BC to 220 AD) based on detailed pottery typology (Zhou, 2008, pp.41-45). The majority of them are single burials with one individual interred in each grave, but there are also a number of multiple burials with two or as many as four individuals buried within one grave. Undisturbed burials show that human remains were usually laid in supine position in a single wooden coffin or directly on the chamber floor without burial furniture. There are also a few undisturbed secondary burials in which disarticulated human remains were piled together, indicating that they were relocated from somewhere else long after the initial burial.

Figure 4 Location of Xuecun site in relation to Chenjiagou site, Hulaoguan pass.

The structure of the Han burials differs significantly from that of the Eastern Zhou burials seen in Yangdi, Chenjiagou, and Xinzheng, reflecting a transformation in mortuary practices. Earthen pit burials, which were common in the Eastern Zhou, are very rare in Xuecun, in which the majority of burials are catacombs composed of a passageway and a cave-like chamber. These catacombs can be further divided into two major groups based on their differences in structure: one group features an earthen chamber and the other features a brick chamber. Catacombs with earthen chambers are usually small ones with a single room simply dug into the soil, while those with brick chambers have one or multiple rooms built like underground houses with fired bricks. The structural variations might reflect the variable economic capacities of their occupants, as might the differences in funerary objects. A large number of ceramics, including daily use utensils, offering vessels, construction models (e.g. houses, wells, stoves, barns etc.) and figurines of servants and animals, chariot components, weapons, and personal ornaments in bronze, glass, or jade were often discovered in multi-chamber brick graves. In contrast, in the small graves with single chambers (either earthen or brick), the most commonly found funerary objects were a few items of daily use ceramics, or nothing at all. Although variation is evident, it is hard to differentiate the social status of the people buried in this cemetery according to their burial remains because of the difficulties introduced in section 2.2.2. Compared with the very few Han burials with known identities (see Zha, 1990; Li, 1991; Song, 1994; Zhao and Gao, 2002 for detailed introductions), none of the Xuecun burials could equal those of high officials or nobles. It is very likely that the individuals buried in this cemetery might include low-rank officials and commoners of variable economic conditions as attested by the variation in grave structures and funerary objects.

Both the apparent variations in funerary objects and burial structures can serve as indicators of economic conditions. But funerary objects had been severely looted before excavation and information on their original number and categories were incomplete, leaving burial structures, which were less affected by looting, the only reliable material indicator of economic capacities. Burial structures in Xuecun varied from large brick-built chambers with as many as four rooms to a simple earthen room capable of containing only one body. They are used as the tentative standard to divide the 53 individuals from 41 burials (some are multiple burials with more than one people) into three status levels for further comparison in the following chapter. Level one includes people buried in brick-built chambers with more than two rooms (three, or four), who are supposed to be well-off commoners, low-rank officials, or landlords. Level two is composed of people buried in single- or double-room chambers built of bricks; they might possibly be the medium socioeconomic layer of the Xuecun population. Level three contains people interred in single-room earthen chambers, who appear to have been the lowest layer, or the poor of this community. Division of economical capacities by burial structure can only be regarded as an alternative method when other evidence is not available, and this is not recommended in other situations.

It is worth noting that weapons such as daggers, swords, knives, and crossbow triggers were common in this cemetery. They were not only found in large graves with multiple brick chambers, but also seen in a number of small burials with single earthen rooms. Considering the very strict controls on weapons during the Qin and Han dynasties (Du, 2013), it is unlikely that those weapons were buried as part of funeral customs for the commoners in Xuecun. One plausible explanation is that they might be related to military experience of their owners. This is not impossible because Xuecun site is about four to five kilometers to the northeast of a well-known ancient strategic pass named *Hulaoguan* (Tiger Cage pass), the majority of which has now already been eroded away by the Yellow River (see figure 4). The strategic importance of *Hulaoguan* pass had been realized since the WSP and it was in use for over 1700 years thereafter because of its geographic advantage in controlling the passage connecting the Central Plains and the western regions (Chen, 2009). It is possible that the Han Empire also stationed troops in this pass, and that some of the soldiers or officials were buried in close proximity after death. However, there is also another possibility that should not be ignored. During the Eastern Han Dynasty, there appeared numerous “great families” (*haozu*) in different areas after the concentration of land into a few hands; these great families usually owned several hundred serfs or peons and even their own armed forces composed of retainers (Li, 2002; Li, 2013, pp.297-

298). Therefore, individuals who were buried with weapons in large brick burials could also be landlords who owned their own forces, and the others with weapons in smaller graves might have served in the private force of some great families.

People buried in this cemetery might also include some travellers or migrants, which is hinted at by an epitaph of later dynasties unearthed in the same burial ground. The epitaph records that a Tang Dynasty (618-907 AD) military official Song Hua, who had served in other places, died at *Hulaoguan* pass during his travel after retirement and was buried in a place nearby (Chu et al., 2010; Liu and Chu, 2009), indicating that it was not unusual for travellers or migrants who died a sudden death when passing this area to be buried in Xuecun cemetery. This could also have happened in the Han Dynasty, and further diversified the identities of people buried in this site.

Despite the complex scenario of Xuecun people's identities as introduced above, there is no marked division in the burial ground that might suggest differences in identity. However, there are several clusters discernible in the overall distribution of human burials (Figure 5, adapted from Zhou, 2008; tentative district divisions are marked by lines). Large burials with multiple brick-built chambers are mostly located in the southeast section of the cemetery (district A) and the majority of small burials are clustered in the western part (district C). Some small clusters of multi-chamber burials are located in the middle section (district B) that can be differentiated from the former two. This may indicate that although the wealthy people and the poor shared the same burial ground, they were not exactly buried together. There might have been small sections of burial ground reserved for certain wealthy families, as reflected by the small burial clusters with relatively sparse distribution seen in districts A and B.

Distribution of the selected individuals in the five temporal phases is uneven, and for some phases the sample sizes are too limited to be statistically meaningful. Thus they were re-grouped into two phases based on the original chronology. Phase one includes the original first and second phases and dates to Late Western Han and the Xin Dynasty (141 BC to 24 AD), and phase two covers the original third to fifth phases and dates to the Eastern Han (25 to 220 AD).

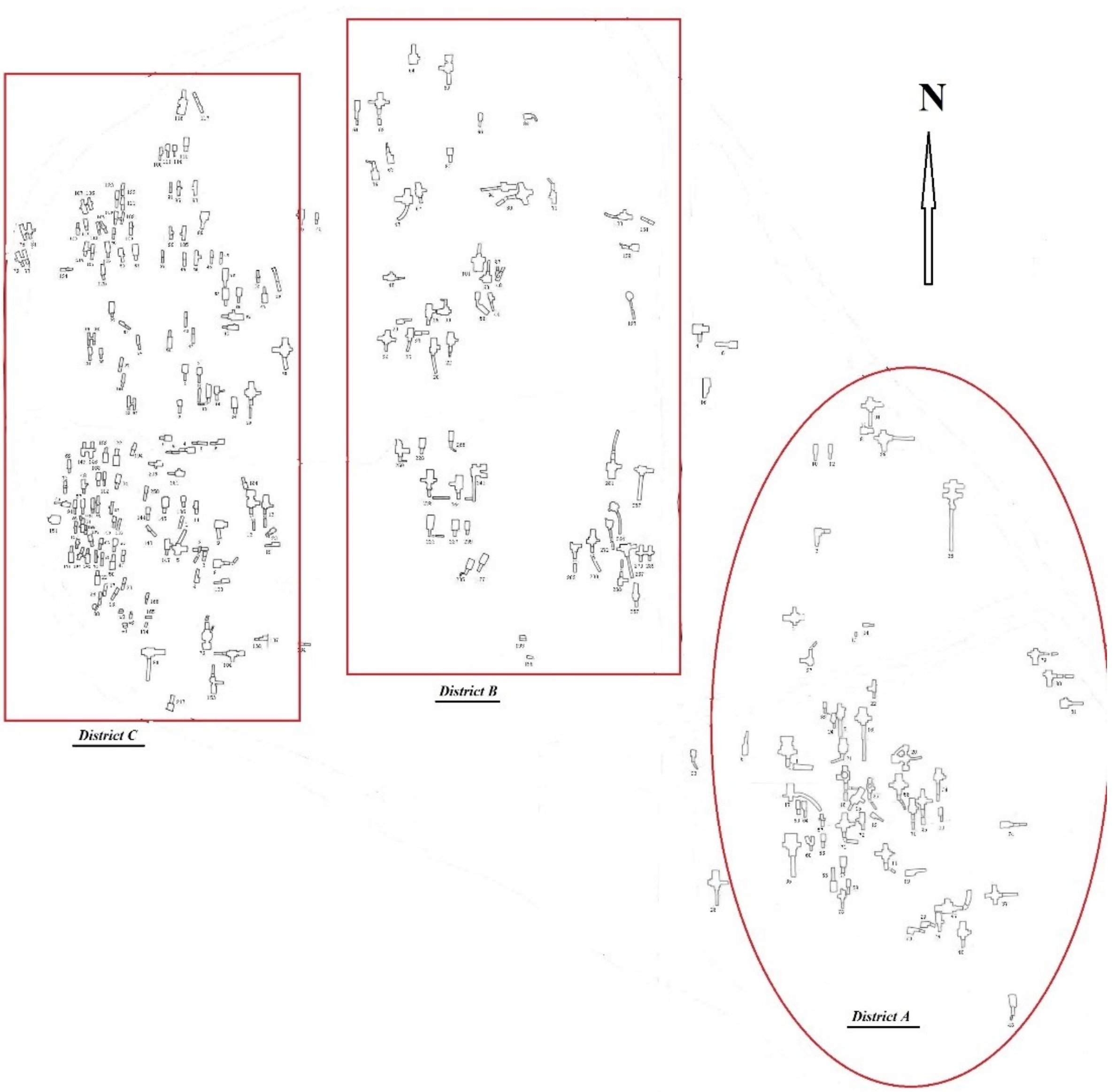

Figure 5. Distribution of Han tombs in Xuecun cemetery

4.2 Animal Samples

When available, contemporary animal remains should always be analyzed together with human remains, because they are able to reflect available meat resources for humans and shed light on animal husbandry strategy. For this study, animal remains dating to the Eastern Zhou Dynasty were chosen as comparisons for the human dietary analysis.

There are very few animal remains in the three Eastern Zhou cemeteries introduced above. The sampled animal remains, including pig, dog, cattle, and sheep, were excavated from a different but contemporary cemetery on the Tianli Food Factory construction site (TL cemetery) located about five kilometers to the south of ancient Xinzheng city (field report in progress; personal communication from the project director, professor Fan Wenquan of HPICHA). Pig and dog bones were found inside pottery *ding* vessels or *li* vessels, both of which are cooking utensils interred in the grave as funerary objects. Sheep and cattle bones were found beside human skeletons. These features indicate that the buried animal parts were likely to have been regarded as food for the afterlife. Some of the animals died at a very young age according to their unfused bone features. In total, fourteen animal samples including four pigs, one dog, three cattle and six sheep were sampled. The species were established by Dr. Wang Juan from the HPICHA.

Unfortunately, no animal remains from the Han cemetery in Xuecun are available for analysis because of the very poor preservation of animal sacrifice and funeral goods. Considering the close temporal and spatial proximity between the Xuecun and Xinzheng sites, it is unlikely that there would be significant differences between animal food resources of these two sites. Therefore, animal isotopic values from Xinzheng will also be used as reference values when analyzing Xuecun human diets.

4.3 Methods

4.3.1 Sex and age estimation of human remains

Sex and age estimations for human skeletons from these sites were previously done by different scholars. Remains from Yangdi and ancient Xinzheng city were examined by Dr. Takahiro Nakahashi from Kyushu University, Japan (Fan and Xu, 2007, pp.189), and the examinations of Chenjiagou and Xuecun skeletons were carried out by Dr. Sun Lei from HPICHA. In order to be consistent in the standards, all the chosen human skeletons from Yangdi, Xinzheng, and Xuecun were re-examined in June 2014 as part of the field work for this study. The results were confirmed or corrected by the programme supervisor Dr. Garvie-Lok from the Department of Anthropology, University of Alberta, during her visit to China in July 2014. The re-examinations followed the standards presented by Buikstra and Ubelaker (1994). Cranial and pelvic nonmetric features were used to determine the sex when available, and age estimations were based on features of the pubic symphysis and auricular surface.

Human remains from Chenjiagou site were added to the sample group in June 2015 after some of the individuals from the Eastern Zhou rural site Yangdi failed to yield any collagen. Age and sex information for these individuals was generously provided by Dr. Sun Lei. As Dr. Sun's estimations for Xuecun individuals are highly consistent with the results from the re-examination, her identifications of the Chenjiagou remains were used with permission.

The majority of the chosen individuals were adults and very few were adolescents; juvenile remains were excluded to avoid the potential effects of breast feeding on nitrogen isotope values. Detailed information for selected human samples is provided in Table 2. The "M?" (probably male) and “F?” (probably female) individuals are included into the Male and Female categories respectively during interpretation.

Table 2 Information about the selected human skeletal samples

Site	Date	Male	M?	Female	F?	Unknown	Total
Yangdi	Late Western Zhou to Early Eastern Zhou	5		3			8
Ancient Xinzheng City	Late Western Zhou to Late WSP	23	1	46		6	76
Chenjiagou	Eastern Zhou (SAP and WSP)	13	4	3	1	20	41
Xuecun	Western and Eastern Han	30	2	11	2	13	58
Total							**183**

4.3.2 Sample preparation and stable isotope analysis

The period of life represented by the stable isotope values of bone collagen depends on the bone types analyzed (Bell et al., 2001; Hedges et al., 2007). Bones with fast turnover rate may reflect dietary features of the most recent years before death, because old tissue archiving early years' isotopic signals have been quickly replaced by newly deposited tissue recording the most recent intake of stable isotopes from the diet. It is known that trabecular bone remodels at a faster rate than cortical bone, and it takes about five years for the adult rib to be completely remodelled because of its higher proportion of trabecular bone compared with others (Valentin, 2002, pp.185-188). So, ribs archive dietary signals in the last few years of life of the archaeological individual and are typically preferred for sampling. Moreover, as stable isotope analysis is a destructive process to archaeological bones, sampling ribs minimizes the destruction of skeletal information by preserving most key features of the remains.

In the sampling process for this study, rib ends of human remains were selected when available. If ribs were not preserved, samples were taken from non-reconstructable edges of other bones to avoid destroying any key features. The same principles were followed during the selection of animal bone samples. In addition, bone preservation was also one of the considerations in the sampling progress and only well preserved ones were chosen.

There are traditionally two methods of extracting bone collagen from archaeological bones for SIA. The University of Cape Town (UCT) method works on "chunk" bone samples, while the revised Longin method requires the samples to be pulverized and includes additional steps of gelatinization and ultrafiltration (Sealy et al., 2014). Comparative study has proven that both methods work effectively on relatively well preserved bone samples and yield reliable collagen without significant differences in stable isotope values (Sealy et al., 2014). The economical and less labor-intensive UCT method was applied in collagen extraction for the current study on account of the good quality of the selected samples.

About five grams of bone sample was initially taken from each human and animal skeleton. The visible superficial contaminants on the samples were mechanically cleaned using a hand motor tool. Then the samples were washed with double distilled water in an ultrasonic cleaner for three runs (ten minutes per run) or until the water became clear. After the washed samples were air-dried and weighed, they were soaked in 1% HCl solution (Sealy, 1986, pp.50-51). This process usually lasted one to two weeks depending on the proportion of trabecular bone in the sample, and the solution was refreshed every two days during this process till the samples were fully demineralized, displaying no more signs of reaction and becoming soft and translucent. Demineralized samples were then taken out of the acid solution, rinsed and kept in double distilled water for 24 hours before being transferred into 0.125M NaOH solution for 20 hours' treatment to remove any possible humic and fulvic acid contaminants (Katzenberg and Weber, 1999). Samples were then rinsed in daily-refreshed double distilled water until the solution was neutral in order to get rid of the NaOH residues attached to the collagen. The final product of this process was extracted bone collagen, which was then freeze-dried and weighed prior to analysis.

Following the method described above, nine of the animal samples were processed for collagen under the direction of Dr. Garvie-Lok in laboratory facilities of the Department of Anthropology, University of Alberta, in order to familiarize this researcher with the method. All other human and animal samples were processed in laboratory facilities of the HPICHA following the same method.

Stable carbon and nitrogen isotope analyses were all conducted at the Agricultural and Environmental Stable Isotope Laboratory of the Chinese Academy of Agricultural Sciences

(AESIL, CAAS, director Dr. Li Yuzhong) using a vario-PYRO cube element analyzer coupled to an ISOPRIME-100 Mass Spectrometer. Lab standard materials with known $\delta^{13}C$ and $\delta^{15}N$ values determined by the IAEA and USGS reference materials were inserted into the sequence after every 12 samples tested during the analysis to calibrate the precision. The $\delta^{13}C$ values were calculated based on international standard V-PDB, and the $\delta^{15}N$ results were calculated based on AIR. Precision for both $\delta^{13}C$ and $\delta^{15}N$ analysis in the lab is ±0.2 ‰ based on long-term monitoring. For the analysis of the current samples, values from the 16 standard lab materials ($\delta^{13}C$=-14.69±0.05‰, $\delta^{15}N$=6.97±0.04‰) confirm that the precision was within the expected range.

4.3.3 Statistical analysis

The Pearson product-moment correlation coefficient test (Pearson test) was used in the current study to test the correlation between $\delta^{13}C$ and $\delta^{15}N$ values. The Student t-test is used to do comparisons between two groups of data, because this method is suggested to be applicable in many situations, even when the sample size is relatively small (Ruxton, 2006; de Winter, 2013). One-way ANOVA test is conducted for inter- or intra- site comparisons when data groups are more than three. All of the tests were run on OriginPro.8.1.

5. Results and Site Level Interpretation

5.1 Sample Preservation

This study evaluated sample preservation using three indicators: the percentage of collagen yield by weight, atomic C/N ratio, and carbon and nitrogen percentage concentration by weight (DeNiro, 1985; Ambrose, 1990). In total, 183 human skeletal samples from four sites (see Table 2) and 14 animal samples from one site were processed to extract bone collagen. Most of these samples yielded intact pseudomorphs after treatment, a preliminary indication that the structural integrity of collagen and overall preservation were good (Sealy et al. 2014).

After chemical treatment, ten samples were rejected from further analysis either because they completely dissolved in the acid solution during processing or due to low collagen yield (less than 1%). The other 187 samples with collagen yields above 1% (range from 1.1% to 24%, average 9%) were sent for stable isotope analysis. The results demonstrate that only one sample had an atomic C/N ratio falling outside the acceptable range of 2.9 to 3.6 (DeNiro, 1985); this sample was thus excluded from the analytical group. The remaining 186 samples had their values falling within a range of 3.15 to 3.37 (average 3.2).

Among the 186 samples with acceptable collagen yield and atomic C/N ratio, 185 had C and N percentage concentrations above the lower limit established by Ambrose (1990) for well-preserved bone collagen (13% carbon and 4.8% nitrogen). Only one had values falling below these limits, though still above the minimal values reported by Ambrose (1990) for marginally preserved collagen (4.5% carbon and 0.9% nitrogen). Although the low values of this sample (8.1% carbon and 2.9% nitrogen) indicate poor preservation, it was finally accepted because both its collagen yield and C/N ratio were within the acceptable range.

Thus, after a detailed and standardized evaluation, 186 human and animal samples were considered to have yielded reliable bone collagen and were finally accepted for this study. Details of the accepted samples from each site are provided in Appendices 1-5. Table 3 lists average isotopic values for each site.

Table 3 Average isotopic values of human samples from each site

Site	**Male (Ave.±SD)**		**Female (Ave.±SD)**		**Total (Ave.±SD)**	
	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
	n=3		n=2		n=5	
Yangdi	-12.1±4.9	9.2±0.9	-13.2±5.1	9.1±1.7	-12.5±5	9.2±1.3
	n=17		n=4		n=39	
Chenjiagou	-9.2±0.8	9.5±0.7	-10.3±1.2	8.9±1	-9.7±1.4	9.2±0.8
	n=24		n=45		n=75	
Xinzheng	-10.5±1.7	9.1±0.9	-11.2±1.4	8.5±0.7	-11±1.6	8.8±0.8
	n=26		n=13		n=53	
Xuecun	-13.6±0.9	10.6±1.1	-14.2±1.1	10.5±1.1	-13.7±1.2	10.6±1.2
Total					**n=172**	

5.2 Stable Isotope Values of Animals

This study analyzed two species of herbivores (cattle, sheep) and two species of omnivores (pig, dog) from Tianli cemetery. Table 4 lists average values for each species, and the details of each animal sample are provided in Appendix 1. Generally, animal isotope values exhibit a wide range of variation in both $\delta^{13}C$ (-18.6‰ to -6.8‰) and $\delta^{15}N$ (5.3‰ to 10.7‰) (Figure 6), indicating significant dietary differences among these species.

Table 4 Average stable isotope values of animal samples from Tianli site

Species	n	$\delta^{13}C$(‰) (Ave.±SD)	$\delta^{15}N$(‰) (Ave.±SD)
Pig	4	-12.5±2.6	6.3±0.9
Dog	1	-9.4	7.3
Cattle	3	-9.5±1.9	7.5±0.2
Sheep	6	-15.7±1.9	9.0±1.4
Overall (n=14)		-13±3.3	7.8±1.5

Sheep stand out from the analyzed animals as shown in Figure 6. Their distinctively low $\delta^{13}C$ values (-13.1‰ to - 18.6‰, average -15.7±1.9‰) suggest that they had considerable amount of C3 plants in their diet, a much higher amount than that of all the other animals. The $\delta^{15}N$ values of sheep are also quite variable among different individuals (6.6‰ to10.7‰, average 9.0±1.4‰), and the majority of them are higher than in other species. Considering the young age of the selected animals as reflected by their immature bone features, it is very likely that these sacrificed sheep were at different stages of weaning, and their $\delta^{15}N$ values were subject to different degrees of the nursing effect (Fogel et al., 1989; Fuller et al., 2006). Individuals with unusually high δ^{15}N values might still have been suckling while others could have been fed at least partly on plant food.

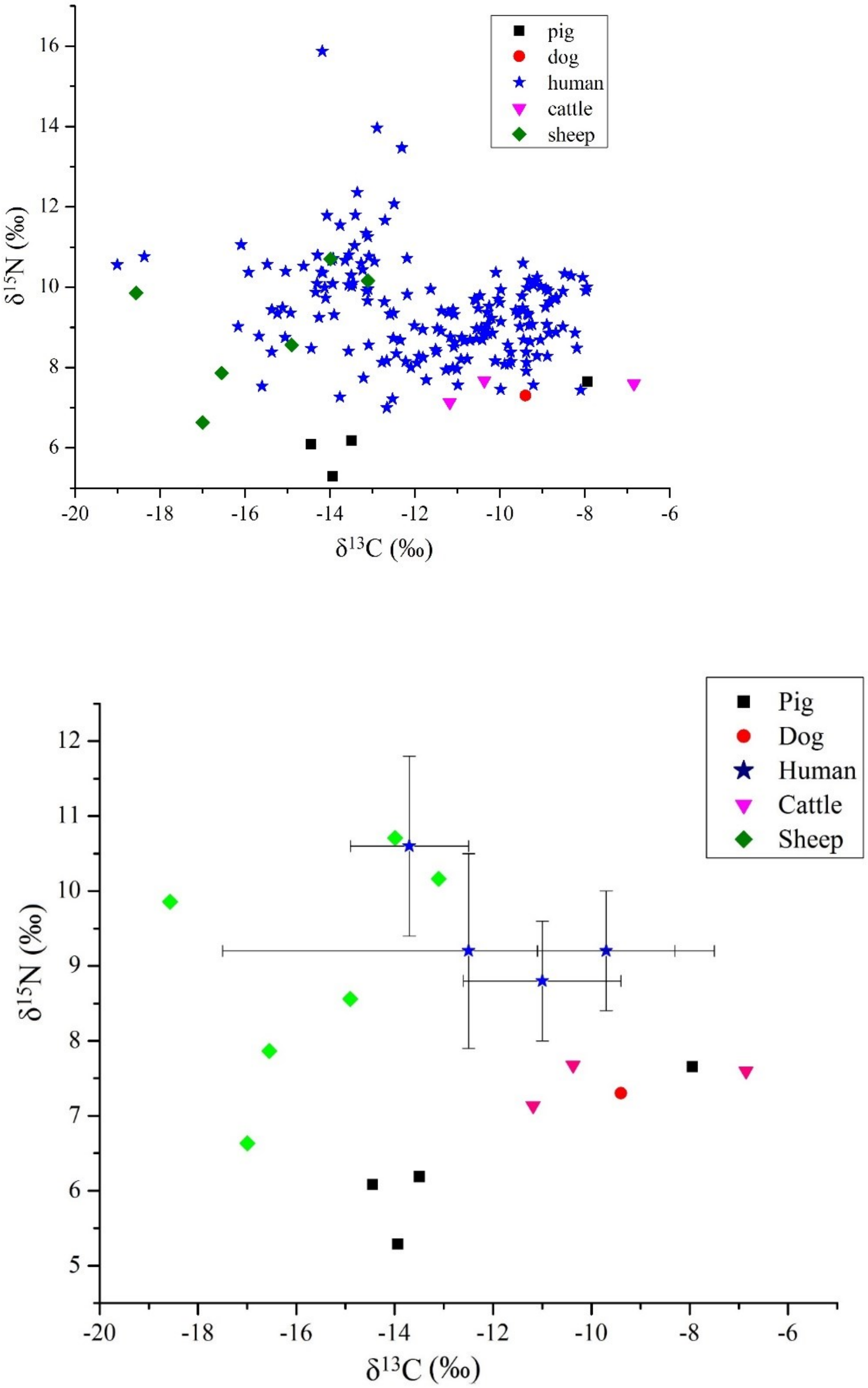

Figure 6 Distribution of animal stable isotopic values and average human values

Although both are domesticated herbivores, the three cattle are isotopically distinct from the sheep. All of their $\delta^{13}C$ values (average -9.5±1.9 ‰) fall above the highest sheep value, indicating that cattle were fed on a distinct diet mainly composed of C4 components. Average $\delta^{15}N$ of cattle (7.5±0.2‰) differs from that of sheep as well, displaying a lower value and very limited variation; this might indicate that these cattle were fully weaned and were not subject to any nursing effect.

The $\delta^{15}N$ differences reflect the varying situation of nursing between cattle and sheep at time of sacrifice, and $\delta^{13}C$ values also reveal more information besides diet. The dietary differences between these two species as reflected by $\delta^{13}C$ might indicate that they experienced different husbandry strategies, determined by their economic values. Since agricultural populations in ancient China did not use milk as human food, sheep were fed mainly for meat and wool. However, cattle were of special value to peasants as an important source of animal labor that could be used to carry loads and pull ploughs. It has been suggested that cattle were already being used to pull ploughs during the Eastern Zhou Dynasty, a practice that greatly benefited agriculture in some areas (Peng, 1991). Therefore, it is plausible that substantial amounts of agricultural by-products such as stalks and leaves of the C4 crop millet were fed to cattle because of their significant contribution, as well as their large requirement for fodder. Less millet waste was fed to sheep because they could easily get enough fodder by pasturing on wild C3 grasses. These different animal husbandry strategies were probably in place by Neolithic times, when more C4 was found in the diet of cattle compared to that of sheep (Chen et al., 2014). Parallel examples are still common today in the Chinese countryside.

Pigs and dogs are usually discussed together as both of them are omnivores with a very close relationship to humans. However, Figure 6 demonstrates these two species display significant differences in their isotopic values. The average $\delta^{13}C$ values of pigs (-12.5±2.6‰) indicate that they had a mixed diet with a larger C3 component than that of the dog ($\delta^{13}C$ =-9.4‰), and $\delta^{15}N$ values suggest that pigs (average $\delta^{15}N$ =6.3±0.9‰) had less animal protein intake than the dog ($\delta^{15}N$ =7.3‰). It is conventionally believed that dogs and pigs frequently scavenge human leftovers and are thus similar to humans in dietary features as reflected in both $\delta^{13}C$ and $\delta^{15}N$ (Hogue, 2003; Hu et al, 2009b). Values for the current samples seem to challenge conventional wisdom: all of the pig and dog $\delta^{15}N$ are markedly lower than human values (Figure 6), indicating that these animals were generally feeding at a lower trophic level than humans and did not benefit much from human leftovers.

It is worth noting that the four pigs from the same site also display apparent dietary variety (Figure 6). One of them had a typical C4-based diet ($\delta^{13}C$=-7.9‰), and its $\delta^{15}N$ value indicates that it fed at a higher trophic level than the other three, who were fed on a diet including a substantial proportion of C3 food and very low amounts of animal protein ($\delta^{13}C$=-14±0.4‰, $\delta^{15}N$=5.9±0.4‰). This indicates that there could have been two distinct ways of rearing pigs. Considering that millet was the only C4 crop and also the staple grain of the time, some pigs might have been raised in pens and fed almost exclusively on by-products of millet. The others were likely to have been fed with mainly C3 plants and limited amount of millet by-products. They could have been either kept in pens and fed with C3 agricultural products such as soybean, low in both $\delta^{13}C$ and $\delta^{15}N$, or herded outdoors in close proximity to human residences and fed on wild grass (mainly C3) and whatever they could find. Different ways of raising pigs have already existed since the Neolithic times (Chen et al., 2014). Even today when it is common to see these animals being kept in a pigsty, outdoor-reared pigs are also not unusual in some remote areas.

The animal stable isotope values indicate dietary variations among different species, as well as suggesting different husbandry strategies applied to cattle and sheep along with variable ways of rearing pigs. These values also provide a baseline $\delta^{15}N$ value to facilitate investigations of human diets by informing the human trophic level in the local food web. The groups average value did not exclude the potential suckling sheep with unusual high $\delta^{15}N$ values: archaeological context suggests that these sheep were treated similarly to the other animals, and literary sources attest that lamb was an important meat dish in the Zhou Dynasty (Jiang, 2008). Therefore, all these animals could possibly have been meat resources for humans, and their average $\delta^{15}N$ value of 7.8‰ will be considered as a reference value in the following discussions.

Some doubt the appropriateness of pooling together all the available terrestrial animal values to establish a $\delta^{15}N$ baseline for human trophic level (Hedges and Reynard, 2007). This is an important point to consider, since it is suggested that the likely common meat resources in both the Zhou and Han Dynasties were pig, dog, and chicken, while cattle and sheep were eaten only on very special occasions (section 2). With this information in mind, the study will use the average value for dog and pigs ($\delta^{15}N$=6.5‰) as an alternative reference value for human trophic levels.

5.3 Human Samples from Yangdi Site

As displayed in Figure 7, the $\delta^{13}C$ and $\delta^{15}N$ values of the Yangdi people show a wide apparent discrepancy. This suggests two distinctive dietary patterns, an unexpected result for a group of rural residents who were estimated to have cultural homogeneity and low mobility. The unusual implication becomes even more intriguing when considering the limited number of individuals (n=5)[2].

Although the individuals' average $\delta^{13}C$ of -12.5‰ seems to indicate a mixed diet with both C3 and C4 components, the very large variation (SD=5‰) suggests that such an interpretation would be unspecific. The three individuals (YY-M7, YY-M8, and YY-M9) with $\delta^{13}C$ values ranging from -8.1‰ to -9.1‰ had an undoubtedly C4-based diet, while the other two (YY-M5, YY-M6) with extremely low $\delta^{13}C$ values ($\delta^{13}C$=-18.4‰ and -19.0‰ respectively) had typical C3-based diet. The $\delta^{15}N$ values further confirm dietary differences between these two groups. The group with a C3-based diet (average $\delta^{15}N$=10.7 ‰) consumed foods with $\delta^{15}N$ values significantly different than those of the group with C4-based diet (average $\delta^{15}N$=8.2 ‰).

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[2] Details of each sample are provided in Appendix 2.

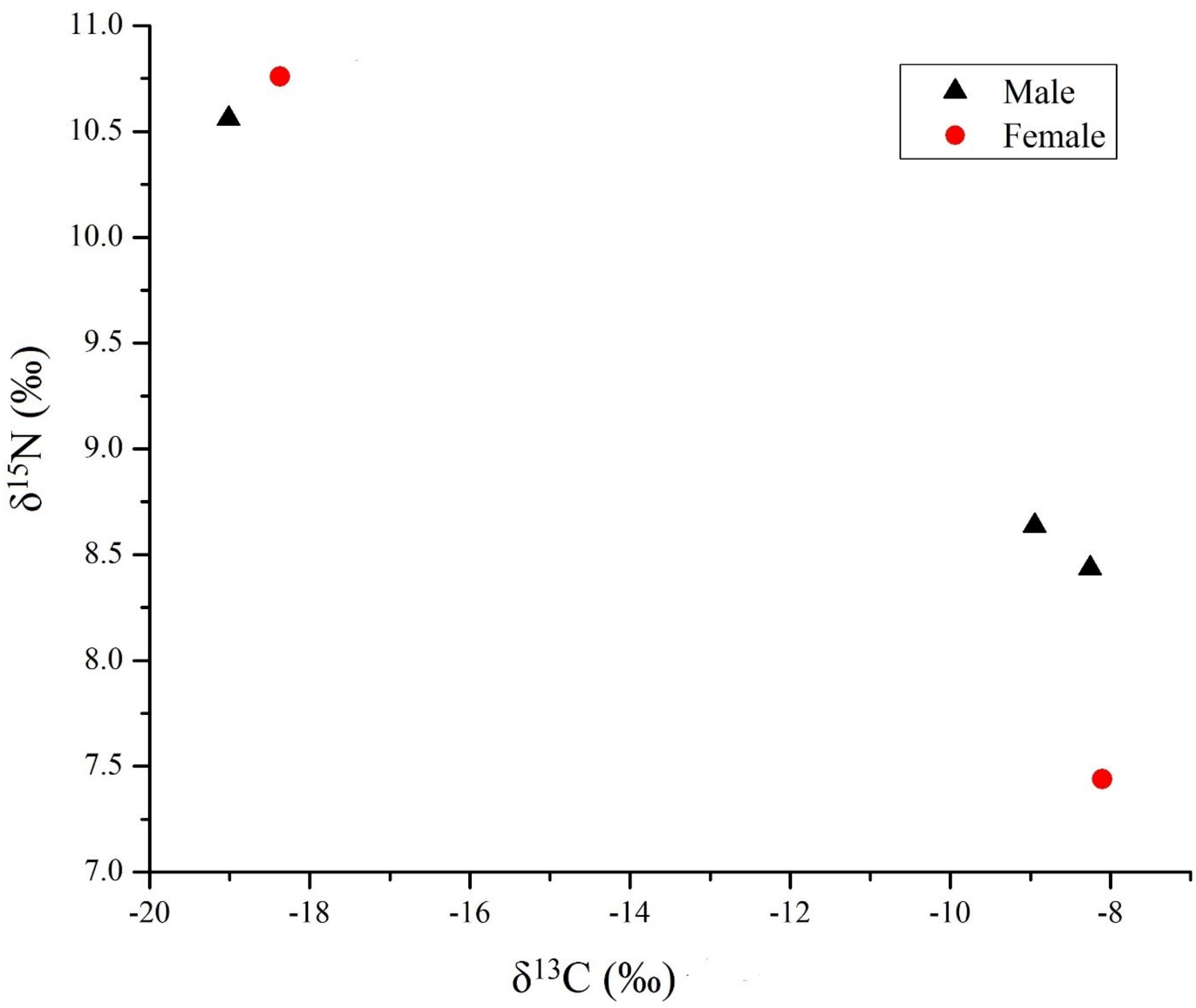

Figure 7. Distribution of stable isotopic values of Yangdi people

Isotopic studies of both ancient and modern millets have revealed variations of millet δ^{13}C. Archaeological millet grains including both broomcorn millet and foxtail millet from different sites had δ^{13}C values varying from -9.6‰ to -11.9‰ (An et al.; 2010). Modern millet seeds from different areas in northern China also display a variation in δ^{13}C ranging from -11.3‰ to -14.3‰ (An et al., 2015). Thus, slight differences within a population with limited variation in δ^{13}C or δ^{15}N values are expected and could be caused by the variable isotopic compositions of the same food components. The situation in Yangdi, however, cannot be explained by such usual intrapopulation dietary variation. Yangdi people's distinctive $\delta^{13}C$ values indicate completely different staple foods in the diet. Such discrepancy in $\delta^{15}N$ values might indicate a substantial trophic level difference; however, it might also imply that totally different meat resources were being consumed because archaeological information for these people has suggested an apparent similarity in their social status and thus their meat consumption level. It is highly likely that the Yangdi people represent a mixture of two groups of individuals with distinct dietary backgrounds. To be more specific, there were probably immigrants from somewhere else buried along with locals in the same place.

Millet, a C4 crop, is the long-cultivated major grain on the plains where the Yangdi site is located. The C3 grains rice or wheat might have been sporadically grown in some regions; current evidence indicates that they were only minor grains of the time, unlikely to affect human diet significantly. Given this context, the three individuals with C4 diets were likely to be locals, and the two with C3-based diets could be immigrants.

Following the region's long traditions, the three locals had millet as their staple grain; their $\delta^{15}N$ of 8.2‰ is slightly over the animal average value ($\delta^{15}N$ of 7.8‰) and less than one trophic level (4.5‰) above the mean pig and dog value ($\delta^{15}N$=6.5‰), suggesting limited meat in their diet. For the hypothesized migrants, their high $\delta^{15}N$ and low $\delta^{13}C$ values do not support a coastal origin (where human diets might be affected by marine foods that are enriched in both stable carbon and nitrogen isotopes). Their stable isotopic values might suggest a diet based on a large amount of freshwater fish, which could be high in $\delta^{15}N$ and low in $\delta^{13}C$, but this possibility is not supported by their social status as inferred by archaeological evidence. More likely, these individuals had links with an agricultural area growing rice or wheat. Further analysis with strontium or oxygen isotopes might be able to help reveal their potential origins. It is the distinctive rib stable isotope values, rather than different burial treatment that suggest the presence of these male and female non-locals at the site. This in turn may mean that migration occurred during the last years of life, such that bone turnover had not yet erased their distinctive stable isotopic values. These individuals have raised intriguing questions for future study.

5.4 Human Samples from Chenjiagou Site

The Chenjiagou site is also in rural Eastern Zhou. There were 39 Chenjiagou human individuals being sampled for this study[3]. Their average $\delta^{13}C$ value ($\delta^{13}C$ =-9.7±1.4 ‰) suggests a C4-based diet with a certain amount of variation, and their average $\delta^{15}N$ of 9.2±0.8 ‰ indicates very limited meat in the diet if compared with the overall animal $\delta^{15}N$ of 7.8‰ or with the alternative value from pig and dog ($\delta^{15}N$ =6.5‰). This is expected in an agricultural population whose diet was unlikely to have included too much meat. There is no correlation between the collagen $\delta^{13}C$ and $\delta^{15}N$ (Pearson r=0.19, p=0.22), and Figure 8 displays a relative compact distribution except for one individual with unusually low $\delta^{13}C$.

The majority of the Chenjiagou people are located at the higher end of the $\delta^{13}C$ scale in Figure 8, indicating that most diets were based on the C4 grain, millet. Thus, the lowest $\delta^{13}C$ value can be considered an outlier. There are no apparent outliers in their $\delta^{15}N$ values, despite the wide variation from 7.6‰ to 10.6‰. This might be attributed to a variable amount of meat and/or freshwater fish consumption; however, the latter possibility can be rejected by the generally low

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[3] Details of each sample are provided in Appendix 3

elevation of nitrogen values compared to that of animals. As meat consumption is always considered to be related to trophic level and social status, such variation might further reflect an internal hierarchy of the rural community in Chenjiagou. This is a question that deserves further investigation.

In order to detect possible factors that might have caused the internal dietary variation, comparative analysis between the two sexes was first conducted. Statistical results reflect that there is no correlation between $\delta^{13}C$ and $\delta^{15}N$ of males (n=16. Pearson r=0.16, p=0.54) or females (n=4. Pearson r=0.16, p=0.54), and that their $\delta^{13}C$ values are significantly different (t-test: t=2.28, $p < 0.05$. Mann–Whitney U test: p=0.04), while their $\delta^{15}N$ values are not (t-test: t=1.54, p=0.14. Mann–Whitney U test: p=0.19). This suggests that the diet of males and females differed in terms of staple foods, but not in terms of meat. As shown in Figure 9, females have a lower average $\delta^{13}C$ value and wider variation (-10.3±1.2‰) than males ($\delta^{13}C$ =-9.2±0.8‰), suggesting that females might have had a greater C3 component in their diet than males. The results might have been partly affected by the limited number of female samples (n=4).

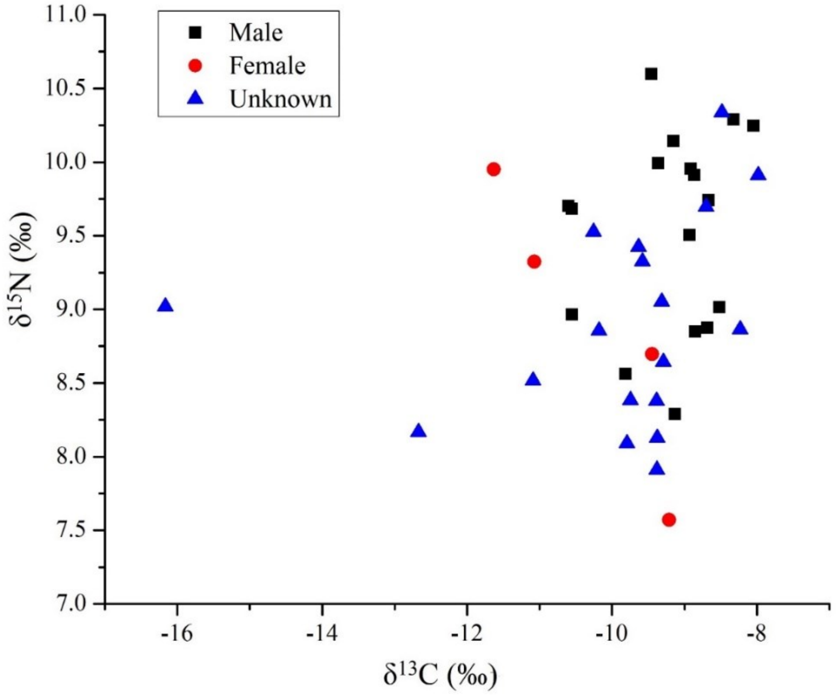

Figure 8. Distribution of stable isotopic values of Chenjiagou people

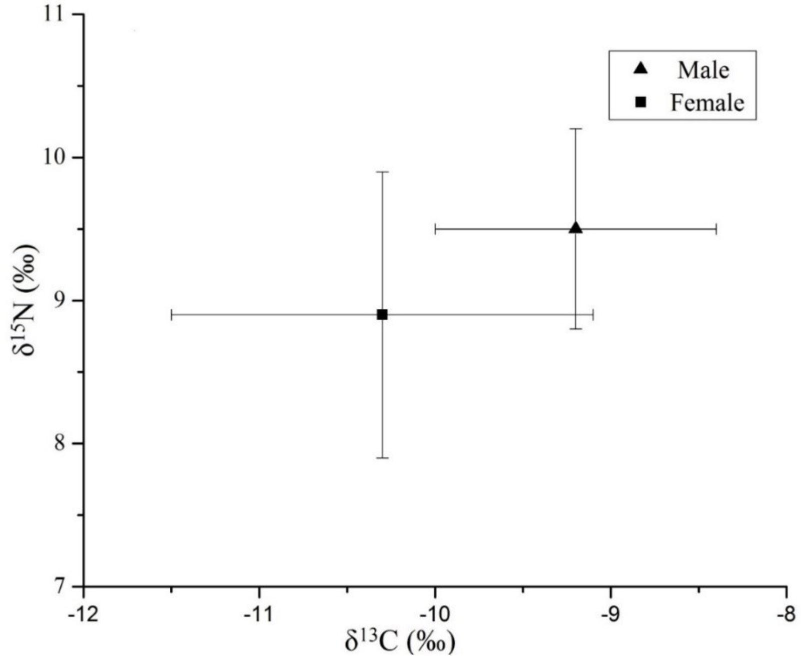

Figure 9. Isotopic comparison between males and females from Chenjiagou (Ave.±SD)

Although all of the Chenjiagou people were commoners living in a rural area, their burial furniture and funerary objects display apparent variations, which, if not related to social status, must reflect economic disparities or other factors. For further comparison, the 39 Chenjiagou individuals were divided into three groups based on their burial furniture (see section 4.1.2). Average isotope values of each group and the results of one-way ANOVA test are listed in Table 5. Neither the δ^{13}C nor the δ^{15}N values of these three groups are significantly different, rejecting the hypothesis that their δ^{13}C or δ^{15}N values are affected by economic conditions.

Table 5. Average isotope values of three groups of Chenjiagou people divided by burial furniture

Group	Burial furniture	N	δ^{13}C(‰) (Ave.±SD)	δ^{15}N(‰) (Ave.±SD)
1	Double	5	-10±0.8	9.3±0.5
2	Single	23	-9.5±1.6	9.3±0.8
3	None	11	-9.8±1.4	8.9±0.8
One-way ANOVA test			**F=0.26; p=0.77**	**F=0.94; p=0.4**

NOTE: Burial furniture groups are divided by number of coffin layers. Double layers refer to one outer coffin (*guo*) and one inner coffin, single coffin refers to the inner one only.

Another way to attempt a look at status and diet is to consider variability in funerary objects. Statistical comparison shows that the three groups of people, divided by the categories of their grave goods, are also not significantly different from each other in either δ^{13}C or δ^{15}N values (Table 6). These two tests suggest that the Chenjiagou people's diet was not subject to economic factors or other aspects of life that affected funerary objects.

Table 6. Average stable isotope values of three groups of Chenjiagou people divided by funeral objects

Group	**Funeral objects**	**N**	**$\delta^{13}C$(‰) (Ave.±SD)**	**$\delta^{15}N$(‰) (Ave.±SD)**
1	Pottery and jade, or jade only	6	-9.2±0.9	9.1±0.9
2	Pottery only	17	-9.3±0.7	9.5±0.7
3	None	16	-10.2±2	9.0±0.8
One-way ANOVA test			**F=2.1; p=0.14**	**F=1.8; p=0.17**

In general, stable isotope values indicate that the rural population of Chenjiagou had a millet-based diet with very limited meat. Despite the variability in burial furniture and grave goods seen at the site, their diet was apparently homogeneous between status groups (as measured by burial furniture and grave goods). A statistically significant sex-related difference suggests that females might have eaten more C3 food than males. The highly similar diet among different groups, along with limited meat consumption, is consistent with the Chenjiagou individuals' agricultural peasant lifestyle and suggests that there was little if any internal hierarchy in diet.

5.5 Human Samples from Ancient Xinzheng City

5.5.1 General features

The Xinzheng human samples come from two cemeteries, XH and TP. They are analyzed and discussed together because of their close proximity inside ancient Xinzheng city[4]. Their average $\delta^{13}C$ value of -11±1.6‰ (n=75) reflects a mixed diet mainly composed of C4 components, but an effect from C3 food is also visible. Compared with the overall animal $\delta^{15}N$ value (7.8‰) and the alternative $\delta^{15}N$ value from pig and dog (6.5‰), Xinzheng people's average $\delta^{15}N$ of 8.8±0.8‰ (n=75) shows little trophic level elevation. This indicates that meat in their diet was very limited. Given that they were from a prosperous capital city with a diverse population, the wide dispersion of individual stable isotope values (Figure 10) is expected and reflects dietary diversity, but the apparently limited meat consumption is a surprising find.

As seen in Figure 10, the $\delta^{13}C$ and $\delta^{15}N$ values display a relatively strong positive correlation (Pearson r=0.56, $p < 0.05$). This positive correlation between bone collagen $\delta^{13}C$ and $\delta^{15}N$ has been found in many aquatic settings, and indicate dietary reliance on marine or freshwater fish species (Ambrose et al., 1997; Weber et al., 2011). However, there are also exceptions that should not be ignored. For example, a similar positive correlation was observed in inland Mongolia, where it is likely to have been caused by environmental factors rather than consumption of aquatic resources (Fenner et al., 2014). Similarly, heavy dietary reliance on aquatic species seems unlikely for ancient Xinzheng city. Although the two rivers passing the eastern and western side of the city (Figure 3 in section 4.1.3) could have provided easy access to freshwater fish, and the trading with the coastal regions might also have enabled marine fish

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[4] Details of each sample are provided in Appendix 4

consumption, the very slight elevation of human $\delta^{15}N$ above domesticated animals (1‰) argues against a significant amount of fish consumption. If marine animals were consumed, we would expect to see human collagen $\delta^{15}N$ values elevated to a higher level. As the low $\delta^{15}N$ of human indicates a terrestrial-based diet, variable consumption of C4-fed animal meat with enriched stable carbon isotope values is likely the cause of the positive correlation between human bone collagen $\delta^{13}C$ and $\delta^{15}N$. This is reasonable, because domesticated animals were fed with considerable amounts of C4 fodder, as demonstrated by the species analyzed in section 5.2.

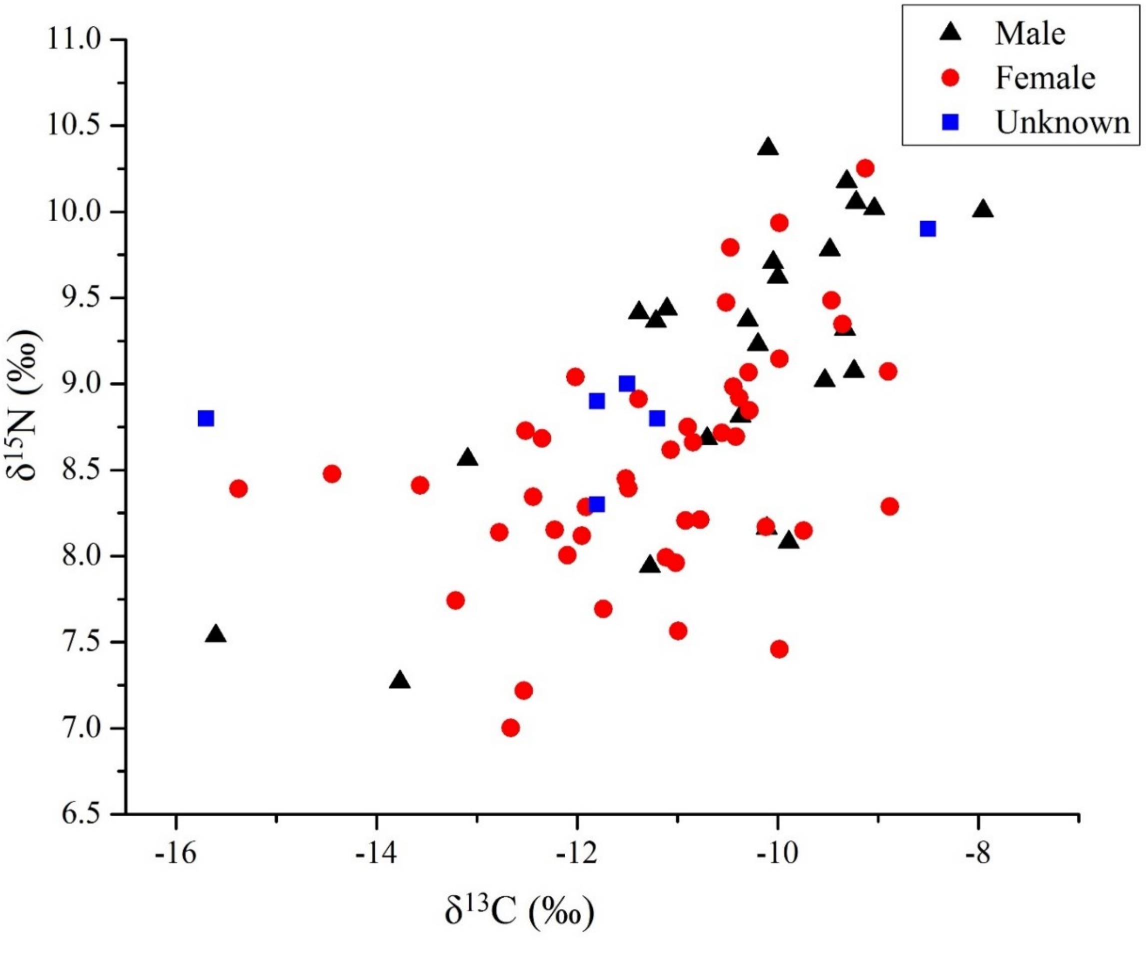

Figure 10. Distribution of human stable isotopic values from ancient Xinzheng city

The Xinzheng collagen $\delta^{13}C$ values feature a large variation ranging from -15.7‰ to -8‰, suggesting substantial dietary differences among these urban people. The individuals at the low end of this distribution might have consumed significant amounts of C3 foods. However, it is hard to identify them as possible non-locals given that the overall distribution of isotope values in Figure 10 does not display a wide discrepancy between those individuals with C3-rich diets and the majority. Although the C4 grain millet was still the staple food (as reflected by both historical documents and isotopic values), the dietary effects from C3 food should be noticed as well. As illustrated in Figure 10, it is obvious that some individuals had a fairly strong reliance on C3 staples, potential candidates for which could be rice, soybean, or wheat. As rice is suggested to have been a luxury grain in northern China during the Eastern Zhou (Hsu, 1984b; Qian, 2009), the C3 isotopic effect should be primarily reflected in the upper classes if this was the C3 food that had consumed by the people of Xinzheng. In another way, if rice was the C3 food consumed by the people of Xinzheng, nobles should display lower $\delta^{13}C$ values than commoners. If this is not the case, the data will instead suggest that the consumption of rice can be excluded and that wheat or soybean were the likely the C3 resources eaten at Xinzheng. To test these possibilities, the dietary features among the different social classes should be compared.

5.5.2 Social status and human diet at ancient Xinzheng city

In this study, diversity in social status of the Xinzheng people will be measured through variations in burial furniture. As introduced in section 4.1.3, the 75 burials are divided into three levels according to their burial furniture, and the average $\delta^{13}C$ and $\delta^{15}N$ of each level are listed in Table 7.

As reflected in Table 7, both the first and second level of people buried in multiple and single coffins display positive correlations between $\delta^{13}C$ and $\delta^{15}N$, but the third level does not. This indicates dietary differences between the first two levels and the third one, a supposition further clarified by one-way ANOVA test. Its results show that the $\delta^{13}C$ values of the three levels are significantly different ($F=12.9$; $p < 0.05$) and there is no significant difference in their $\delta^{15}N$ values. When the average $\delta^{13}C$ and $\delta^{15}N$ values of these three levels are plotted with standard deviation in Figure 11, the difference becomes much clearer. Levels one and two almost overlap with each other in both $\delta^{13}C$ and $\delta^{15}N$, demonstrating that the diets of people buried in one or more coffins were highly similar. The third group of people were buried with no coffin and presumably belonged to the lowest social stratum in the city. These individuals stand out with significantly lower $\delta^{13}C$ values (Figure 11). Thus, economically disadvantaged people (average $\delta^{13}C=-13.6\pm2.4‰$) likely had a considerable reliance on C3 food, unlike the wealthy and the nobility. Rice could not have been the poor's choice of grain because of the difficulty of growing it in the north. The other two potential choices were wheat and soybean. As the difference in $\delta^{13}C$ but not $\delta^{15}N$ (as seen in Table 7) likely reflects a difference in staple grain rather than protein resource, the possible candidate of soybean can be excluded. It can thus be confidently proposed that the C3 dietary signal reflected in $\delta^{13}C$ values is a consequence of wheat consumption by individuals from the lowest economic stratum of Xinzheng city.

Table 7. Average isotope values of three levels of Xinzheng people divided by burial furniture

Level	Burial furniture	N	$\delta^{13}C$(‰) (Ave.±SD)	$\delta^{15}N$(‰) (Ave.±SD)	$\delta^{13}C$-$\delta^{15}N$ correlation Pearson test
1	Multiple	19	-10.8±1.4	8.9±0.8	$r=0.7, p<0.05$
2	Single	49	-10.7±1.2	8.7±0.7	$r=0.5, p<0.05$
3	None	7	-13.6±2.4	8.5±1	$r=0.7, p=0.06$
One-way ANOVA test			**$F=12.9; p<0.05$**	**$F=0.58; p=0.56$**	

Wheat was introduced from the west and took a long time to be significantly incorporated into human diet in northern China (Zhou and Garvie-Lok, 2015). Isotopic data from ancient Xinzheng city suggests that substantial wheat consumption on the plains could have begun in Eastern Zhou urban communities. This is probably related to the specific historical background. It is estimated that the population living in the ancient Xinzheng city during WSP exceeded 200,000 (Tao, 2008, p.19); this might have put great pressure on food provision, considering the tremendous food requirements of so many people. Additionally, the capital city suffered frequent disasters such as fire or famine in this era (Tao, 2008, p.34), further increasing the possibility of food crisis. Given such conditions, it would have been natural for people who had difficulties accessing traditionally accepted grains to seek new and unfamiliar resources for survival. Therefore, it is plausible that the disadvantaged urban residents would have begun to eat substantial amounts of wheat. While it was grown long before that time, it was not eaten as a staple grain for a long period, until triggering factors encouraged a dietary transition.

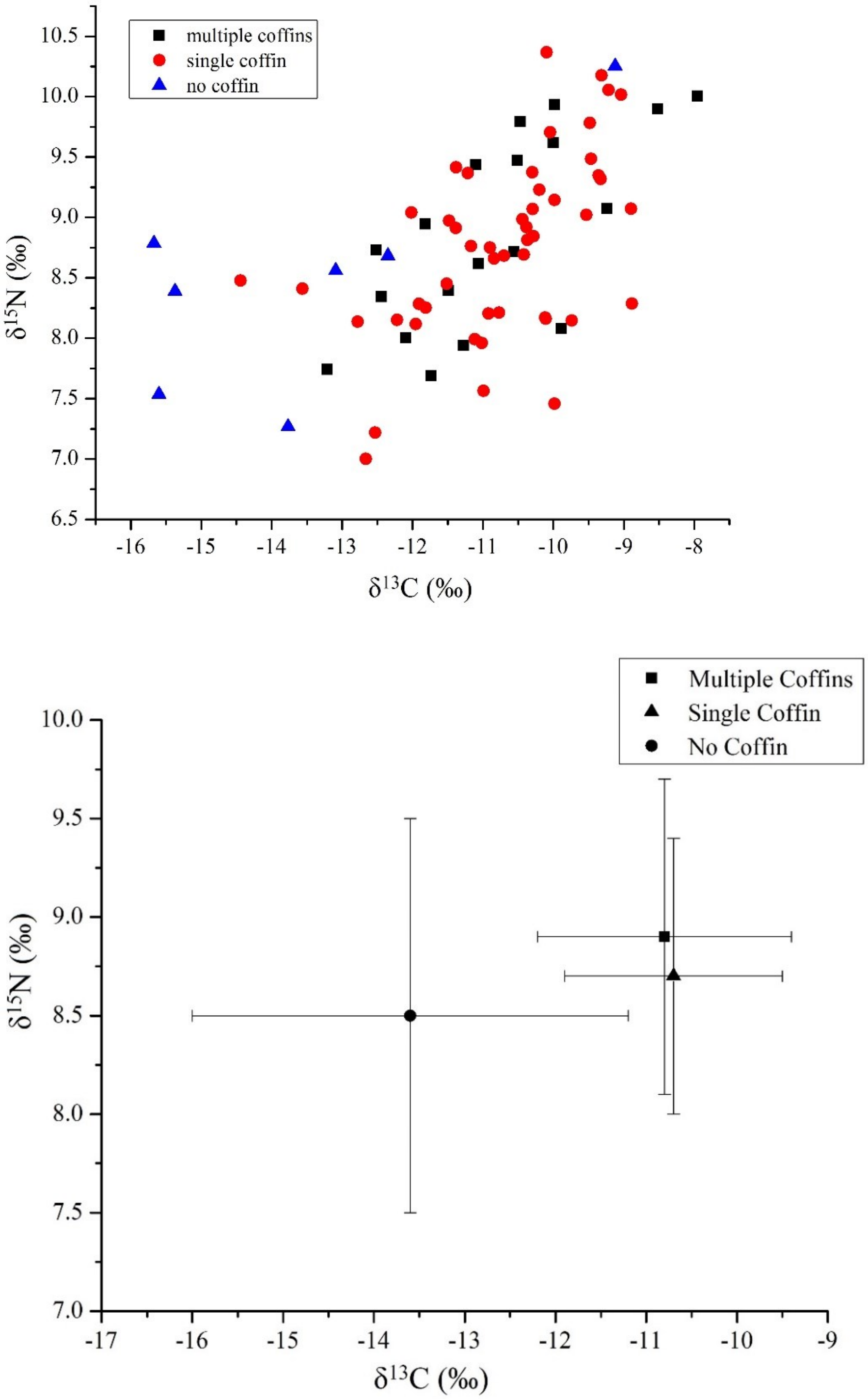

Figure 11. Isotopic comparison among three levels of Xinzheng people differentiated by burial furniture (top: scatter, bottom: Ave. ±1SD).

5.5.3 Temporal comparison

Since the field report has provided detailed chronological information on these urban burials, a comparison of the dietary features of different major phases might be able to reveal a detailed temporal pattern of wheat consumption. As introduced in section 4.1.3, the 75 individuals from Xinzheng were grouped into three major phases based on the chronological sequence provided in the report. Average δ^{13}C and δ^{15}N values of each phase and the results of one-way ANOVA test are listed in Table 8. Only individuals dated to phase two (SAP) display a strong positive correlation of δ^{13}C and δ^{15}N. While individuals in each of the three phases have similar δ^{15}N values, suggesting no temporal change in meat consumption, the significant difference in their δ^{13}C values ($F=7.1$; $p < 0.05$) suggests that dietary reliance on wheat changed substantially throughout the Eastern Zhou. It can be seen that individuals dated to phase three (WSP) had lower mean δ^{13}C and larger δ^{13}C variation than those from the two earlier phases (Figure 12), further indicating that wheat became important in human diet during the last phase of the Eastern Zhou (WSP).

The status-based dietary comparison revealed that wheat consumption started in the lowest social strata, and temporal comparison has made it clear that wheat became important during the WSP. However, as shown in Figure 12 and Figure 13, both of these two comparisons do not display apparent stepwise changes in δ^{13}C values, suggesting that neither did wheat consumption gradually decrease from the lower to the upper social strata, nor did it gradually increase temporally. Rather, it seems that the dietary role of wheat suddenly became visible in the WSP and was largely constrained to the poor, and that this C3 grain did not significantly influenced other people's diets at the site throughout the Zhou Dynasty.

Table 8. Average isotope values of Xinzheng people dated to three major phases

Phase	Date	N	$\delta^{13}C$(‰) (Ave.±SD)	$\delta^{15}N$(‰) (Ave.±SD)	$\delta^{13}C$-$\delta^{15}N$ correlation Pearson test
1	Late Western Zhou	9	-10.2±0.9	8.5±0.7	r=0.16, p=0.68
2	Eastern Zhou: SAP	30	-10.4±1	8.9±0.8	r=0.68, $p < 0.05$
3	Eastern Zhou: WSP	16	-11.6±1.4	8.7±0.7	r=0.7, p=0.06
One-way ANOVA test			**F=7.1; $p < 0.05$**	**F=1.5; p=0.24**	

NOTE:

1. The correlation between the three major phases and the original nine phases is introduced in section 4.1.3.

2. Twenty burials were not assigned to specific phases for lack of pottery evidence.

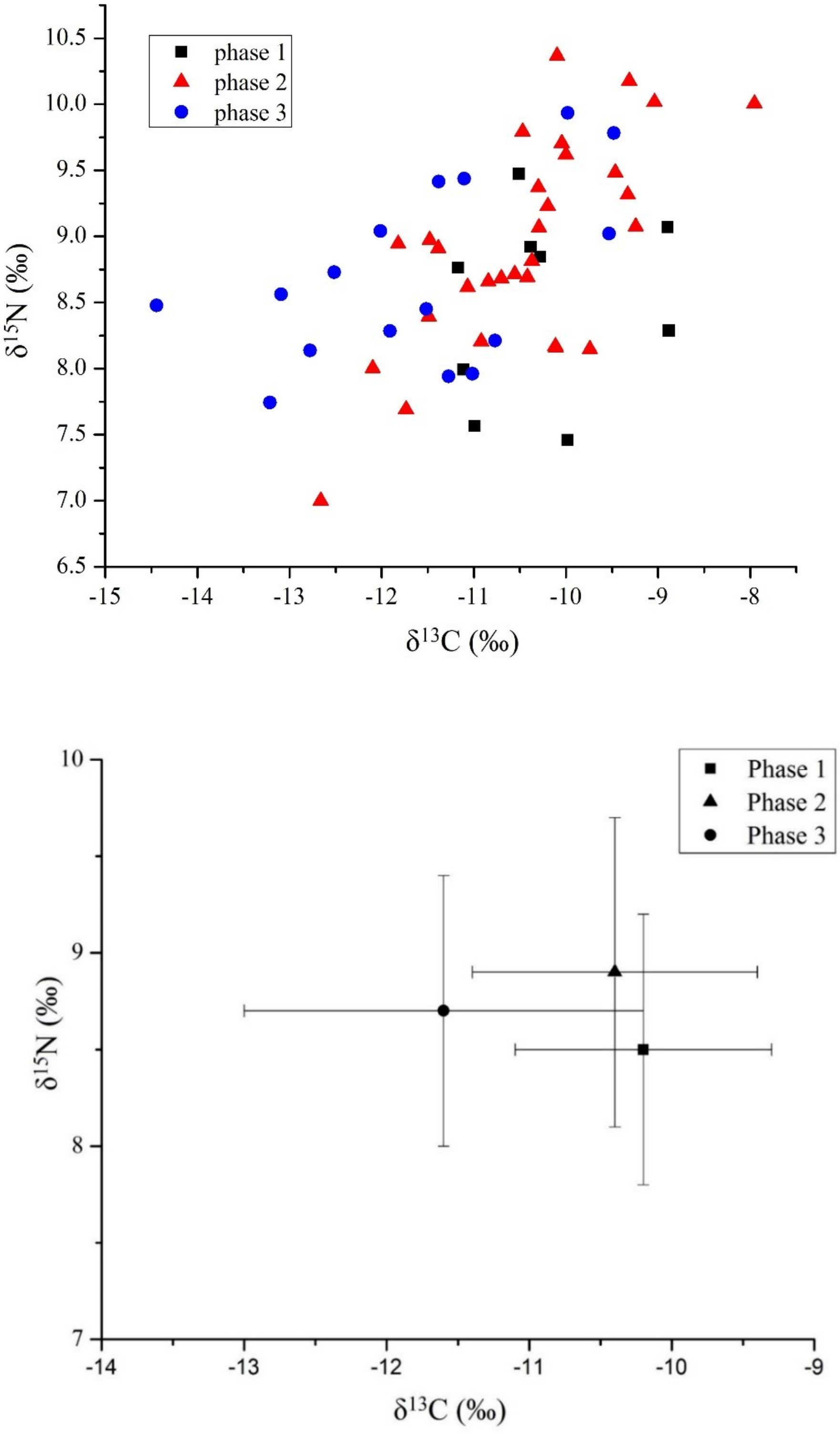

Figure 12 Temporal comparison of stable isotope values of the Xinzheng people (top: scatter, bottom: Ave. ±1SD).

5.5.4 Sex-based dietary comparison

There are 23 males ($\delta^{13}C$=-10.5±1.7‰, $\delta^{15}N$=9.1±0.9‰) and 45 females ($\delta^{13}C$=-11.2±1.4‰, $\delta^{15}N$=8.5±0.7‰) identified among the Xinzheng people. Both sexes display a positive correlation between their $\delta^{13}C$ and $\delta^{15}N$ values (males: r=0.7, $p < 0.05$; females: r=0.4, $p < 0.05$), but that of females is comparatively weaker. As suggested earlier, the positive correlations might be related to consumption of C4-fed animal meat, implying that the differences between male and female data could be attributed to variable meat consumption. This is evaluated by Student t-tests on their $\delta^{13}C$ and $\delta^{15}N$ values respectively. The results reflect that there is no significant difference in $\delta^{13}C$ between the two sexes (t=1.76, p=0.08), but their $\delta^{15}N$ values are significantly different (t-test: t=2.99, $p < 0.05$), supporting the hypothesis that males and females differed in amounts of meat intake or patterns of meat consumption. Males might have had slightly more meat than females, as shown in Figure 13 (for the individual values of males and females, please see Figure 10, page 98).

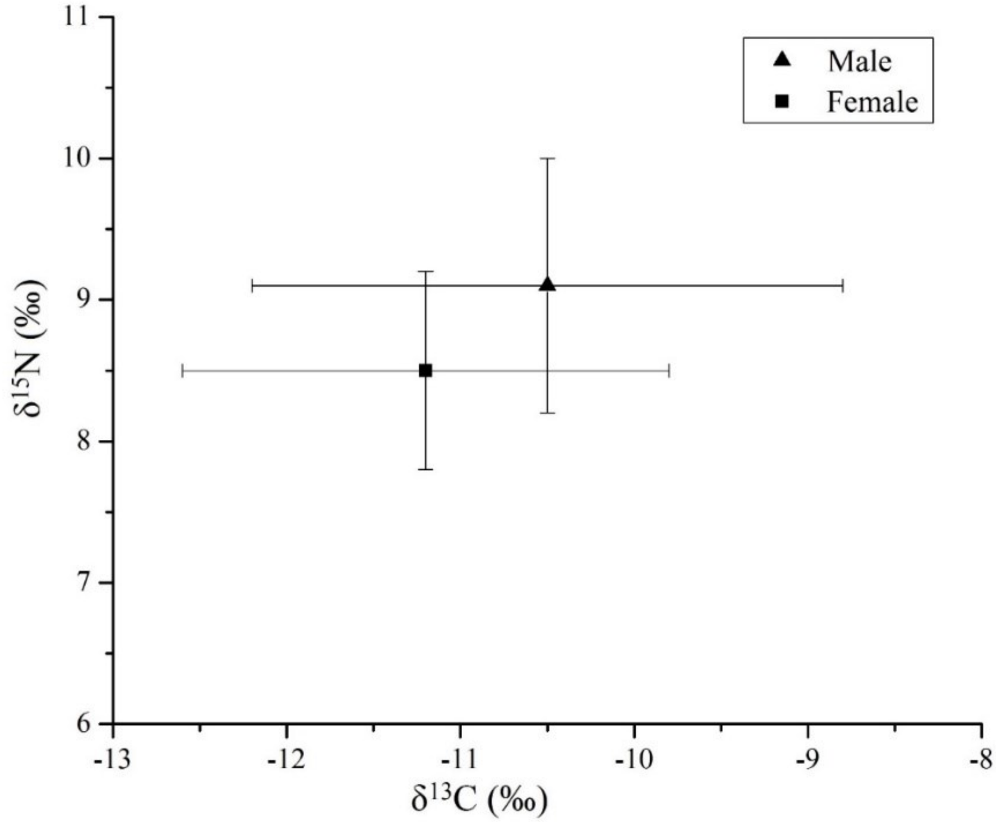

Figure 13. Isotopic comparison between Xinzheng males and females (Ave. ± SD)

5.5.5 Dietary features of distinctive individuals

Archaeological information suggests that there are some individuals in the samples with special identities or backgrounds, and their dietary features require attention as well. For example, the only individual buried in three layers of coffins (double outer coffins and one inner coffin) likely had the highest status among these 75 people. This is also supported by luxurious funerary objects in the grave (including bronzes and pottery ritual vessels) and a big tomb size (3.25 meters in length) compared to the others in the two cemeteries. All of this evidence suggests that the individual numbered as XH-M35 (female, 35-39 years old) was a low-ranked noble. This noble's collagen $\delta^{15}N$ of 9.8‰ falls at the higher end of all the nitrogen values (ranging from 7.0‰ to 10.4‰). If this individual did not suffer from special pathological conditions that would elevate $\delta^{15}N$ (e.g. Fuller et al., 2004; Metoka et al., 2006), but not be evident from the remains, such a high $\delta^{15}N$ value indicates a higher trophic level position than the majority of individuals from the site, meaning that this individual XH-M35 ate more meat than the others.

Additionally, there are two males (XH-M11 and XH-M19, both 35-39 years old) buried with weapons. Their average isotopic values ($\delta^{13}C$ =-10.2 ‰, $\delta^{15}N$ = 9.8‰) are very close to the noble numbered XH-M35, implying that they were also in a relatively advantageous dietary position. Their diet might have benefited from their occupation as warriors. The likely warrior numbered XH-M11, along with another male adult XH-M41, also differ from the other individuals because of their burial style, featuring a waist-pit (a pit dug at the level of the body's waist on the bottom of the burial) with a dog interred inside. The waist-pit with a dog inside has been identified as a common funeral custom of the Shang people predating the Zhou Dynasty. It was inherited by some in different areas of the Zhou, probably due to religious beliefs (Falkenhausen, 2006, pp.192-194). This custom was not common inside ancient Xinzheng city, with only 11 cases discovered among the 214 burials from the XH and TP cemeteries (5%), and the status of each of the 11 individuals varied (Fan and Xu, 2007, p.147). The only two of them that were isotopically analyzed (XH-M11, XH-M41) have relatively high stable carbon and nitrogen isotope values (mean $\delta^{13}C$=-9.7‰, $\delta^{15}N$=10‰) compared with those in more common burials, suggesting a diet based on millet, possibly with more meat than the others. Perhaps individuals with this inherited religious background played special roles or enjoyed relatively high status in the Zhou society, which enabled them to consume more meat, like low-rank nobles. Future archaeological research should use these clues and pieces of information to further explore this type of burial.

In the Eastern Zhou, the diet of ancient Xinzheng was based on millet; however, the effects of a C3 component (likely wheat) are isotopically visible. Status-based analysis and temporal comparison suggest that people of the lowest social stratum began to eat significantly more wheat than low-rank nobles and the wealthy during the WSP. It may be that food crises in this urban area forced the poor to accept a grain seen as inferior as a supplementary staple food. Overall, meat consumption was limited and it displays no significant status-related or chronological variation. Furthermore, there is no evidence supporting the consumption of aquatic resources. The few individuals with special social status or background may have been exceptions to these findings: their social roles may have earned them more meat than others. In terms of sex differences, males seemed to have eaten slightly more meat than females. However, the overall dietary features of the site suggest that status-related dietary differences inside this capital city were reflected more by wheat consumption than by meat intake.

5.6 Human Samples from Xuecun Site

5.6.1 General feature

The 53 individuals from Xuecun site, dated to the Han Dynasty, display a compact distribution of $\delta^{13}C$ and $\delta^{15}N$ values except for two outliers (XC1-M15; XC1-M20) that can be easily noted in Figure 14[5]. Xuecun people's average $\delta^{13}C$ of -13.7±1.2‰ suggests a significant proportion of C3 dietary components. If some key assumptions are made, this proportion can be estimated using the two end-member linear mixing model once used to evaluate dietary proportions of C3 and C4 food respectively (e.g. Vogel and van der Merwe, 1977; Schwarcz et al., 1985). When

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[5] Details of each sample are listed in Appendix 5

the average $\delta^{13}C$ of archaeological millet (-10.7‰, average of foxtail millet and broomcorn millet) reported by An et al. (2010) and the modern global mean $\delta^{13}C$ of C3 crops (-26.5‰) are used as values of the two end members, and a 5‰ diet-to-collagen $\delta^{13}C$ fractionation is applied, the approximate proportions of C3 and C4 resources appear to be 50% and 50% in the Xuecun people's diet. However, this result is actually far from reliable. There are certainly more than two potential dietary resources for a population, and their isotopic compositions vary (Schwarcz, 1991). The collagen is primarily, but not exclusively, reflecting dietary protein (Hare et al., 1991; Ambrose and Norr, 1993; Tieszen and Fagre, 1993; Jimet al., 2004). Collagen will not be as sensitive to low-protein resources, so that low-protein C3 or C4 resources will end up under-represented in this balance. Moreover, unknown proportions of carbon from carbohydrates and lipids will also be included in collagen; this makes the diet-to-collagen $\delta^{13}C$ fractionation not exactly 5‰. For all of these reasons, this C3 proportional estimates should only be regarded as a general indication that C3 foods played a significant role in the Xuecun people's diet. Such a strong dietary influence from C3 resources would not be possible without large-scale cultivation of the related crop. The influence may be direct (people eating the C3 crop), or indirect (people eating C3-fed animals), or both. This is difficult to determine because there is no faunal material from the Han era for comparison. However, wheat is a more reasonable candidate for such an influential C3 crop than rice, which definitely could not be so widely grown in the north because of environmental constraints.

When compared with the average animal $\delta^{15}N$ (7.8‰) from the Eastern Zhou site, the average bone collagen $\delta^{15}N$ of the Xuecun people (10.6±1.2‰) suggests a diet with a moderate meat component. However, the Xuecun people would be almost one trophic level higher (4.1‰, recalling that the $\delta^{15}N$ trophic level enrichment value assumed for this dissertation is 4.5‰)

above the animals if δ^{15}N of pigs and dogs (6.5‰) was used as reference value. If we assume continuity between Eastern Zhou and Han animal husbandry practices, this would suggest that pigs and dogs remained the most common meat resources for these people and were consumed frequently.

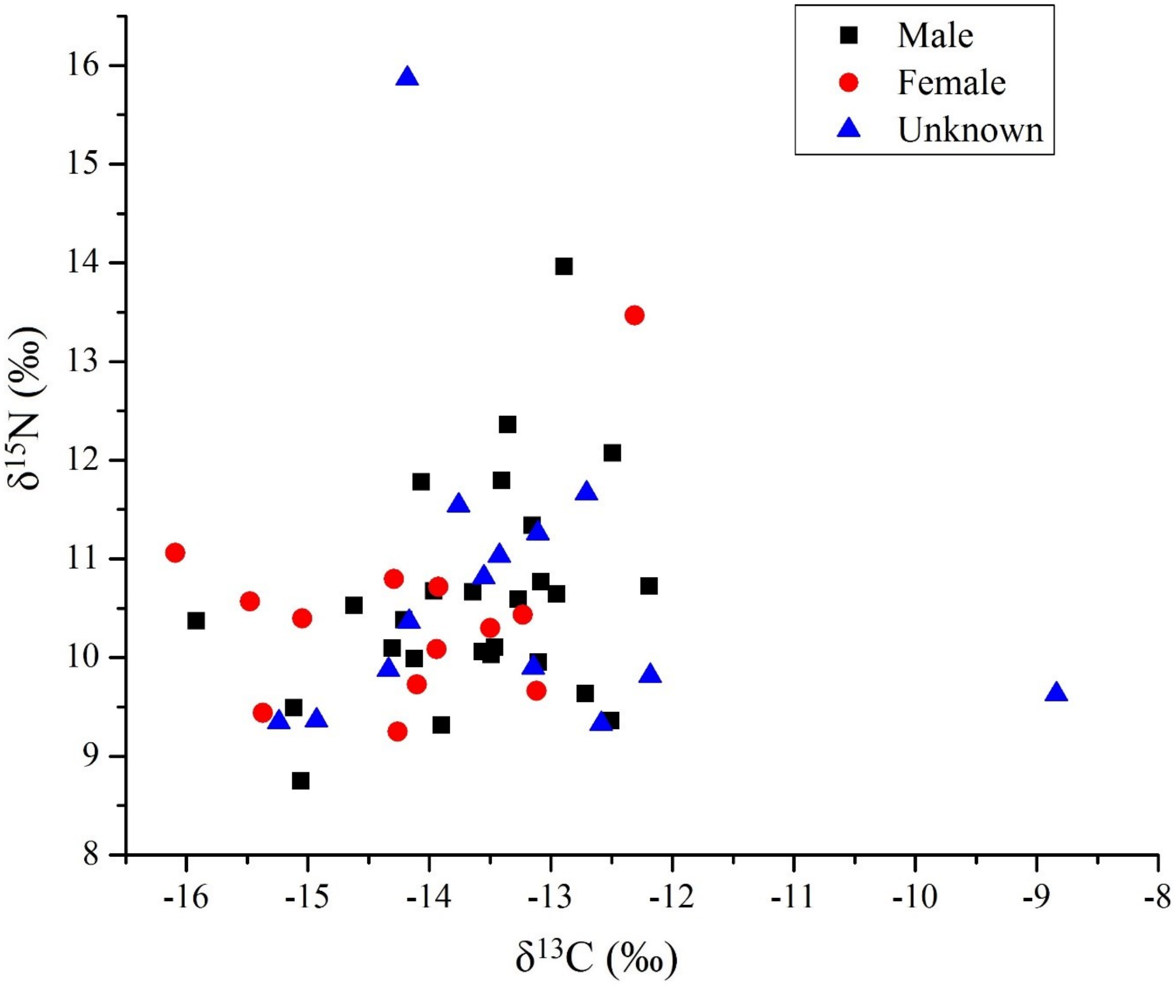
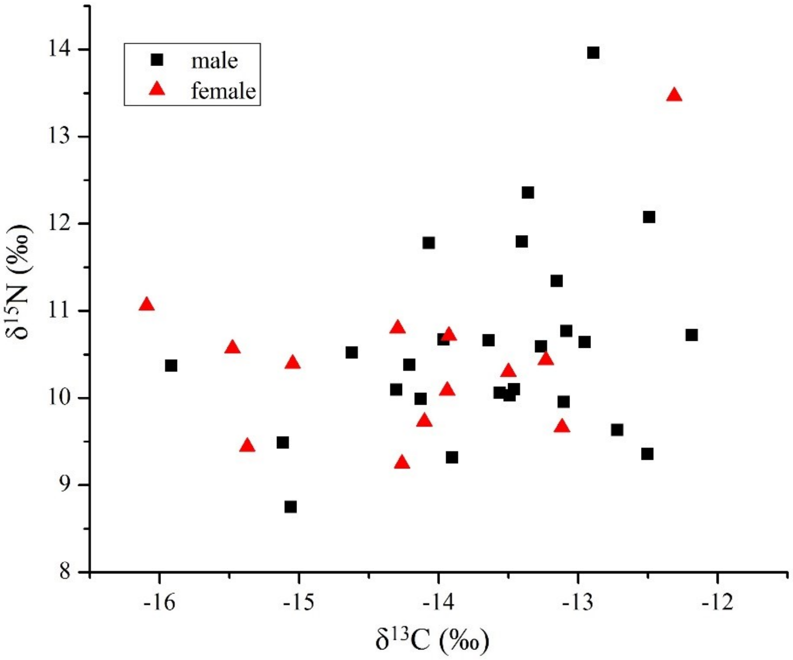


Figure 14. Distribution of human stable isotopic values from Xuecun

Considering their close proximity to the Yellow River, Xuecun people could have had easy access to freshwater fish, another potential meat resource for them. Freshwater resources in human diets are always hard to verify isotopically without local comparative samples because they vary significantly in isotopic compositions (e.g. Dufour et al., 1999). However, in the case of Xuecun, heavy dependence on aquatic resources appears unlikely because the average human $\delta^{15}N$ value is less than one trophic level above comparative faunal samples; this does not support heavy reliance on aquatic resources, which typically have high $\delta^{15}N$ values. Thus, it can be concluded, conservatively, that Xuecun people may have consumed freshwater from the Yellow River in amounts too limited to be isotopically evident.

5.6.2 Sex-related comparison

Males and females from Xuecun do not display any correlation between their $\delta^{13}C$ and $\delta^{15}N$ values. Their dietary features were not significantly different from each other in either $\delta^{13}C$ (Student t-test: t=1.7, p=0.1) or $\delta^{15}N$ (Student t-test: t=1.7, p=0.1). Figure 15 demonstrates that the average isotopic values and the variability of males ($\delta^{13}C$ =-13.6±0.9‰; $\delta^{15}N$=10.6±1.1‰) and females ($\delta^{13}C$ =-14.2±1.1‰; $\delta^{15}N$=10.5±1.1‰) are very close, indicating that they might have had very similar diets.



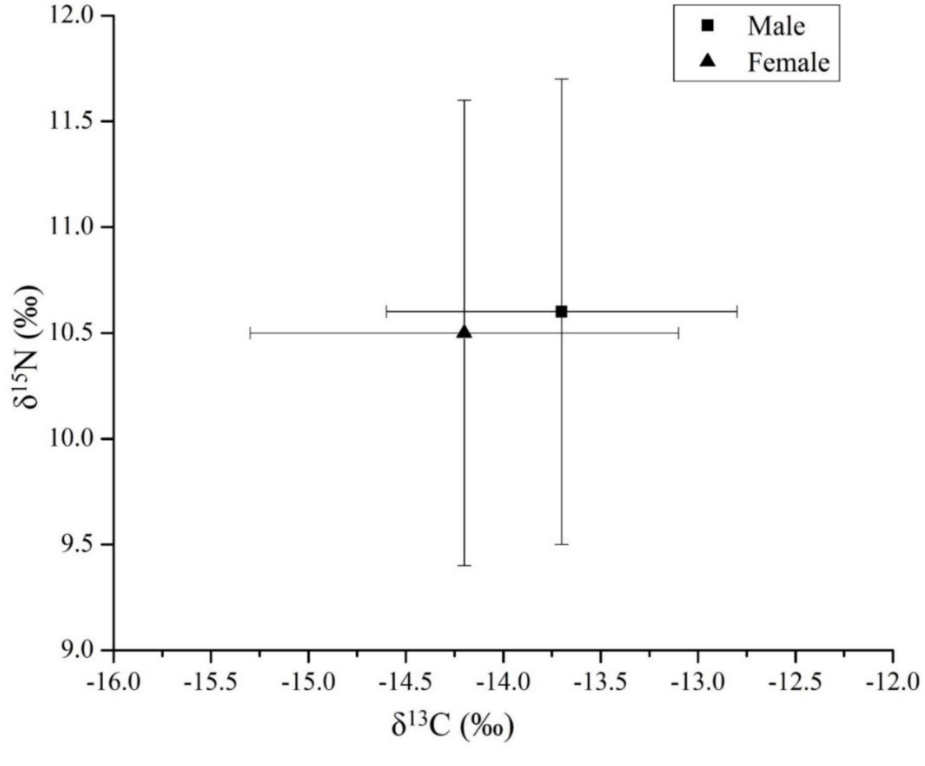


Figure 15. Isotopic comparison between Xuecun males and females (top: scatter, bottom: Ave. ±1SD).

5.6.3 Economic condition and human diet

There are significant variations in Xuecun's burial structures and funerary goods, indicating that the individuals in this study are likely to vary at least in economic capacity, if not social status or rank. This has raised the interest to compare the dietary features of people with different economic backgrounds. As introduced in section 4.1.4, human individual from Xuecun were divided into three levels according to their burial structure.

Each level's average $\delta^{13}C$ and $\delta^{15}N$ values, as well as the results of statistical comparisons are listed in Table 9, showing that the three status levels of Xuecun people differ significantly in $\delta^{13}C$ values both with and without outliers. However, their $\delta^{15}N$ values are not statistically different.

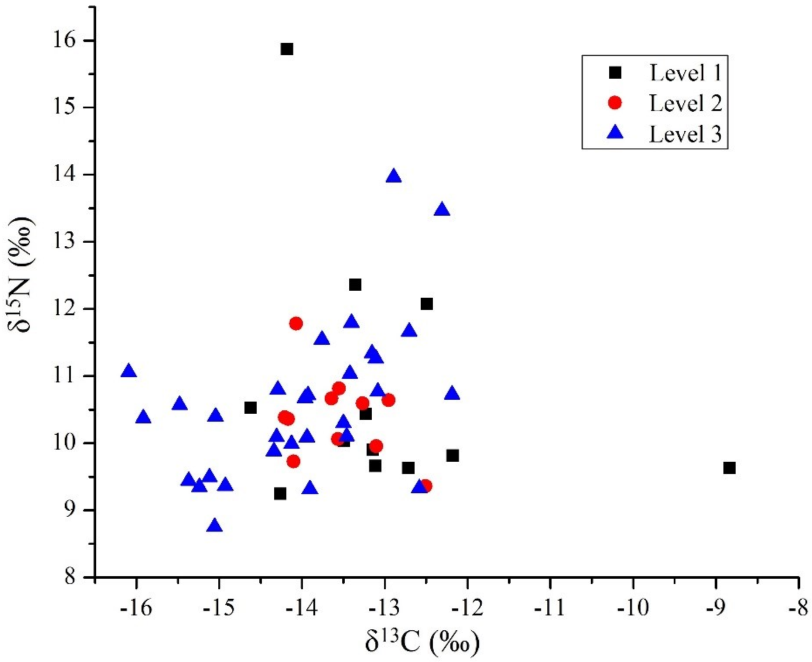
Table 9. Average isotope values of three levels of Xuecun people divided by burial structure

Level	**Burial structure***	**N**	**$\delta^{13}C$(‰) (Ave.±SD)**	**$\delta^{15}N$(‰) (Ave.±SD)**	**$\delta^{13}C$-$\delta^{15}N$ correlation Pearson test**
1	b-3, b-4	12	-13±1.5	10.8±1.9	r=-0.28, p=0.36
2	b-1, b-2	11	-13.6±0.6	10.4±0.6	r=0.39, p=0.2
3	e	30	-14±1	10.6±1.2	r=0.5, $p < 0.05$
One-way ANOVA test			**F=4; $p < 0.05$**	**F=0.2; p=0.78**	(outliers included)[#]
			F=3.2; $p < 0.05$	**F=0.4; p=0.66**	(outliers excluded)

NOTE: * "b" refers to tombs built of bricks; "e" refers to earthen catacombs without other material; number of chambers are shown after the letter.

 # The two outliers with unusual values are XC1-M20 ($\delta^{13}C$=-14.2‰, $\delta^{15}N$=15.9‰) and XC1-M15 ($\delta^{13}C$=-8.8‰, $\delta^{15}N$=9.6‰), both from level one.

The differences in isotopic values are laid out in in Figure 16 (outliers excluded at the Ave. ±SD pattern), which indicate that people of the upper levels had higher $\delta^{13}C$ values. When the two outliers with unusual extreme values (XC1-M20; XC1-M15) are excluded, it narrows down the variation of isotopic values for level one (Figure 16), but results of a one-way ANOVA test once again confirm a significant differences in their $\delta^{13}C$ values ($F=3.2$; $p<0.05$) and a stepwise increase in $\delta^{13}C$ from level three to level one (Figure 16). As discussed above, diet at the site in general was significantly affected by C3 resources, most likely wheat. However, the dietary reliance on wheat appears to have been variable and likely subject to economic conditions. The comparison in Figure 16 suggest that people of the lowest economic status had the most wheat in their diet, while those with best economic conditions had the least. The small difference of 1‰ in $\delta^{13}C$ between level one and level three individuals does not represent a large difference in the actual amount of wheat consumption; however, the presence of this statistically significant difference might indicate that wheat was in fact less preferred by people of better economic conditions. This is consistent with some textual sources suggesting that wheat was regarded as an inferior grain to millet during the Han Dynasty (see Yu, 1977 for a review), even during times of great famine (Fan, 1965, p.376).



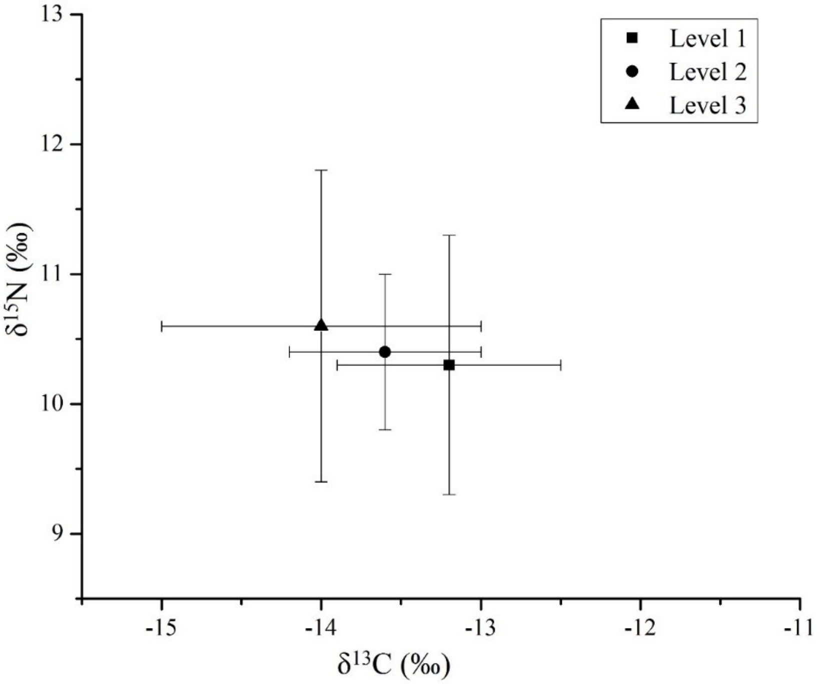


Figure 16. Isotopic comparison among three levels of Xuecun people divided by burial structure (top: scatter, bottom: Ave. ±1SD)

Note: The two excluded outliers in the bottom figure are XC1-M20 and XC1-M15

5.6.4 Grave distribution and diet

As stated in section 4.1.4, there was no marked spatial division in the burial ground of Xuecun. However, the overall distribution of the 287 burials can still be divided into three districts. District A includes most of the large tombs with multiple brick rooms, District B is occupied by small clusters of burials, and District C displays a very compact distribution of small burials (see Figure 5 in section 4.1.4). This indicates that the attribution of burial space was likely subject to economic constraints. A dietary comparison of these three districts may reveal further lifestyle variations. Results listed in Table 10 demonstrate that there is a stepwise decrease in $\delta^{13}C$ from District A to District C, or from the rich group to the poor group, but their discrepancies are so limited that there are no significant differences (F=0.9; p=0.4). The $\delta^{15}N$ values show even closer proximity than $\delta^{13}C$ values and also lack significant differences (F=0.2; p=0.8). Given these results, all the districts of interred individuals have close isotopic similarity, and perhaps dietary similarity.

Table 10. Average isotope values of three groups of Xuecun people buried in different districts

District	**N**	**$\delta^{13}C$(‰) (Ave.±SD)**	**$\delta^{15}N$(‰) (Ave.±SD)**	**$\delta^{13}C$-$\delta^{15}N$ correlation Pearson test**
A	13	-13.4±1.6	10.8±1.8	r=-0.13, p=0.7
B	10	-13.6±1.1	10.5±1	r=-0.04, p=0.9
C	30	-13.9±1	10.5±1	r=-0.4, $p < 0.05$
One-way ANOVA test		**F=0.9; p=0.4**	**F=0.2; p=0.8**	

Note: Distribution of Xuecun burials and tentative district divisions are shown in Figure 5 in section 4.1.4

5.6.5 Temporal comparisons

The analyzed 53 human individuals were divided into two temporal phases (Western Han and Eastern Han respectively) based on the original chronological sequence provided in Zhou (2008). Their average isotopic values and statistical results are listed in Table 11. Surprisingly, both the average $\delta^{13}C$ and $\delta^{15}N$ values are almost identical between the two phases except for slight discrepancies in the ranges of variation, suggesting a consistent human diet throughout the Han Dynasty. These results are unexpected because the Han Empire suffered high frequencies of natural disasters, especially in the Eastern Han (Yang, 1999), and the grain harvest declined sharply from the late years of the Western Han to the Eastern Han and thereafter, as a consequence of climate change (Su et al., 2014). Nevertheless, current isotopic results from Xuecun suggest that human diet was not affected, implying that there were stable food provisions throughout the Han Dynasty (or at least at Xuecun). Historically, these are likely signs of the development of agriculture and a prosperous empire.

Table 11. Average isotope values of Xuecun people dated to two major phases

Phase	**Date**	**N**	**$\delta^{13}C$(‰) (Ave.±SD)**	**$\delta^{15}N$(‰) (Ave.±SD)**	**$\delta^{13}C$-$\delta^{15}N$ correlation Pearson test**
1	Western Han and Xin	15	-13.8±0.9	10.6±0.9	r=0.4, p=0.1
2	Eastern Han	36	-13.6±1.3	10.6±1.4	r=0.06, p=0.7
	t-test		**t=-0.6; p=0.55**	**t=0.18; p=0.86**	

NOTE:

1. The correspondence between the two major phases and the original nine phases assigned by Zhou (2008) is introduced in section 4.1.4.

2. Two samples were not assigned to specific phases for lack of pottery or coin evidence

5.6.6 Diets of distinctive individuals

Despite the slight difference in C3 resource consumption among people of different economic capacities, all the sex-based, district-related, spatial, and temporal comparisons conducted above have revealed the highly homogeneous nature of the Xuecun people's diet. However, the two isotopic outliers located at the upper left and lower right corner respectively on Figure 15 should not be ignored given their unusual values and related archaeological context.

The individual (XC1-M20, adult, unknown sex) with the highest $\delta^{15}N$ value (15.9‰) was buried in one of the two biggest tombs in this cemetery (Zhou, 2008, p.87), likely confirming a correlation between social status (or economic capacity) and dietary trophic level. This person's $\delta^{15}N$ value is 8.1‰ higher than the average of all domesticated animals from the Eastern Zhou sample ($\delta^{15}N$ =7.8‰), and 9.4‰ higher above that of pigs and dog ($\delta^{15}N$ =6.5‰), meaning that this individual was almost two trophic levels higher than domesticated animals in the food chain. Often, this points to a reliance on aquatic resources. In XC1-M20's case, freshwater species are more likely than marine fish due to the relatively low $\delta^{13}C$ value (-14.2‰). Given the economic superiority displayed by the large tomb and luxury burial goods, it is plausible that XC1-M20 could have had more access to fish. A second possibility is that the unusually high value reflects a pathological condition that would elevate tissue ^{15}N value (e.g. Fuller et al., 2004; Metoka et al., 2006). Although the pathological conditions are hard to verify using SIA currently, the possibility cannot be completely excluded.

The other isotopic outlier is XC1-M15, an adult of unknown sex with the highest δ^{13}C value (-8.8‰) among the Xuecun individuals. XC1-M15's extremely high δ^{13}C suggests a millet-based diet, one that stands out because unlike the others, it was never heavily influenced by C3 resources. This individual was buried in a tomb with three rooms built of bricks, indicating a superior economic status as well. Thus, a diet based exclusively on millet is not only possible but also plausible, as millet was valued more highly than wheat. In contrast to the high δ^{13}C suggesting an advantageous diet based on millet, XC1-M15's relatively low δ^{15}N of 9.6‰ is located at the lower end of the Xuecun values and suggests limited meat consumption. While this may seem contradictory, XC1-M15 may have special dietary preferences: perhaps they enjoyed millet more than meat, or enjoyed animal resources that happened to have low δ^{15}N.

As mentioned in section 4.1.4, there may be some travellers buried in Xuecun cemetery because of its close proximity to the strategic pass *Hulaoguan*. The two isotopic outliers with the highest δ^{13}C (XC1-M15) and the highest ^{15}N (XC1-M20) may, therefore, also be migrants. If their homes had different dietary features than the plains, perhaps they died a sudden death when travelling and were buried in Xuecun. While this hypothesis is interesting, it is unlikely given their burial contexts. Both of the individuals in question were buried in well-constructed tombs with multiple chambers that were designed for collective burial of different family members rather than a single person. Archaeological excavations also show that neither of them was buried alone, meaning that both of them probably had roots in this area and relatively influential families. It is highly unlikely that a traveller would be buried in such a well-prepared manner after a sudden death while travelling; the retired Tang military official, for instance, was buried in a simple earthen catacomb with only several items of daily use porcelains and some coins (Chu et al., 2010).

If the outliers are not travellers, they could also be long-term migrants. This too is hard to verify: the related archaeological remains do not display any non-local features and there are many potential patterns of migration. They could have moved to the plains during their last years of life and developed a link to influential families in this area, still carrying the dietary signal of their hometowns. Alternatively, they could have been members of powerful local families, who sought a career somewhere else but were buried in the family grave after death. Finally, migration could also be related to marriage. All of these possibilities can only be tested by future studies based on multiple lines of evidence.

In Xuecun cemetery, almost one third of the selected burial samples (n=41) were found with weapons (n=13) and are therefore worthy of an exclusive analysis. Weapon burials include large burials with multiple rooms as well as small ones with a single room. As mentioned in section 4.1.4, individuals who were interred in large burials with weapons (for example, XC1-M20), could be military officials stationed in the *Hulaoguan* pass or local landlords with their own armed forces. The ten persons in simple tombs (levels two and three) with weapons were likely soldiers or private military force members: these were analyzed to see if their diet was altered by their occupation. The ten potential soldiers have average δ^{13}C (-14.2±1‰) and δ^{15}N (10.3±0.6‰) values quite similar to level three people (δ^{13}C=-14±1‰, δ^{15}N=10.6±1.2‰). Indeed, the majority of the possible soldiers (7/10) were from the lowest status level. These soldiers or private force members were likely economically disadvantaged individuals who did not benefit much from their careers, as their diet did remained similar to the rest of the poor. The very limited variation in their isotopic values suggests that they were mostly locals, or had at least been stationed in this area for a long period before death.

5.6.7 Dietary comparison within multiple burials

Among the multiple burial tombs chosen for this study, eight of them have more than one occupant being sampled. It is obvious that individuals buried in the same grave were of very close affinity. In the Han Dynasty, individuals buried in the same grave were likely family members of the same or multiple generations (Li, 2003, pp.217-221). These Xuecun individuals have thus provided the opportunity to compare dietary features between family members.

Figure 17 plots nineteen individuals from eight families (from eight multiple burials) by their $\delta^{13}C$ and $\delta^{15}N$ values; labels distinguish members of different families. Four of these families (XC1-M11, XC2-M5, XC4-M56, and XC4-M111) display apparent dietary similarity between their members, but the other four families (XC2-M50, XC2-M80, XC2-M206, and XC2-M281) have members differing noticeably in either $\delta^{13}C$ or $\delta^{15}N$. Both of these situations are expected, because members of the same family could have had similar lives and diets if they were from the same generation, or they could have had significantly different life experiences and diets if they belonged to different generations. As such, relatively complex patterning might be seen within a single family.

However, two of the four families displaying significant internal dietary differences, XC2-M50 and XC2-M80, require more attention. Not only do they have internal dietary variation, but they also contain two members with unusual high $\delta^{15}N$ values. These two individuals were labeled XC2-M50: R (male, 35-45 years old; $\delta^{15}N=14‰$) and XC2-M80: R (female, adult; $\delta^{15}N=13.5‰$) during excavation, meaning that both of them were interred on the right side of their graves. Their $\delta^{15}N$ values are the second and third highest values among all the 53 human samples from Xuecun, and fall 3‰ or more above the group average of 10.6‰. However, the other two members accompanying them (XC2-M50: L, adolescent, $\delta^{15}N=11‰$; XC2-M80: L, male, 50-59 years old, $\delta^{15}N$=10.7‰) are very close to the group average. The two outlier individuals may have had significantly more meat in their diets than both their family members and the majority of Xuecun people. Alternatively, their high $\delta^{15}N$ values, over one trophic level above the average animal value ($\delta^{15}N$=7.8‰), could mean that they ate a significant amount of aquatic resources. As introduced in section 2.3.3, meat or fish consumption in the Han Dynasty were likely subject to economic conditions. Thus, the hypothesis of higher meat or fish consumption is economically unlikely because these two people were interred in simple earthen chambers, probably the smallest ones in Xuecun, reflecting limited economic capacity. There is also no evidence indicating that the two individuals with high $\delta^{15}N$ had a career related to fishing, which also does not support the hypothesis of significant amount of fish consumption. This provokes a more detailed examination of their burial contexts.

Each of the two burials, XC2-M50 and XC2-M80, contains two individuals interred in a single small room. There is one original burial and one secondary burial, as attested by disarticulated human remains. Secondary burials in the Han Dynasty were not unusual: they were practiced for numerous reasons, but the ones discovered archaeologically have usually revealed individuals relocated from somewhere else to accompany the person in the primary burial (Li, 2003, pp.222-223). This is true for the current two cases; the different burial arrangements suggest that the two in the grave died, were buried in different places, but were later reburied together by relocating one of them to Xuecun (Zhou and Chu, 2009). It is highly likely that in both XC2-M50 and XC2-M80, the two individuals in the tomb spent their last years in different places, and this may have caused distinctive dietary differences between them. Therefore, archaeological context supports the possibility that the dietary differences between tomb occupants in XC2-M50 and XC2-M80 are caused by human migration. Although the exact pattern of migration is hard to determine, this finding indicates that dietary differences can be used as indicators of human migration in some cases.

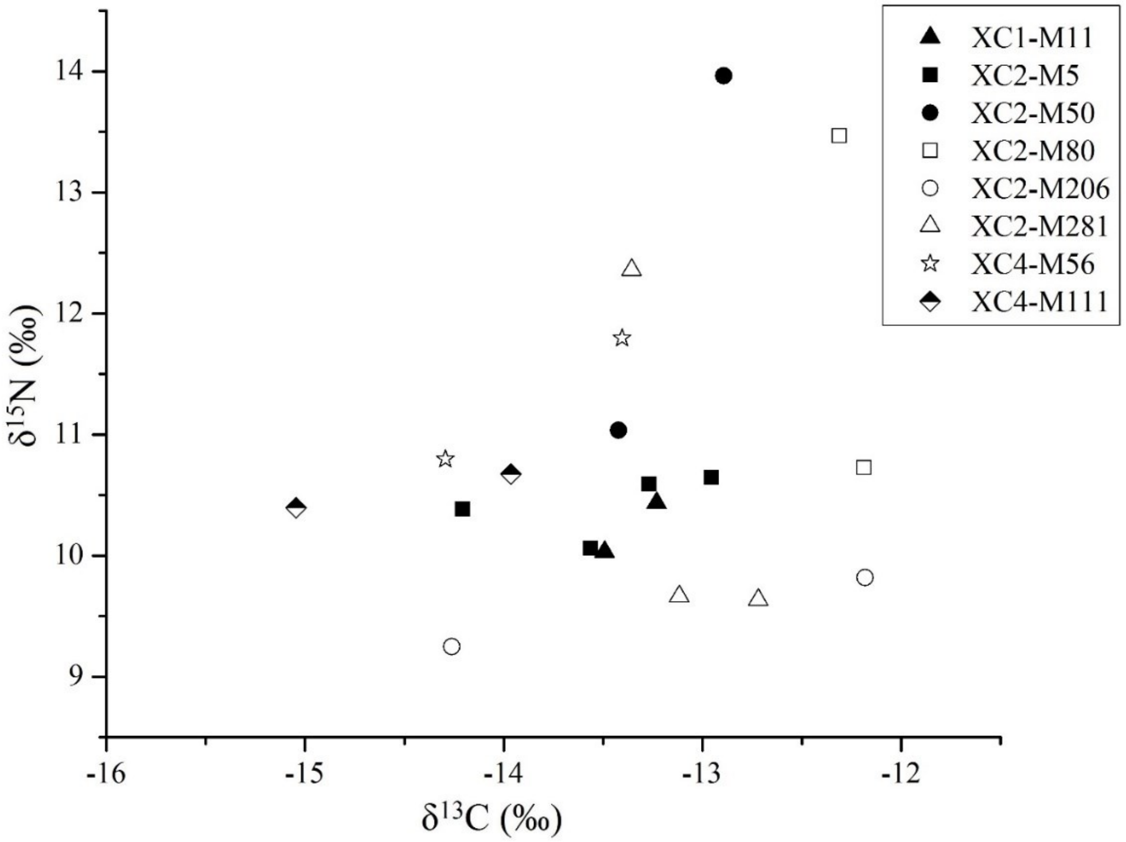


Figure 17. Isotopic comparison of family members from multiple burials in Xuecun

5.6.8 Conclusion of human dietary feature at Xuecun site

In general, the stable isotope results suggest that Xuecun people had a mixed diet including both millet and wheat. Here however, the significant proportions of dietary wheat nearly obscure millet's predominant role. Additionally, all individuals likely had a moderate proportion of terrestrial-based meat in their diet. If the relative isotopic values of individual animal species were similar to data from the Eastern Zhou faunal samples, their most likely meat resources were pig and dog, with some consumption of meat from sheep, cattle, or freshwater fish. Xuecun people’s dietary features were highly homogeneous, displaying no significant difference between males and females, among people buried in different districts, or between people of different temporal phases. Xuecun diets were, however, subject to economic conditions, demonstrated by variable amounts of C3 resource consumption. The poor likely ate more wheat than the rich, suggesting that wheat was still regarded as an inferior grain. Two individuals with outlying nitrogen and carbon values might have very special dietary preferences; the differences could also reflect migration or (for one individual) a long-term pathological condition. Individuals who may have been soldiers did not have a better diet due to their occupation, and had similar data to the lowest economic status level. Intra-family dietary comparisons create a relatively complex scenario wherein family members have similar or dissimilar dietary features depending on circumstance. A further examination of burial context suggests that some of the intra-family dietary variation may be related to migration.

5.7 Summary of Chapter 5

This chapter first evaluates sample preservation using three indicators, and finds that the majority of analyzed samples are well preserved and their stable isotopic values are acceptable for further discussions. Next, the section presents and discusses the results of site-level stable isotope analysis.

The chapter then analyzes potential animal husbandry practices using faunal stable isotope data, information that also establishes a baseline stable nitrogen value that is used to evaluate possible meat resources for humans. Human dietary features at different sites vary significantly. At Yangdi, a small number of people display two distinctive diets, with one group eating a C3-

based diet and the other eating a C4-based diet. The Yangdi samples might, therefore, include immigrants from a place with different agricultural traditions or dietary habits.

The Eastern Zhou rural population at Chenjiagou make up the second set of human remains for analysis. They had a C4-based diet and limited meat. There are no significant dietary differences between individuals buried with different furniture or goods, but isotopic data suggest that females might have eaten more C3 food than males. Similarly, the urban Eastern Zhou inside ancient Xinzheng city had a C4-based diet; however, there are visible dietary effects from a C3 component, most likely wheat. The chapter conducts a comparison using economic status, which suggests that hierarchy impacts wheat consumption. People of the lowest social status ate significantly more wheat than low-rank nobles and the wealthy. Despite urban prosperity, Xinzheng people consumed limited terrestrial meat and no aquatic resources. Finally, at the Han era site Xuecun, people had a diet of both C3 and C4 resources with moderate meat consumption. Chapter 6 will discuss several specific questions based on Chapter 5 data and site-level analyses.

6. Inter-site Comparisons and General Trends

The former chapter presents and discusses the results of stable isotope analysis of faunal and human samples. However, these site-level discussions have not yet addressed the major questions put forward in section 2.4, which are fundamental to our understanding of diets in transition over time. Chapter 6 will use inter-site comparisons to learn more about general trends in dietary features.

6.1 Dietary Significance of Millet and Wheat

People in the Zhou and Han Dynasties cultivated and ate similar main species of grains; however, each grain's dietary importance changed temporally. Millet was undoubtedly the predominant grain in the Eastern Zhou (Qian, 2009; Hsu, 1984a), while other crops, including wheat, barley, rice, hemp, and soybean, were probably not cultivated widely before the SAP (Qian 2009). The situation became complicated in the Han Dynasty, and opinions vary on the dietary importance of millet and wheat. Many scholars argue that wheat was elevated to the same status as millet (e.g. Huang, 1982; Li, 1997, pp.8-10; Jin, 2007; Hsu, 2005, pp.79-81); however, more conservative voices suggest that wheat was still regarded as an inferior grain (Yu, 1977) and was unable to challenge the predominance of millet until later times (Wang, 2000, pp.70-72; Zeng, 2005; An et al., 2013). Ambiguous historical sources are likely responsible for these disagreements; they surround problems that cannot be resolved using only literary evidence. Fortunately, as the two grains under debate are isotopically distinct, SIA is a fruitful source of new information in the effort to evaluate the relative importance of wheat and millet.

The C3 crop wheat was introduced into northern China during 3000 to 2000 BC (Jin, 2007); agricultural diets predating this time period were indisputably based on the C4 crop millet and were free of wheat's isotopic influence. For comparisons in this study, this typical millet-based diet will be represented by the human isotopic data from two sites dated to the Late Neolithic times (5000-3000 BC), Xishan (mean $\delta^{13}C$ =-9.7±1.1‰) and Xipo (mean $\delta^{13}C$ =-8.2±1.5‰) (Zhang XL et al., 2010). Both locations are on China's Central Plains (Table 12). Theoretically, if a population incorporates significant amounts of the wheat into their traditional millet-based diet, they should display lower human bone collagen $\delta^{13}C$ values than the level of these two millet-based sites (Xishan, Xipo). However, minor amounts of wheat or other C3 grains (which can be tested in future work using enamel carbonates) will not affect collagen $\delta^{13}C$ values significantly. A decline in collagen $\delta^{13}C$ values will only be evident if wheat was consumed in relatively large amounts. Therefore a comparison of isotopic data from the two early wheat-free sites and other later sites should be able to reveal temporal changes in the use of millet and wheat as major staples in human diets on the plains.

Table 12 summarizes average human bone collagen $\delta^{13}C$ and $\delta^{15}N$ values from twelve sites on the plains (including all the currently available data and those analyzed in the current study), and Figures 18 and 19 lay out further details. It can be seen that bone collagen isotopic values fluctuated from the Late Neolithic times (5000-3000 BC) to the Han Dynasty (206BC-220 AD). Figure 18 shows that $\delta^{13}C$ values from the Neolithic to Chenjiagou never fall below -9.7‰, which is the value of Xishan site with its millet-based, wheat-free agricultural diet. Thus, Central Plains people from these sites likely consumed millet as their staple food, and their diet included little to no wheat even though some sites are included in or postdate the period when wheat first appeared in this area. Additionally, fluctuation in collagen $\delta^{13}C$ from -7.6‰ to -9.7‰ among these populations does not suggest significant use of a different C3 staple.

However, the relatively stable $\delta^{13}C$ patterning that lasts over 2000 years from Xipo to Chenjiagou changed during the Eastern Zhou, when the average $\delta^{13}C$ of urban people from Xinzheng (-11‰) falls below the value of -9.7‰ for the first time. A second decline is observed in the later site Xuecun. The decrease in $\delta^{13}C$ values of Xinzheng and Xuecun indicates that humans in these sites included C3 resources in their diets in isotopically detectable amounts. As discussed in sections 2.3.2, 2.3.3, 5.5.2 and 5.6.1, the most likely C3 staple for the people of Xinzheng and Xuecun was wheat. In this region, then, wheat was initially incorporated in significant amounts into the diets of Eastern Zhou urban people, and it increased in dietary significance during the following period.

Temporal changes in the dietary significance of millet and wheat now become clearer after pooling together the isotopic data from different sites on the Central Plains. The C4 grain millet maintained its role as the only staple grain in the area for over 2000 years starting with the Late Neolithic. A C3 grain (most likely wheat) was consumed in isotopically detectable amounts starting from the Eastern Zhou and had increasing significance thereafter. However, the Eastern Zhou people did not accept wheat neither widely nor quickly; even after its incorporation into human diets, wheat was likely still regarded as an inferior grain compared to millet.

Table 12. Average bone collagen stable isotope values from the sites on the Central Plains

Site	Date	N	$\delta^{13}C$(‰) (Ave. ±SD)	$\delta^{15}N$(‰)[1] (Ave.±SD)	Reference
Xipo	5000-3000 BC	39	-8.2±1.5	9.4±1	Zhang XL et al., 2010
Xishan	5000-3000 BC	31	-9.7±1.1	9±0.8	Zhang XL et al., 2010
Liuzhuang	2000-1600 BC	32	-7.6±0.6	9.6±1	Hou et al., 2013
Nanzhai	2000-1600 BC	9	-9.6±1.2	----	Zhang XL et al., 2003
Xinzhai	1870-1720 BC	8	-9.6±1.4	9±1	Wu et al., 2007
Erlitou[2]	1735 BC-1530 BC	22	-9.3±2.4	11.9±3.8	Zhang XL et al., 2007
Yanshi Shang City	1600-1260 BC	3	-7.6±0.6	----	Zhang XL et al., 2003
Yin Xu	1300-1046 BC	39	-8.2±2.4	----	Zhang XL et al., 2003
Yangdi[3]	Early 8th Century BC	3	-8.4±0.4	8.2±0.5	Current study
Chenjiagou	770-221 BC	39	-9.7±1.4	9.2±0.8	Current study
Xinzheng	770-221 BC	75	-11±1.6	8.8±0.8	Current study
Xuecun	141BC-220 AD	53	-13.7±1.2	10.6±1.2	Current study

Note:

1. '----' means that these studies did not publish stable nitrogen isotope values.

2. Only five of the twenty-two samples from this site were analyzed for stable nitrogen isotope values.

3. Only the three locals from the Yangdi site are included. The mean $\delta^{13}C$ and $\delta^{15}N$ for all Yangdi individuals are -12.5±5 ‰ and 9.2±1.3‰.

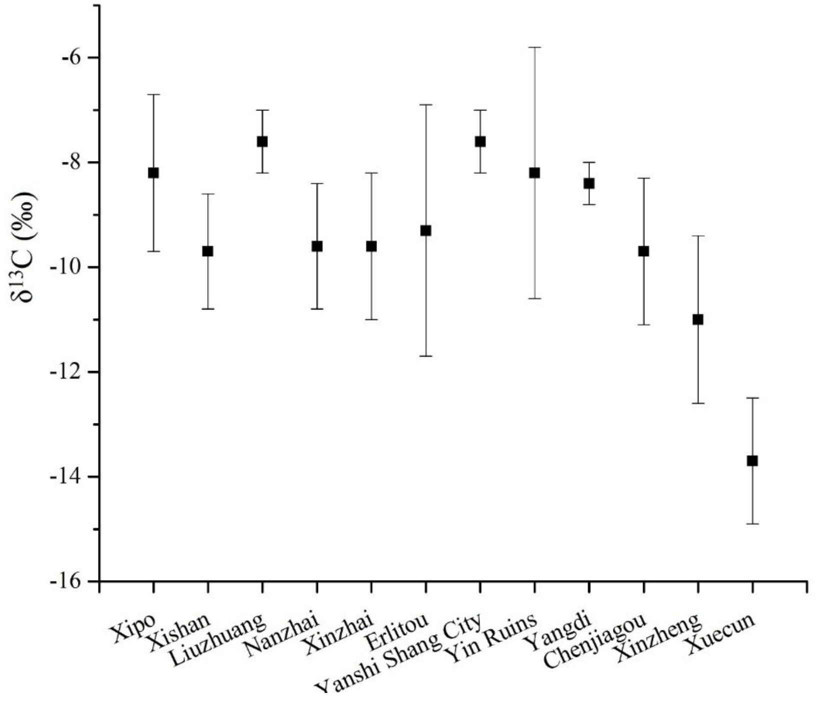


Figure 18. Temporal change of human bone collagen $\delta^{13}C$ on the Central Plains (Ave.±SD)

Note: Sites are arranged from earliest to latest, see Table 12 for the ages of sites.

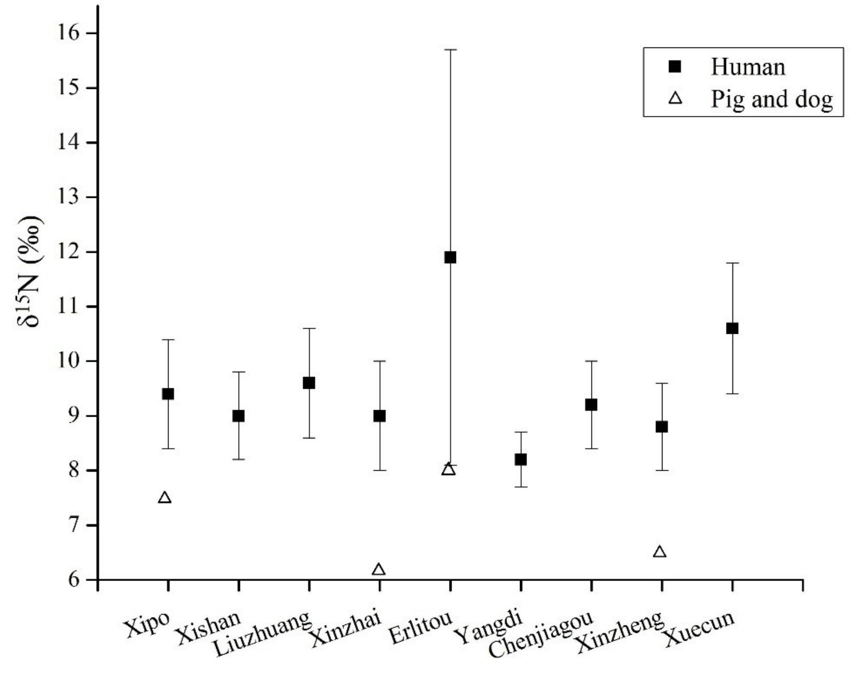


Figure 19. Temporal change of human bone collagen $\delta^{15}N$ on the Central Plains (Ave.±SD)

Note: Sites are arranged from earliest to latest. See Table 12 for the ages of sites, table 13 for Animal values.

Figure 18 shows that Eastern Zhou urban people of Xinzheng likely incorporated a certain amount of wheat into their diet, while the rural population of the same era in Chenjiagou displays no effect from C3 grains. Early acceptance of wheat was thus likely limited to the urban community, though even in the city wheat consumption displayed significant status-based differences. As described in prior chapters, a status-based dietary comparison inside the capital city Xinzheng demonstrates that people of the two upper status levels, who were possibly low-rank nobles and well-off commoners, had limited evidence of wheat in their diets (see Table 7). Their average δ^{13}C values (-10.5‰ and -10.8‰ respectively) are slightly below the bottom value of -9.7‰ observed for the millet-only baseline. In contrast, the lowest status level of the city displayed average δ^{13}C values of -12.8‰, significantly below the millet-only values as well as values of the upper two status levels. Figure 11 shows that people of the two upper levels, who make up the majority of the sample (68/75), were consuming significantly less C3. Assuming that the C3 resource involved is wheat, this would suggest that this grain was very likely regarded as inferior in the urban area, and that only the very poor ate significant amounts of it.

Temporal analysis of the urban Xinzheng group (Table 8; Figure 12) reveals that δ^{13}C values for individuals of the two earlier eras (-10.2 and -10.4‰) depart very little from the millet-only baseline value of -9.7‰; this suggests that little to no wheat was eaten by people before the WSP. However, the mean value for the final phase (WSP: -11.6‰) displays significant differences from both the earlier sites and the former two phases. Wheat consumption increased enough at this time to become isotopically visible; thus the temporal patterning also implies a sudden, rather than gradual, increase in wheat consumption at the end of the three phases in question. This raises an important question: what triggered such an abrupt dietary shift toward a grain seen as inferior, when millet had been grown and eaten for several thousand years?

It is unlikely that this dietary shift reflects an active choice of (or preference for) wheat on the part of populations exploring new food resources, as there is no sign of significant wheat consumption before the WSP. Instead, external pressures impacting food provision in ancient Xinzheng are more likely to have caused change. The ancient Xinzheng city had a large urban population (Tao, 2008, p.19) and suffered frequent warfare (e.g. Song, 1996; Shi, 1998) and a high incidence of natural disasters (Tao, 2008, p.34). Famine was the second most common major disaster during the Eastern Zhou period (Wang, 2010), and historical evidence records at least one famine in the Zheng state (whose capital was ancient Xinzheng city) (Yang, 1981, p.1157). During food crises, the lowest economic stratum of urban residents were the most vulnerable population: thus, it is reasonable that they had to turn to an 'inferior' grain for survival. Wheat consumption was first observed in the very few Xinzheng people who could not even afford a coffin. For them, eating wheat became an adaptive strategy for survival rather than a willing or active choice.

The sharp decline in $\delta^{13}C$ of the Xuecun people, dated to the Han Dynasty, suggests that the dietary proportion of wheat increased substantially from the WSP to the Han. In analysis, a two end-member linear mixing model was used to tentatively determine that wheat may have almost taken up an equal status with millet in Xuecun (section 5.6.1). Moreover, the distribution of $\delta^{13}C$ values among the Xuecun people of different social status (Table 9; the largest discrepancy is 1‰) is narrower than that of Xinzheng (Table 7; the largest discrepancy is 2.8‰), suggesting that wheat played a significant role in the diets of all classes by this time. The absence of temporal change in $\delta^{13}C$ throughout the Han Dynasty site also suggests that wheat's dietary proportion was relatively stable (Table 11). All these changes imply that wheat was widely accepted by people of the Han Dynasty and was elevated to equal or surpass millet's proportion in human diets. It seems that the poor still ate more wheat than the wealthy, however, as indicated by the significant differences and socially stratified $\delta^{13}C$ values in Xuecun (Table 9; Figures 16a and 16b). Despite its significant role in Han era diet, wheat was likely still regarded as an inferior grain.

A recent study has reviewed the process of wheat's expansion into the human diets of northern China based on published isotopic data, and it suggests a very slow west-east trend (Zhou and Garvie-Lok, 2015). The middle and lower reaches of the Yellow River were last to be affected, and in these areas the absence of isotopic data from the eighth century BC to the third century AD has prevented an accurate estimate of when humans first consumed wheat in detectable amounts. The Central Plains are also among these last affected areas. New isotopic data analyzed in the current study begins to make up for the lack of historical data in previous studies, creating a clearer scenario of wheat's integration into human diets in China.

Isotopic evidence from this study's Eastern Zhou sites suggests that wheat consumption was likely triggered by pressure on food supplies during the WSP (480-221BC); however, initial changes began with the lowest socioeconomic level of the city. This dietary shift toward wheat progressed considerably during the Han Dynasty (206 BC-221 AD). Wheat became a significant component in human diets but was still regarded as an inferior grain, not the preferred food of the wealthy. Thus, new isotopic data has not only developed a more accurate time range for wheat's initial incorporation into the millet-based diet of the Central Plains, but has also revealed some possible causes of this change.

The dietary shift from millet to wheat, which changed the long-established agricultural and dietary patterns of ancient northern China, displayed a typical bottom-up model. It therefore encountered unsurprising resistance; people did not willingly abandon their traditional grain. It is also interesting to see that in prehistoric Gansu, the dietary shift toward C3 crops between 2000-1800 BC also displayed a similar bottom-up mode; however, the shift occurred shortly after wheat was introduced into the region and progressed more smoothly (Liu et al., 2014). While there were variable situations in agriculture and human diet throughout northern China, both studies suggest that the acceptance of this imported crop as a staple food, in areas with long-established agricultural and dietary traditions, had to experience a bottom-up expansion.

As introduced in section 2.3, historical evidence suggests that soybean, which is also a C3 crop, might have played an important role in human diets of ancient China. Indeed, the temporal change in collagen $\delta^{13}C$ values may also be attributed to soybean consumption; this possibility will be discussed exclusively in the following section.

6.2 The Role of Soybean in Human Diets

Soybean seems to have played a significant role in the human diets of ancient China. Textual records always list it in the category of grains, together with millet and wheat (for a list of the related sources see Shurtleff et al, 2014, pp. 5-7). For this reason, all text-based studies have portrayed soybean without question as an important staple food in Zhou and Han times (e.g. Song, 1987; Gu, 1992; Yang, 2000; Chen WH, 2007; Zeng, 2012; Yu, 2011, pp.98-99). The one exception argues that soybean might have been a principal vegetable in ancient China, rather than a staple food (Knechtges, 1997). This theory is based on the idea that boiled soybeans do not taste very good, and that large amounts of bean eating would cause uncomfortable effects for biological reasons (Knechtges, 1997).

Legumes such as soybeans distinguish themselves from the other plants with extremely low δ^{15}N values close to 0‰ (Hoering and Ford, 1960; Delwiche and Steyn, 1970). Thus, a heavy dietary reliance on this crop would theoretically result in very low human bone collagen δ^{15}N values and should be possible to detect in paleodiets (DeNiro and Epstein, 1981). A low human bone collagen δ^{15}N value would be coupled with very low δ^{13}C value because legumes are C3 plants. However, although many ancient populations ate soybeans and other legumes, isotopic studies have not yet identified a heavy dietary reliance on them. Only some outlying individuals are thought to have eaten large quantities of legumes because of their low δ^{13}C and δ^{15}N values (e.g. Varalli et al., 2015). Therefore, it is the unusual literary emphasis on soybeans in ancient China that triggers this study's interest in evaluating the actual role of this crop in human diets.

Just as when evaluating the temporal changes in wheat's dietary importance in section 6.1, all the average human collagen δ^{15}N values from the isotopically analyzed sites on the plains before the Han Dynasty are listed in Table 12 and plotted in Figure 19 in the form of average ± SD (see section 6.1). As mentioned in the notes for Table 12, the Erlitou δ^{15}N values only represent a small subset (n=5) of the samples analyzed for δ^{13}C values (n=22). Since individual details are not provided, these values are difficult to interpret even though the high mean and wide dispersion are interesting. All the other human collagen δ^{15}N values from the Late Neolithic site Xipo to the Eastern Zhou site Xinzheng display slight fluctuations within the range of 8.2‰ to 9.6‰ and suggest limited changes in the δ^{15}N values of dietary protein over a long period of time. The lack of a clear change does not support addition of a major dietary component with extremely low δ^{15}N to human diets in the Eastern Zhou, the period in which literary emphasis on soybeans was initially seen. The first significant change in δ^{15}N is an increase from Xinzheng

(8.8‰) to Xuecun (10.6‰), and this does not imply an increase in soybean consumption because δ^{15}N values rise rather than falling.

Taking the potential variation in the trophic level enrichment of δ^{15}N into consideration, the largest diet-to-collagen δ^{15}N enrichment reported for humans so far is 6‰ (obtained from a recent controlled dietary study) (O'Connell et al., 2012). Even the lowest human δ^{15}N value of 8.2‰, listed in Table 12, would reflect a dietary δ^{15}N of about 2.2‰ based on this maximum value of trophic level enrichment. Additionally, none of the average δ^{13}C values from the sites listed in Table 12 suggest diets with large amounts of C3 resources; this also does not support heavy dependence on soybean consumption. Considering both the δ^{15}N and δ^{13}C values, none of the average site values agree with a diet whose protein component was soybean-based. Indeed, we can further confirm the mismatch between site values and a soybean-rich diet by comparing human and contemporary animal δ^{15}N values, which inform human trophic levels at the different sites and point to potential protein resources. Table 13 lists available δ^{15}N values of dogs and pigs from four of the sites, and they are plotted in Figure 19. Human values are always well above those of the animals, indicating that all of these populations had some amount of animal meat in their diet. Thus, the available evidence indicates that the people of these sites did not rely primarily on soybeans for dietary protein and instead consumed a mixed protein diet, again demonstrating no sign of a heavy dietary reliance on soybeans.

Table 13. Stable isotope values of pigs and dogs on the Central Plains before the Han Dynasty

Site	Date	N	$\delta^{13}C$(‰) (Ave.)	$\delta^{15}N$(‰) (Ave.)	Reference
Xipo	5000-3000 BC	3	-7.7	7.5	Pechenkina et al., 2005
Xinzhai	1870-1720 BC	12	-9.2	6.2	Wu et al. 2007
Erlitou	1735 BC-1530 BC	3	-10.5	8	Zhang XL et al. 2007
Tianli	770-221 BC	39	-11.8	6.5	Current study

The above argument has rejected the hypothesis of heavy soybean consumption at the population level. However, the investigation should also address claims that soybeans were the staple food mainly for the poor during the Zhou and Han Dynasties (Yang, 2000; Yu, 2011, pp.99; Ban, 1962, p.3682 [1st century AD]). Heavy reliance on legumes is sometimes detected in particular individuals but not the whole population (Varalli et al., 2015), and this calls our attention to lowest social status in each site. Site-level interpretation in the previous chapter showed that among the four groups of people analyzed in the current study (Yangdi, Chenjiagou, Xinzheng, and Xuecun), none display significant differences in $\delta^{15}N$ when compared by estimated social status or economic capacity. This suggests a relatively homogenous nature of protein resources in each site, meaning that the poor, living in both rural and urban areas, did not use soybean as their staple protein source. However, the relatively strong positive correlation between $\delta^{13}C$ and $\delta^{15}N$ values (Pearson r=0.56, $p < 0.05$) of the Xinzheng people suggests that some individuals had a diet with both low $\delta^{13}C$ and $\delta^{15}N$. There may have been significant soybean participation in these diets because soybean is a C3 legume featuring both low $\delta^{13}C$ and $\delta^{15}N$. The lowest collagen $\delta^{15}N$ value of 7.0‰ (TP-M24) among them implies a very low dietary $\delta^{15}N$, and $\delta^{13}C$

value of the same individual (-12.7‰) also suggest a diet mixed with C3 and C4 resources. Both this individual and those with similar low δ^{13}C and δ^{15}N values may have consumed large quantities of soybeans. It should be clarified, however, that Xinzheng's most likely soybean-eaters were not necessarily in poverty. A glance at their δ^{15}N values shows that among the nine individuals with the lowest δ^{15}N (ranging from 7.0‰ to 7.9‰) only two were so poor that they were not able to afford a coffin, and the other seven were well-off or low-rank nobles buried in single- or double-layered coffins. Literary records on soybean eating in ancient China, which often suggest that poor people had heavy dietary reliance on soybeans, may not be so accurate.

The main criterion used to evaluate soybean consumption is collagen δ^{15}N, which can be elevated by many factors such as aridity (Heaton, 1987; Hartman, 2011), leaching and salinity (Handley and Raven, 1992), and manuring (Choi et al., 2002; Bogaard et al., 2007; Fraser et al., 2011). This plethora of variables may further complicate any consideration of the role of soybeans in ancient Chinese diets. Manuring should be particularly considered here, for the reason that Chinese people employed multiple ways to fertilize crop fields during the Zhou and Han Dynasties (Bin, 1981; Hsu, 1984a; Hsu, 2005, pp. 217-219). Fertilization through manuring could have elevated the δ^{15}N of soybean to a level higher than 0‰ and thus make the results presented above unreliable.

Manuring does, however, have a very limited effect on legumes that are able to fix atmospheric nitrogen and thus do not rely on soil nitrogen provided by fertilizer (Fraser et al., 2011; Bogaard et al., 2013). There are two studies showing that legume δ^{15}N could be elevated above 0‰ by manuring: one involves intensive manuring at a rate of over 35 tons per hectare over a prolonged period (Bogaard et al., 2013; Vaiglova et al., 2014), and the other entails manuring with fertilizer extremely high in δ^{15}N such as seabird guano (Szpak et al., 2014). Neither of these scenarios seems applicable to most ancient agricultural societies of inland areas such as China's Central Plains, where fertilizer mainly came from human or domesticated animal waste and rotten grass (Bin, 1981; Hsu, 1984a; Hsu, 2005, pp. 217-219). Animal husbandry may have been limited in the sites analyzed, as implied by $\delta^{15}N$ values and textual records (e.g. Ban, 1962, p.1120 [1^{st} century AD]). Large amounts of animal waste to fertilize the crop fields would have been unavailable in this context. Manuring effects on soybean $\delta^{15}N$, as well as other crop $\delta^{15}N$ values, would likely have been too slight to be isotopically visible in ancient China, at least before the Eastern Zhou. This supports the above evaluations on soybean in human diet based on an assumed legume $\delta^{15}N$ value of about 0‰, and confirms that heavy dietary reliance on soybean at a population level was unlikely then.

Given the numerous textual records on soybean eating in ancient China (Gu, 1992; Yang, 2000; Shurtleff et al, 2014, pp. 5-7), there is no doubt that humans had already been consuming this crop by the time of the Zhou and Han Dynasties. Isotopic data demonstrates that some individuals from Xinzheng, both poor and wealthy, might have incorporated significant amounts of soybean into their diets. However, the isotopic evidence presented here lends no support to a primary dietary reliance on soybeans by people of different periods or different classes. The soybean was most likely an important vegetable in ancient Chinese diets, as suggested by Knechtges (1997). Given this paper's data and analysis, textual records claiming that the poor could only rely on soybeans and water for survival (e.g. Ban, 1962, p.3682 [1^{st} century AD]) seem more like a rhetoric conveying sympathy. The rhetoric, however, does reflect the fact that soybean was not a preferred food.

6.3 Meat Resources

Diverse meat resources are featured in textual records and funeral art from the Zhou and Han dynasties (see section 2.3). All edible terrestrial animals (beasts, fowls, both domesticated and wild), were likely regarded as potential meat resources. Fish and other aquatic species such as turtles were also valued highly in literary records of the Zhou period, and they frequently appeared in Han mural art related to food and diet. However, evidence from historical documents and funeral art should both be scrutinized critically, because the sumptuous diets they recorded may have been reserved for special occasions (Hsu, 1984b, p.248). The Zhou population's most common meats may have been only pork, fish, chicken (and eggs), and turtles (Hsu, 1984b; Knechtges, 1997). In the Han Dynasty, the government-promoted animal husbandry strategy suggested that every household should raise pigs, dogs, and chickens (Ban, 1962, p.112 [1st century AD]); therefore, the most common meat resources would likely not exceed these species. Isotopic analysis can test the potential discrepancies between literary evidence and actual diets.

The usual way to evaluate possible meat resources for humans is to locate their trophic level position in the local food web by comparing the collagen $\delta^{15}N$ and $\delta^{13}C$ of human and local contemporary animals (see section 3.1.2.2). Trophic level $\delta^{15}N$ enrichments typically vary from 3‰ to 6‰ (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984; Sealy et al., 1987; Bocherens and Drucker, 2003; O'Connell et al., 2012); thus, the mid-value of 4.5‰ is applied in the current study. Average $\delta^{15}N$ of 7.8‰ and $\delta^{13}C$ of -13‰ for the 14 domesticated animals from Tianli will be our baseline values for comparison. However, considering that sheep and cattle may not have existed on a large scale on the agricultural plains, the average $\delta^{15}N$ of 6.5‰ and $\delta^{13}C$ of -11.8‰ of the most common animals (pig and dog) will also be used for a reference value.

None of the populations from the three Eastern Zhou sites (Yangdi $\delta^{15}N$=9.2‰; Chenjiagou $\delta^{15}N$=9.2‰; Xinzheng $\delta^{15}N$=8.8‰) show much trophic level elevation compared to domesticated animals as a whole (with an average $\delta^{15}N$ of 7.8‰). It is likely, then, that meat consumption was relatively limited in all three sites, regardless of their archaeological contexts.

The top $\delta^{15}N$ values from the same sites are 10.8‰ (YY-M5), 10.6‰ (WC-M73), and 10.4‰ (XH-M140). These values are fairly close, although the individual from Yangdi site was likely a migrant (see section 5.3). Even these individuals with the highest values are still less than one trophic level above the domesticated animals, a result that does not support the possibility of substantial fish consumption. The highest individuals are, however, very close to one trophic level above pigs and dogs, which matches literary evidence portraying these as the most likely meat resources. The probable low-rank noble with the highest material status among the Zhou, XH-M35 (Fan and Xu, 2007, pp.146-147), $\delta^{15}N$=9.8‰, also does not display a substantial trophic level elevation compared to domesticated animals. This individual's stable isotope values do not reflect a substantial amount of dietary meat from fish, cattle, or sheep. Sumptuary rules are partially corroborated by this evidence, as they imply that fresh fish was highly valued and only served to the highest rank (represented by nine *ding*- tripods) while nobles of the lowest rank (represented by only three or one *ding*-tripod) were served with pork only (Zhang WJ, 2012).

In brief, Zhou individuals of all social tiers mainly consumed domesticated animals, particularly pigs and dogs, for their meat resources. Diets of low-ranking nobility did not differ remarkably with that of commoners in rural or urban areas in terms of meat resources. Even though these people all lived in close proximity to rivers, they did not eat a substantial amount of fish. Fish was likely highly valued and served to high-ranking nobles only.

The average $\delta^{15}N$ value of the Han people from Xuecun (10.6‰) is similar to the highest values from the three Eastern Zhou sites. Assuming that animal husbandry strategies did not change significantly from the Eastern Zhou to Han, a comparison of the average Xuecun $\delta^{15}N$ with that of Eastern Zhou pigs and dogs (6.5‰) reveals that humans were almost one trophic level above these two animal species. Pigs and dogs may therefore have been the most common meat resources for Han people. This is consistent with government-promoted animal husbandry strategy encouraging every household to raise pigs, dogs, and chickens (Ban, 1962, p.1120[1st century AD]). Cattle and sheep, which had higher $\delta^{15}N$ at Tianli, were likely not eaten very frequently or widely; indeed, this evidence agrees with records indicating that these two species were usually raised by specialized households and mainly used for trade (Wen, 2007). Additionally, cattle were an important source of animal labour for average households and would not have been eaten frequently on the agricultural plains.

There are 12 sets of remains from Xuecun that have $\delta^{15}N$ values higher than 11‰, meaning that they are more than one trophic level above the Tianli pigs and dogs. However, the situations of these individuals vary. Section 5.6 demonstrates that the individual with the highest value of 15.9‰ (XC1-M20) likely consumed a significant amount of fish. The other two individuals with $\delta^{15}N$ values of 13.5‰ and 14‰ were from burials XC2-M80 and XC2-M50 respectively, and their burial styles suggest that they were migrants (section 5.6.7). The other nine people with $\delta^{15}N$ values ranging from 11‰ to 12.4‰ need not have eaten fish, but instead could have eaten a certain amount of meat with higher $\delta^{15}N$ values than pork and dog.

Therefore, the most important meat resources for all Han people still appear to have been domesticated animals including cattle, sheep, pig, and dog. Among these species, pig and dog were likely the most common meat resources, while cattle and sheep were eaten by fewer people.

This is largely consistent with written histories that identify cattle and sheep as food for the wealthy: “on sacrificial events, the rich ones killed cattle, the middle class ate sheep and dogs, and even the poor had pigs and chickens to eat” (Wang, 1992, pp.351-352). Fish and other aquatic species, although frequently illustrated in different forms of funeral art, appear to have been uncommon. Aside from a few outlying individuals who might have eaten a lot of fish, stable isotope values do not suggest that people ate fish very frequently or in very large amounts.

There is one other species that may also have been a common meat resource for both the Zhou and Han people. Chicken is suggested as one of the main meats for nobles’ daily consumption (Hsu, 1984b; Knechtges, 1997), and the government encouraged households to feed chickens alongside pigs and dogs (Ban, 1962, p.1120 [1st century AD]). It was not mentioned in the above discussion based on isotopic values because there were no skeletal remains available for analysis. However, this does not mean that chickens can be ignored as a potential meat resource of great importance, in part because they are often the easiest to feed among all domesticated animals in agricultural areas. More importantly, chicken $\delta^{15}N$ is usually higher than other domesticated animals. For example, a chicken from a Han Dynasty site located in the southwest mountainous area of Henan Province yielded a $\delta^{15}N$ of 9.2‰: the human average $\delta^{15}N$ was 8.4‰, and cattle and sheep fell at 7.7‰ (Hou et al., 2012). The few isotopic studies providing $\delta^{15}N$ values for archaeological chickens outside China report similarly high values such as 8.4‰ (Fuller et al., 2012), 9.1‰ (Reitsema et al., 2013), 10.3‰ (Yoder, 2012), 9.1‰ (Guiry et al., 2012), and 11.5‰ (Guiry et al., 2014). Chickens are typically found at a higher trophic level in local food webs than domesticated herbivores because they eat organisms such as insects and worms.

With this information in mind, the higher human $\delta^{15}N$ values discussed above (thought to indicate possible consumption of meat from cattle or sheep) could also arise from eating chicken.

In other words, poor individuals who ate only chicken (or eggs) for animal protein would display high δ^{15}N values, similar to or even higher than values for people who ate mutton or beef. This could obscure any status-related differences in δ^{15}N and make it difficult to detect variations in meat consumption between different classes. This must be kept in mind when analyzing high human δ^{15}N values, which can too easily be interpreted as simple signs of a privileged meat-rich diet.

In conclusion, isotopic data suggest that meat resources for both the Zhou and Han people on the plains were mainly terrestrial animals, among which pigs and dogs were the most commonly eaten species. Sheep and cattle were likely more precious meats, eaten only by a very low proportion of individuals from the Han Dynasty. Most SIA data did not point to the consumption of fish and other aquatic species, supporting records which suggest that fish was the most privileged meat in the Zhou times. One set of remains from Xuecun was the exception to this rule, suggesting that fish was still not a common meat in the Han era. Chicken could also have been an important meat resource, and it is a complication because its isotopic signature can easily be mistaken for those of sheep or cattle.

Due to the absence of isotopic data for high-ranking nobles in the Zhou Dynasty, it is not possible to test whether or not they habitually consumed meats including pork, fish, chicken (and egg), and turtles (Hsu, 1984b; Knechtges, 1997). The results presented here do suggest that meat of fish, cattle, and sheep were more precious than pork and dog, and that these foods were not available to low-rank nobles or to commoners; this lends partial support to the theorized sumptuary rules of diet in the Zhou Dynasty (Zhang WJ, 2012). All of the Han meat resources identified by SIA are consistent with the era's known official animal husbandry strategy, which encouraged the cultivation of pig, dog, and chicken for the majority. Thus, the frequent appearances of fish and other aquatic species in mural arts exaggerate, and fish consumption was not apparently common.

6.4 Social Status, Occupation, and Human Diet

Social stratification has been theorized in numerous different ways but generally involves an unequal distribution of resources, be they political, religious, or natural. An unequal distribution of resources is likely to affect human diet, and as such has been an important concern in paleodietary studies. In China, social stratification has been archaeologically visible since Late Neolithic times (5000-3000 years BC) (Ren and Wu, 1999; Wang, 2009). In historical eras, it became not only more visible but also institutionalized. Stratification impacted human diet in the Late Neolithic (Zhang XL and Li, 2014) and in the Bronze Age (Zhang XL et al., 2012), during which isotopic studies suggest that people of higher status usually had higher δ^{15}N than others (indicating more meat or sometimes fish in their diets). This likely reflects unequal access to prestigious food resources.

Social stratification of the Eastern Zhou and Han dynasties was institutionalized by rituals or laws in the form of the "Five Ranks" hierarchical system or the "Twenty Ranks System"; it is often reflected in hierarchies of material goods, particularly burial remains (section 2.2). Inequality in status, either political or economic, has been revealed in three of the four cemeteries included in the current study. The exception, Yangdi cemetery, appeared to be filled entirely with the economically disadvantaged (section 4.1). A dietary comparison of the different social groups or levels represented by burial remains could reveal whether social stratification was still influential on human diet in historical times.

In Chenjiagou, variable forms of burial furniture imply discrepancies in status of the cemetery's rural residents. Their burial furniture varied from double-layered coffins (one inner and one outer coffin) to coffins of a single layer, and some people were buried with no coffin at all. As introduced in section 4.1.2, it is very likely that the double-layered coffins seen at this site reflect economic resources rather than a higher social rank. Results of one-way ANOVA tests among the three levels of people divided by their burial furniture revealed no significant difference in either $\delta^{13}C$ (F=0.26; p=0.77) or $\delta^{15}N$ (F=0.94; p=0.4) (section 5.4, Table 5). A similar test based on funerary objects also revealed no significant difference (section 5.4, Table 6). This suggests similar dietary resource use in Chenjiagou despite the apparent economic variations.

The archaeological context of Xinzheng differed significantly from that of Chenjiagou. Individuals lived and were buried in the capital city, and the remains are composed of low-rank nobles, commoners, and the very poor (as suggested by funerary objects and burial furniture). A dietary comparison between these three social layers divided by burial furniture did not reveal significant differences in their $\delta^{15}N$ (F=0.58; p=0.56); this could be consistent with an overall constant level of meat consumption. However, the significant differences in their $\delta^{13}C$ values (one-way ANOVA test: F=12.9; $p < 0.05$) (section 5.5.2, Table 7) imply that poor people who were buried without a coffin ate considerable amounts of C3 resources, most likely wheat, while people of higher status did not (section 5.5.2, Figure 11). As there is no corresponding difference in $\delta^{15}N$ values (section 5.5.2, Figure 11), soybeans can be ruled out as an explanation for status-related differences in $\delta^{13}C$ values. Thus, it is likely that in this Eastern Zhou urban area social status mainly had an impact on grain consumption. It is worth noting that the individual of the highest status (XH-M35) among those analyzed at Xinzheng had a relatively high $\delta^{15}N$, but did not display a clear dietary advantage compared to people of lower status. Based on their stable isotope values, people buried in double-layered coffins had broadly similar diets to those buried in single-layered coffins; this suggests that there were no major dietary differences between low-rank nobles and well-off commoners, or that these differences took a form not visible in stable isotopes.

The situation in the Han Dynasty site Xuecun is complex. On the one hand, economic stratification has an effect similar to that seen for the urban Eastern Zhou group, and this indicates that economic conditions probably affected grain consumption rather than meat consumption, with rich people eating less wheat than the poor (δ^{13}C: F=4; $p < 0.05$; δ^{15}N: F=0.2; p=0.78. See section 5.6.3, Table 9). On the other hand, the wide variation of δ^{15}N values from 8.8‰ to 15.9‰ demonstrates significant internal variation in meat consumption patterns. In addition to one individual who may well have eaten fish (XC1-M20) and two potential migrants (XC2-M80, XC2-M50), there are nine individuals whose high δ^{15}N values suggest that their diet might have included the meat of cattle or sheep. The majority (41/53) of Xuecun people more likely relied on pork and dog as their meat resources (section 6.3). Cattle and sheep were more expensive than pig and dog because the former were not usually raised by common agricultural households and were of significant economic value. However, among the nine individuals who might have eaten more expensive meat (δ^{15}N ranging from 11‰ to 12.4‰), seven were buried in earthen chambers representing inferior economic status. Thus, the relationship between meat consumption patterns and δ^{15}N values was not necessarily simple. If these high δ^{15}N values resulted from a high frequency of eating chicken, which typically has high δ^{15}N values and was among the most common household-raised species (section 6.3), this would make it more difficult to isotopically investigate the potential differences in meat consumption. Overall, as in the earlier period, dietary differences in the Han Dynasty seem to be more clearly reflected in grain consumption than in meat consumption. However, the narrow difference between $\delta^{13}C$ of people of all economic capacities (1‰) also demonstrates that C3 resource consumption's variation was not as wide as it was in the Eastern Zhou urban area; in this respect, dietary differences had probably been minimized.

In summary, no apparent status-related dietary differences were observed in the rural Eastern Zhou sample, even though their actual economic conditions probably varied. In comparison, the Eastern Zhou urban people and the Han people both displayed status-based dietary variation. Surprisingly, these differences do not appear to have been represented by the variable amount of meat consumption that was seen in the Late Neolithic Age and the Bronze Age (Zhang XL and Li, 2014; Zhang XL et al., 2012), though this observation is complicated by $\delta^{15}N$ variation in available meats. Instead, dietary differences are reflected by discrepancies in grain consumption. People of higher status or better economic conditions had fewer C3 resources in their staple foods, while people of the lowest stratum appear to have eaten more of wheat, an inferior grain. This study's results disagree with the literary records that suggest a noble-commoner dietary dichotomy reflected in meat consumption during the Eastern Zhou, as we have concluded that nobles likely did not eat more meat than commoners. However, the divide in wheat consumption narrows down during the Han Dynasty and in this regard agrees with textual records displaying weakened emphasis on dietary dichotomy in this era.

Human diet may also have been affected by occupation. Two of the burials in ancient Xinzheng city were interred with weapons, implying that their owners were warriors or soldiers (XH-M11, XH-M19). Both of these individuals had high $\delta^{13}C$ and $\delta^{15}N$ values compared to the majority of the sample, possibly indicating a diet with less wheat and more meat than others (section 5.5.5). It is possible that their occupation granted them more access to millet and animal products. For comparison, ten individuals were buried with weapons in the Xuecun cemetery and were also identified as possible soldiers or private force members. Their average $\delta^{13}C$ of -14.2±1‰ and $\delta^{15}N$ of 10.3±0.6‰ are very close to the values for people belonging to the lowest economic layer ($\delta^{13}C$=-14±1‰, $\delta^{15}N$=10.6±1.2‰). Considering that seven of the Xuecun weapon-bearers were buried in simple earthen chambers representing inferior economic status, it seems that serving in the state army or private force did not enhance diet or wealth. The comparison suggests that these two sites had different occupation-and-diet relationships. Such differences could have been caused by changes in soldiers' identity and status or the military enrollment system, and this topic has potential for future research.

6.5 Sex and Human Diet

In many cultures, gender roles condition types of labour as well as social status. Paleodietary experts internationally are increasingly interested in the impact of gender on diet. Different studies have generated varying results. There are cases showing that a gendered division of labour caused dietary differences between males and females; for example, in Medieval Trino Vercellese, Italy (Reitsema and Vercellotti, 2012), the Southeastern Solomon Islands (Kinaston et al., 2013), and Late Prehistoric Central Texas (Mauldin et al., 2013). Meanwhile, social status stemming from gender roles could also affect human diet and lead to sex-based dietary variation, as suggested by studies in South Korea and Thailand (Choy et al., 2010; King et al., 2013). In China, sex-based differences in human diet are rare, and they are usually attributed to sexual division of labor (Ling et al., 2010) or potential sex-related biological differences in food consumption and digestion process (Zhang QC et al., 2006). The relationship between sex and human diet in historical China has not been thoroughly studied before, but human isotopic data from the four sites analyzed in the current study may provoke further investigation.

Table 14 lists average δ^{13}C and δ^{15}N values of males and females from the four sites; the differences within each site are analyzed using t-tests. Statistical results show that significant sexual differences exist in δ^{13}C values at Chenjiagou (t-test, $t=2.28$, $p < 0.05$) and δ^{15}N values at Xinzheng (t-test, $t=2.99$, $p < 0.05$). Chenjiagou females might therefore have eaten more C3 components than males, while Xinzheng females may have eaten less meat than males. There are no significant sex-related differences at Yangdi or Xuecun, although the Yangdi people were likely composed of two groups with distinctive dietary features. However, a closer observation of the data listed in Table 14 reveals that across all four analyzed sites, females' average δ^{13}C and δ^{15}N values are always lower than that of males from the same site, even if some of the differences are not statistically significant. Whether such a unidirectional difference is meaningful or just coincidence raises a new question that requires a collective comparison of these sex-related isotopic data.

Table 14. Comparison of mean isotopic values between males and females in the four sites

Site	**Sex**	**δ^{13}C(‰) (Ave.±SD)**	**t-test**	**δ^{15}N(‰) (Ave.±SD)**	**t-test**
Yangdi	M	-12.1±6	$t=0.2$, $p=0.85$	9.2±1.1	$t=0.1$, $p=0.93$
	F	-13.2±7.3		9.1±2.3	
Chenjiagou	M	-9.2±0.8	**$t=2.28$, $p < 0.05$**	9.5±0.7	$t=1.54$, $p=0.14$

	F	-10.3±1.2		8.9±1	
Xinzheng	M	-10.5±1.7	t=1.76, p=0.08	9.1±0.9	**t=2.99, p＜0.05**
	F	-11.2±1.4		8.5±0.7	
Xuecun	M	-13.6±0.9	t=1.7, p=0.1	10.6±1.1	t=0.3, p=0.7
	F	-14.2±1.1		10.5±1.1	

In order to compare all sites together as a group, each male's and female's value is transformed into the ‰ deviation from the site's mean value by subtracting the mean value from the individual values (Appendix 6). This format standardizes individual values in terms of their relative position to the average values of their own sites; it thus enables the comparison of males and females among different sites and areas (e.g. Schurr and Powell, 2005; Bourbou et al., 2013). The standardized values of all the males (n=70) and females (n=64) from the four sites are laid out together in Figure 20, in which the unidirectional isotopic difference becomes clear. Females are generally lower in both δ^{13}C and δ^{15}N than males. Additionally, females make up the majority of individuals falling under the average values for their sites, as represented by data points with minus values on both the X and Y axis in Figure 20. Statistical comparisons between the standardized δ^{13}C and δ^{15}N values of males and females (standardized δ^{13}C: t=-2.8, p＜0.05; δ^{15}N: t=-3.2, p＜0.05) suggest that the sexes have significant differences for both isotopes. This confirms the difference suggested by the patterning in average values listed in Table 14. Most of these differences are not statistically significant within individual sites, and archaeological remains from all sites fail to indicate any visible sexual inequality; therefore, it seems unlikely that such a unidirectional isotopic difference could be attributed to sex-based variation in social status. A gendered division of labour may be more closely related to subsistence patterns. To address this possibility, a comparison of contemporary sites with variable subsistence strategies becomes necessary.

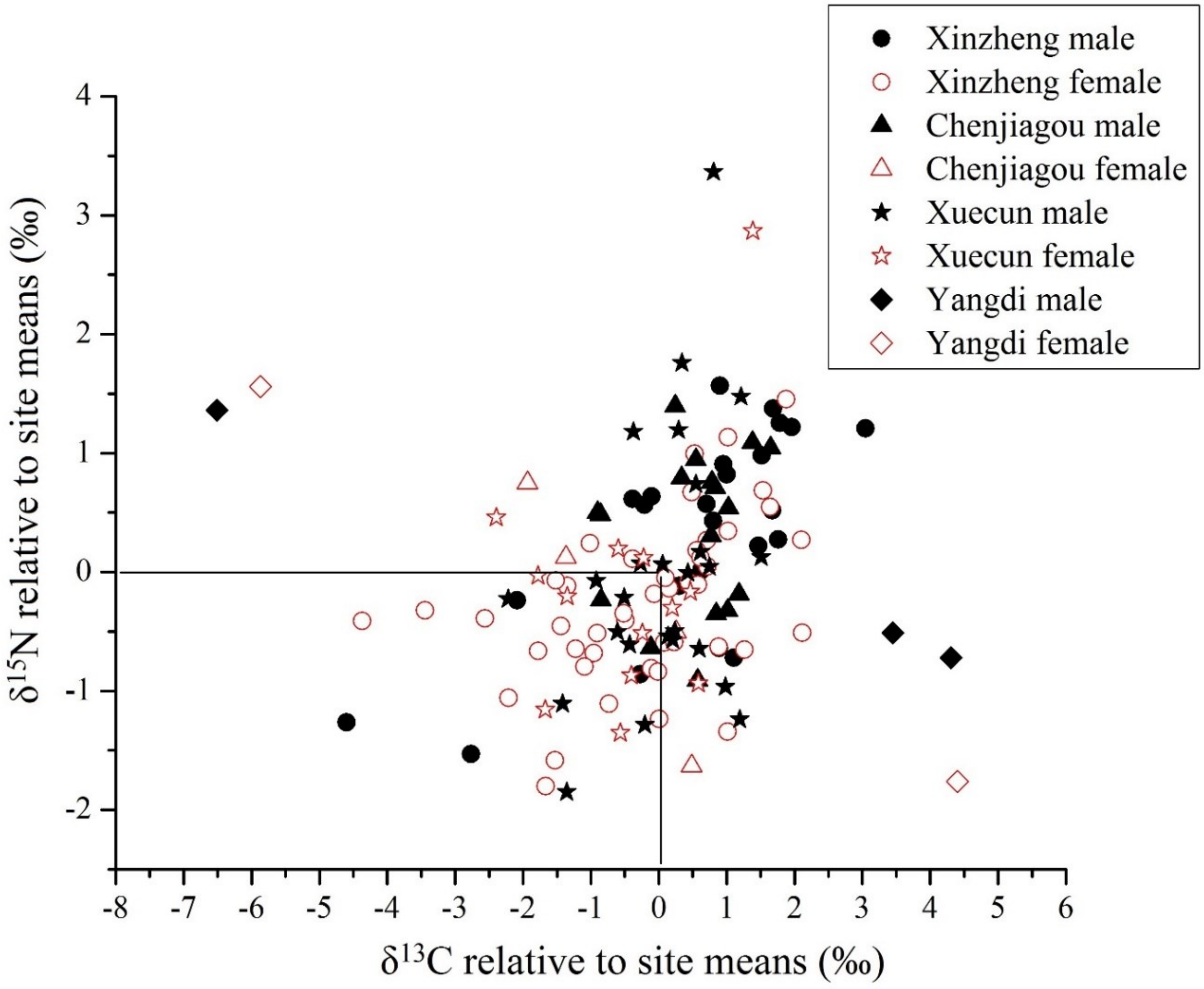


Figure 20. Males' and females' $\delta^{13}C$ and $\delta^{15}N$ values in terms of ‰ deviation in relative to their sites' mean values.

In addition to this study's four sites, data from seven other contemporary sites (all currently available data) located in Hubei province, Inner Mongolia, and Xinjiang Autonomous Region are used in this comparison (Table 15).

The unidirectional isotopic differences seen in the current study's data were initially observed from mean rather than individual values. Accordingly, this comparison uses mean values as well. Average $\delta^{13}C$ and $\delta^{15}N$ values for males and females from each contemporary site are converted into a measure of elevation or depression relative to the site mean. Similar to the method used above on data from this study, a positive value indicates that the mean for this sex is above the site's mean value, while a negative value indicates that the mean is lower than the site's mean. This method enables us to efficiently observe potential differences between several sites.

Table 15 reveals two different patterns. First, there are similar trends in data for the four sites on the plains and the one site from Hubei, adjacent to the plains and south. Again a pattern of the unidirectional isotopic differences between males and females is observed, wherein males are generally located at a higher position in both $\delta^{13}C$ and $\delta^{15}N$ than females. Second, results from Inner Mongolia and Xinjiang display a different pattern: the isotopic values of males and females differ in multiple directions in each area. The Central Plains and the Hubei province in the south are both agricultural areas, whereas Inner Mongolia and Xinjiang are pastoral and agropastoral areas. This may indicate that the different patterns revealed in Table 15 belong to distinctive subsistence strategies, which in turn imply different patterns of gendered labour division.

In traditional Chinese agricultural societies, people live sedentary lives, grow their own food, and raise animals for meat. In this system, food resources and division of labor are both relatively stable and a consistent sex-related dietary difference might therefore be expected. Males could have been seen as requiring more nutrition for heavier work, resulting in meat consumption and relatively higher $\delta^{13}C$ and $\delta^{15}N$. A difference like this could reflect general dietary patterns within agricultural groups but be unaffected by the specific agricultural crop, so that sites from the millet-growing plains and the rice-growing Hubei province display similar sex-related differences. In contrast, life in pastoral or agropastoral areas cannot be sedentary; people are always moving after water and grass resources. The sexual division of labour may have differed under this life pattern. Under these conditions, dietary differences between the two sexes could exhibit more than one trend, as reflected by the data in Table 15.

During the Zhou and Han dynasties, females were underrepresented in textual records; however, this does not necessarily mean that they had lower social status than males. As demonstrated by a study on females in early imperial China (Qin and Han dynasties, 221BC-220AD), they were regarded as equal to males in most ways, and their interests were also protected by law (Hinsch, 2011, pp. 83-94). Females played important roles in the government (Hinsch, 2011, pp. 97-115), as well as industrial and commercial activities (Wang, 2004). Archaeology has also analyzed relationships between sex and social status (Linduff and Sun, 2004; Falkenhausen, 2006, pp. 123-126). However, no compelling evidence currently supports sexual or gender inequality in Zhou and Han Dynasties. Even though the isotopic data analyzed above does reveal unidirectional dietary differences, it also does not necessarily imply corresponding social inequalities. Dietary differences could instead be related to sexual division of labour in agricultural societies. This is the first time that sex-related variation in Chinese dietary studies has been observed across several sites, rather than at an individual location. The comparison and analysis of a large body of isotopic data has provided a new window into the relationship between sex and social roles in ancient China.

Table 15. Standardized δ^{13}C and δ^{15}N values for males and females relative to their sites' mean values in different sites dated to Eastern Zhou and Han Dynasties

Site	Location (Province)	Date	Site mean value		Mean and Relative δ^{13}C (‰)		Mean and Relative δ^{15}N (‰)	
			δ^{13}C(‰)	δ^{15}N(‰)	**M**	**F**	**M**	**F**
Chenjiagou[1]	Henan	Zhou	-9.7±1.4	9.2±0.8	-9.2±0.8	-10.3±1.2	9.5±0.7	8.9±1
					0.5	**-0.6**	**0.3**	**-0.3**
Yangdi[1]		Zhou	-12.5±5	9.2±1.3	-12.1±4.9	-13.2±5.1	9.2±0.9	9.1±1.7
					0.4	**-0.7**	**0**	**-0.1**
Xinzheng[1]		Zhou	-11±1.6	8.8±0.8	-10.5±1.7	-11.2±1.4	9.1±0.9	8.5±0.7
					0.5	**-0.2**	**0.3**	**-0.3**
Xuecun[1]		Han	-13.7±1.2	10.6±1.2	-13.6±0.9	-14.2±1.1	10.6±1.1	10.5±1.1
					0.1	**-0.5**	**0**	**-0.1**
Qinglongquan[2]	Hubei	Zhou	-14.5±1	7.1±1	-14.3±1.1	-15.2±0.6	7.2±1	6.8±0.4
					0.2	**-0.7**	**0.1**	**-0.3**
Nalintaohai[3]	Inner Mongolia	Han	-10±0.8	13.3±1.2	-10.1±0.7	-9.8±0.7	13.1±1.2	13.6±1
					-0.1	**0.2**	**-0.2**	**0.3**
Xindianzi[4]		Zhou	-11.6±0.9	10.3±0.8	-11.7±0.6	-11.4±1.3	10.6±0.7	9.8±0.7
					-0.1	**0.2**	**0.3**	**-0.5**
Tuchengzi[5]		Zhou	-9.9±1.9	7.7±1	-9.8±1.7	-10.1±2.2	8±	7.1±0.9
					0.1	**-0.2**	**0.3**	**-0.6**
Duogang[6]	Xinjiang	Zhou	-14.5±1	12.6±0.6	-14.6±1	-14.5±0.8	12.6±0.6	12.5±0.6
					-0.1	**0**	**0**	**-0.1**
Heigouliang[7]		Han	-18.3±0.3	13±0.3	-18.5±1	-18.2±0.3	12.7±0.1	13.2±0.3
					-0.2	**0.1**	**-0.3**	**0.2**
Dongheigou[8]		Han	-18.4±0.4	13.3±0.6	-18.1±0.4	-18.4±0.3	13.1±0.3	13.2±0.6
					0.3	**0**	**-0.2**	**-0.1**

Note (references for Table 15): 1. Current study; 2. Zhang QC et al., 2012b; 3. Zhang QC et al., 2012a; 4. Zhang QC et al., 2006; 5. Gu, 2010, pp.42-51; 6. Zhang XL et al., 2014; 7. Zhang QC et al., 2009; 8. Ling et al., 2013.

6.6 Human Diet in Urban and Rural Areas

The distinct socioeconomic environments of urban and rural areas condition human diet, an effect that has been demonstrated well in Europe. In imperial Rome, for example, the rural diet included more millet than the urban, and millet was likely regarded as a substandard food (Killgrove and Tykot, 2013). In Iron Age Britain (under the influence of Roman control) the urban British population displayed evident dietary diversity while rural areas were more uniform (Müldner, 2013). For historical China, Xinzheng provides the first group of urban human remains that have been analyzed isotopically; thus, a dietary comparison between the Eastern Zhou urban and rural populations will for the first time touch this topic from the Chinese perspective.

Section 4.1 outlines background information for all the Eastern Zhou sites, two rural and one urban. As discussed in Chapter 5, people from the rural site, Yangdi, display apparent homogeneity in cultural background and social status; however, they unexpectedly include two possible migrants with C3-based diets. The second rural site at Chenjiagou evidences variation in economic conditions, even though the dietary features of these groups appear to have been similar. The urban population from ancient Xinzheng city was diverse, both in social status and in dietary features. Excluding the two possible migrants found in Yangdi, the 42 rural individuals ($\delta^{13}C$ = -9.6±1.4‰) had a C4-based diet, while the 75 urban people ($\delta^{13}C$ = -11±1.6‰) display a more mixed diet with visible effects from C3 foods.

A statistical comparison indicates that both $\delta^{13}C$ and $\delta^{15}N$ values differ significantly between the rural and urban areas (Table 16). This further demonstrates that human diet in these two types of locales varied substantially, and Figure 21 makes a visual comparison to reinforce this observation. Figure 22 further clarifies dietary differences by displaying the low urban $\delta^{13}C$ values, suggesting that the urban diet had more C3 food than the rural diet. The minimal difference between mean $\delta^{15}N$ values of the urban and rural groups, although statistically significant, might not suggest major difference in meat resources.

Table 16. Average isotopic values of the urban and rural population

Area	**Site**	**N**	**$\delta^{13}C$(‰)** **(Ave.±SD)**	**$\delta^{15}N$(‰)** **(Ave.±SD)**
Rural	Yangdi, Chenjiagou	42*	-9.6±1.4	9.1±0.8
		44#	-10±2.4	9.2±0.8
Urban	Xinzheng	75	-11±1.6	8.8±0.8
Student t-test		Outliers excluded	t=-4.9; p＜0.05	t=-2.4; p＜0.05
		All included	t=-2.8; p＜0.05	t=-2.8; p＜0.05

Note: * Two possible migrants from Yangdi excluded
 # All rural individuals included

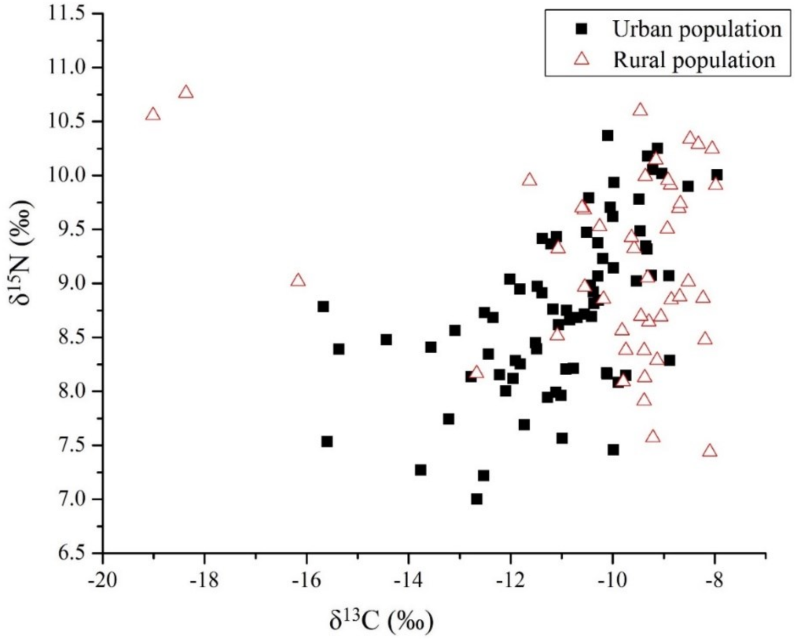


Figure 21. Isotopic comparison between urban and rural population

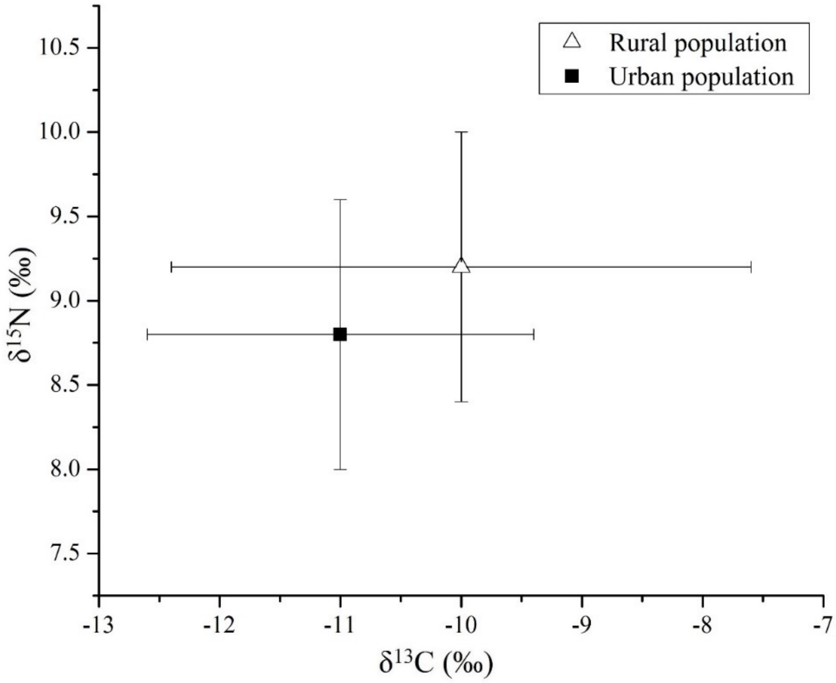


Figure 22. Isotopic comparison between urban and rural population (Ave.± SD, all individuals included)

Section 5.5.2 argues that wheat is the only likely C3 candidate for the urban people in Xinzheng, and that it was likely regarded as an inferior grain. Considering that economic prosperity might have allowed for a more affluent city life, the fact that urban people apparently ate more of the 'inferior' grain than the rural people is unexpected. Furthermore, it is surprising that urban people had no more meat in their diet than the rural group. Thus, this study suggests that the sampled urban residents did not benefit much from the prosperity and convenience of city life in terms of diet, as they did not eat as well as people living outside the city, particularly in terms of grain consumption.

Wheat was largely eaten by the poor, as mentioned in section 5.5.2. While this has the potential to cause an overall dietary pattern, the mean isotopic values of the 19 wealthy individuals who were buried in double or even triple layers of coffin (Table7: $\delta^{13}C$= -10.8±1.4‰, $\delta^{15}N$=8.9±0.8‰) still show no isotopic difference compared to the rural population. Rural individuals still ate a lower proportion of wheat or experienced higher meat consumption. In addition, the highest $\delta^{15}N$ value of the urban group (10.4‰) is similar to those of the two rural groups (10.8‰, 10.6‰); this suggests that maximum meat consumption did not differ between urban and rural areas. Even the noble with the highest apparent rank among the entire Eastern Zhou population (XH-M35, $\delta^{13}C$=-10.5‰, $\delta^{15}N$=9.8‰) does not appear to have eaten more meat than the richest rural people. Well-off commoners or even low-rank nobles in the city did not necessarily eat better than wealthy commoners living in the countryside, and poor urban individuals were disadvantaged relative to rural people in terms of diet. Overall, human diet in agricultural regions seems to have been superior to the urban diet, at least as measured by staple grains.

These sites are all close together, so this study excludes environmental or agricultural differences as potential reasons for the rural-urban dietary divide. Regional history can, however, provide some insights. In 720 BC, the Zheng state army reportedly raided a place named Wen and looted the wheat in the fields; Wen was located in the current Wenxian County covering Chenjiagou (Yang, 1981, vol.1, pp.26-27). This suggests that Chenjiagou farmers probably grew wheat or at least knew the crop, but their stable isotopic values show that they did not eat a detectable amount of it. Presumably, they had sufficient millet provisions from their own fields and did not have to rely on the inferior grain.

The urban people living in the capital city of Zheng state, however, were in a different situation: the military raid on crops points to limited food provisions. Zheng's army not only looted the wheat of Wen in 720 BC, but it also stole millet from the Zhou royal court in the same autumn (Yang, 1981, vol.1, pp.26-27). A coalition of troops from five states took their revenge on Zheng in the next year by reaping Zheng's millet from its fields (Yang, 1981, vol.1, pp.36-37). The purpose of these crop lootings was to destroy the enemy's food provisions while collecting grains: such military actions all occurred in the harvesting season, and crops were invariably stolen rather than destroyed.

If food requirements in urban areas were so large they required raids, grain resources and animal species were understandably diverse because they might come from many different areas through looting or sale. In this context, stratification in staple grain consumption is to be expected; the inferior grains were naturally left for those of the lowest status, as reflected by the isotopic data (section 5.5.2). Along with diversified and stratified food resources, frequent warfare likely impacted human diets in the capital city if food supplies were heavily reliant on different areas of the state. Similarly, the overall trend of limited meat consumption could also have been a consequence of constant warfare.

In brief, Eastern Zhou history featured frequent warfare, altering human diets in strategically vulnerable urban regions. Urban people of all classes consumed similarly limited meat, but their staple grains varied and were stratified. In contrast, rural people produced their own food and seem to have been less affected. Their meat consumption was likely similar to urban populations', but they did not have to eat a significant amount of wheat. Moreover, rural diets do not seem to be significantly affected by social stratification.

The Eastern Zhou situation was similar to that of Roman Britain. In both places, urban diets were diverse and sensitive to external factors (such as influence from other cultures) while rural diets were less affected (Müldner, 2013). This seems to indicate that urban diets relied heavily on provision from other areas and were thus more likely to be impacted by regional instability. By way of comparison, there is an important difference between China and Imperial Rome. In Eastern Zhou China, urban people consumed substandard or inferior grain; in Rome it was the rural residents who did so (Killgrove and Tykot, 2013). Urban Romans likely benefited from the prosperity of their economy during peaceful times. Interestingly, the substandard grain in Rome (millet) was preferred in China, and vice versa.

6.7 Human Diet and Migration

In archaeological chemistry, human migration is usually studied using tracing isotopes such as strontium, oxygen, and hydrogen. Sometimes, dietary isotopes such as carbon and nitrogen are analyzed in combination with these tracing isotopes to get a better understanding of human mobility (e.g. Dupras and Schwarcz, 2001; Knudson et al., 2012). However, dietary isotopes themselves are able to independently identify possible immigrants, and they frequently shed light on migration from the perspective of diet. Animal studies first demonstrated dietary isotopes' potential (for a review see Hobson, 1999), and this research is echoed by a recent study that uses carbon and nitrogen isotopes to trace the provenance of elephant ivory artefacts from Amsterdam (Rijkelijkhuize et al., 2015). Recent scholarship has considered the potential application of dietary isotopes to studies of migration (Garvie-Lok, 2013), and some studies have begun to tentatively identify immigrants based on their distinctive dietary features (e.g. Maudlin et al., 2013).

In China, an isotopic study of the Zongri site in Qinghai Province notes that a group of people with distinct dietary features also culturally differentiated themselves from locals through burial customs (Cui et al., 2006). Similarly, dietary isotopic data in this study has also pointed to possible human migration. At Yangdi site, the two individuals with C3 diets (YY-M5, YY-M6) in a millet-growing area may be immigrants. In Chenjiagou, the individual WC-M52 stands out with the lowest δ^{13}C value (-16.2‰), which is 6.5‰ (over 4 standard deviations) below the site's mean value (-9.7±1.4‰); this displays a strong C3 dietary contribution that is very likely not local. This study did not expect to identify potential migrants in Eastern Zhou rural areas, nor did it anticipate the absence of migrants in Xinzheng, an urban area where human mobility should be high. At the Han Dynasty era site Xuecun, although two individuals with extreme δ^{13}C and δ^{15}N values (XC1-M15, XC1-M20) could not be definitively identified as immigrants or as locals (section 5.6.6), another pair of outliers at the same site (XC2-M50:R, XC2-M80:R) were likely migrants, based on their unusual high $\delta^{15}N$ values and burial context; they were each buried in the same space as a second individual with a local diet and burial style (section 5.6.7). All these examples have triggered the interest to investigate the potential of using dietary isotopes to study human migration in ancient China.

Identifying potential immigrants is just the first step in studying human migration; to further understand the related migrating activities, it is necessary to discover each migrant's possible origin. Migration studies that use tracing isotopes often try to correlate the isotopic values of immigrants with a region displaying similar isotopic signals, though geological similarities between different areas often make results difficult to confirm. Thus, if dietary features within a large area are diverse enough, an immigrant's origin may be proposed or narrowed down using dietary isotopic values. This study uses such a method for the first time here in Chinese archaeology, and the following pages will test it in the context of Eastern Zhou and Han dynasties.

Table 17 pools together all the isotopically analyzed sites dated to the Zhou Dynasty in China in order to map any discernible difference in human diet by region. Figure 23 shows the locations of each site, and corresponding average isotopic values with SD are laid out together in Figure 24 to form a "dietary map". This process reveals noticeable diversity, as expected.

Table 17. Human stable isotope values from sites dated to the Zhou Dynasty* in China

Site	n#	δ^{13}C(‰) (Ave.±SD)	δ^{15}N(‰) (Ave.±SD)	Reference
Chenjiagou	38	-9.5±1.0	9.2±0.8	Current study
Yangdi	3	-8.4±0.4	8.2±0.5	Current study
Xinzheng	75	-11±1.6	8.8±0.8	Current study
Shenmingpu	14	-12.7±0.8	8.7±1.2	Hou et al., 2012
Qinglongquan	9	-14.5±1	7.1±1	Zhang QC et al., 2012b
Qianzhangda	36	-8.9±1.3	10.2±1.2	Zhang XL et al., 2012
Beiqian	4	-9.2 ±0.7	10.5±0.4	Wang et al., 2014
Tuchengzi	16	-9.9±1.9	7.7±1	Gu, 2010
Xindianzi	20	-11.6±0.9	10.3±0.8	Zhang QC et al., 2006
Jinggouzi	10	-12.4±0.7	9.8±0.6	Zhang QC et al., 2008
Duogang	39	-14.5±1	12.6±0.6	Zhang XL et al., 2014
Qiongkeke	8	-16.2±0.1	12.7±0.3	Zhang QC and Li., 2006

Note: * All sites dated to the Zhou Dynasty (Western and Eastern Zhou) are included considering that some of the dates are not clear cut.

Possible non-locals in Yangdi (n=2) and Chenjiagou (n=1) are not included

Figure 23. Location of the isotopically analyzed Zhou sites in China

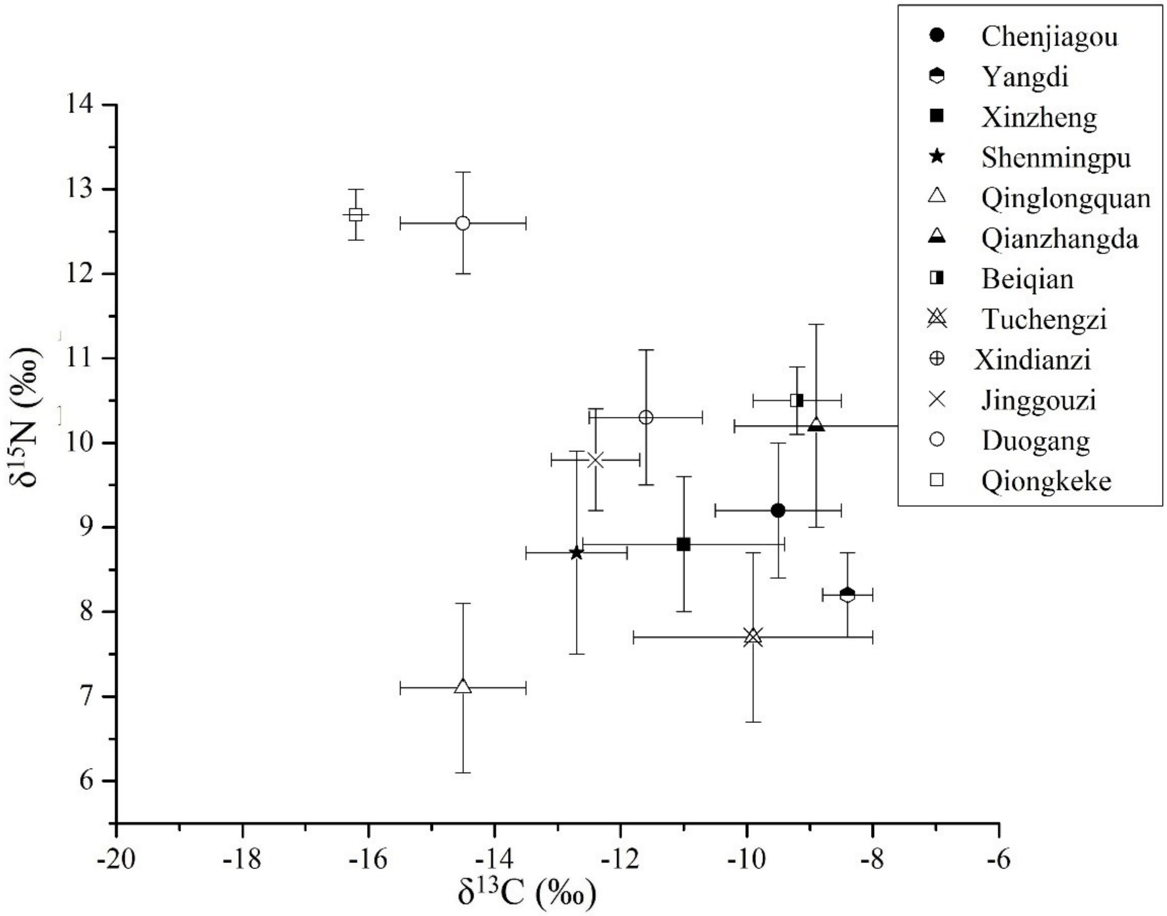


Figure 24. Isotopic comparison among different Zhou sites (Ave. ± SD)

As displayed in Figure 24, the two sites located in the northwest corner (Duogang and Qiongkek) distinguish themselves from all other locations with the lowest mean δ^{13}C and highest mean δ^{15}N values. Such a distinctive pattern likely results from a combination of wheat consumption and a pastoral subsistence pattern involving large amounts of dietary beef and mutton (Zhang QC and Li, 2006; Zhang XL et al., 2014; Zhou and Garvie-Lok, 2015). These sites' high δ^{15}N values could also be attributed at least partly to the aridity of this semi-desert area (Heaton, 1987; Hartman, 2011). Qinglongquan is the only site located in southern China with a long history of rice agriculture, and it displays very low δ^{13}C and δ^{15}N values indicating a typical agricultural

C3-based diet with limited meat (Zhang QC et al., 2012b). Beiqian and Qianzhangda are the two sites in close proximity to the eastern coast; they are enriched in both $\delta^{13}C$ and $\delta^{15}N$ compared to inland sites on the Central Plains (e.g. Chenjiagou, Xinzheng, and Yangdi), very likely resulting from the effect of marine resources in the diet (Zhang XL et al., 2012; Wang et al., 2014). Inner Mongolia sites, Jinggouzi and Xindianzi, have higher mean $\delta^{15}N$ values than the agricultural sites, suggesting that more meat was included in these diets (consistent with a pastoral subsistence pattern). Agricultural sites on the plains, including Chenjiagou, Xinzheng, and Yangdi, can be differentiated from other regions without difficulty based on their moderate isotopic features. Additionally, even though Shenmingpu site belongs to the same province as these three sites, it is isotopically different; it is located in the southwestern mountainous area and is very likely affected by the rice agriculture of the south (Hou et al., 2012).

Surprisingly, the distribution of these sites on the “dietary map” (Figure 24) generally correlates with their geographical locations shown on the map in Figure 23. Tuchengzi is the one exception, and it is located on the Inner Mongolia steppe. While this site is geographically close to Xindianzi, it is isotopically distant from its neighbour. As shown on the “dietary map”, Tuchengzi is closer to the agricultural sites on the plains than to the pastoral sites on the northern steppe in terms of diet. Its unique qualities may suggest that its inhabitants had important links to peasants from the agricultural area south of the steppe. At first this assertion may seem bold, since the unusual isotopic features of the site could be attributed to other factors. However, physical anthropological evidence and archaeological remains indicate that the people of Tuchengzi were likely immigrants from the Zhao state in the south of the steppe (close to the northern plains and unquestionably sustained by agriculture), and that the men of the community were probably frontier soldiers (Gu, 2010, p. 113). This suggests that dietary features could be valuable preliminary indicators of human migration, and capable of pointing out the possible origins of immigrants given that dietary diversity in the targeted area is discernible.

In contrast to geological features that usually remain stable for a very long time, human dietary features are variable and subject to many factors. This study will consider human diet and migration in the Han Dynasty separately from the previous era in order to avoid the potential effect of temporal dietary variation. Table 18 presents Han Dynasty average isotopic values, geographical locations are displayed in Figure 25, and the distribution of dietary features are shown in the "dietary map" of Figure 26. Again, the dietary map is generally consistent with the geographical map, confirming that dietary features of the Han era were also closely related to subsistence patterns and environmental factors. The two sites in the northwest (Heigouliang and Dongheigou) remain distinctive in both $\delta^{13}C$ and $\delta^{15}N$, indicating that diets with wheat and abundant meat persisted in this period (Ling et al., 2013; Zhang QC et al., 2009). On the dietary map, Shenmingpu is farther from plains values than it was in the Zhou era, and this indicates that dietary differences between the mountainous area and the plains increased in the Han Dynasty. The three sites from Inner Mongolia differ from each other. Two of them (Nalintaohai and the pooled Sandaowan and Bagou data) still show much higher $\delta^{15}N$ values than agricultural sites such as Xuecun, although their $\delta^{13}C$ values vary significantly. Pastoral subsistence could generate much more meat than its agricultural counterpart, but $\delta^{13}C$ values of meat and other staple foods need not be consistent since human and animals on this vast steppe would have always been moving. The third Inner Mongolia site, Huhewusu, distinguishes itself from the others in both $\delta^{13}C$ and $\delta^{15}N$, and this requires further attention.

Table 18. Human stable isotope values from sites dated to the Han Dynasty in China

Site	n	$\delta^{13}C$(‰) (Ave.±SD)	$\delta^{15}N$(‰) (Ave.±SD)	Reference
Xuecun	54	-13.7±1.2	10.6±1.2	Current study
Shenmingpu	19	-16.1±1.7	8.4±0.9	Hou et al., 2012
Dongheigou	11	-18.4±0.4	13.3±0.6	Ling et al., 2013
Heigouliang	9	-18.3±0.3	13±0.3	Zhang QC et al., 2009
Huhewusu	5	-9.3 ±0.5	9.1±0.6	Zhang QC et al., 2012c
Nalintaohai	7	-10±0.8	13.3±1.2	Zhang QC et al., 2012a
Sandaowan & Bagou*	18	-14.7±0.8	12±0.9	Zhang GW et al., 2011

Note: Sandaowan and Bagou are two sites located in very close proximity.

Figure 25. Location of the isotopically analyzed Han sites in China

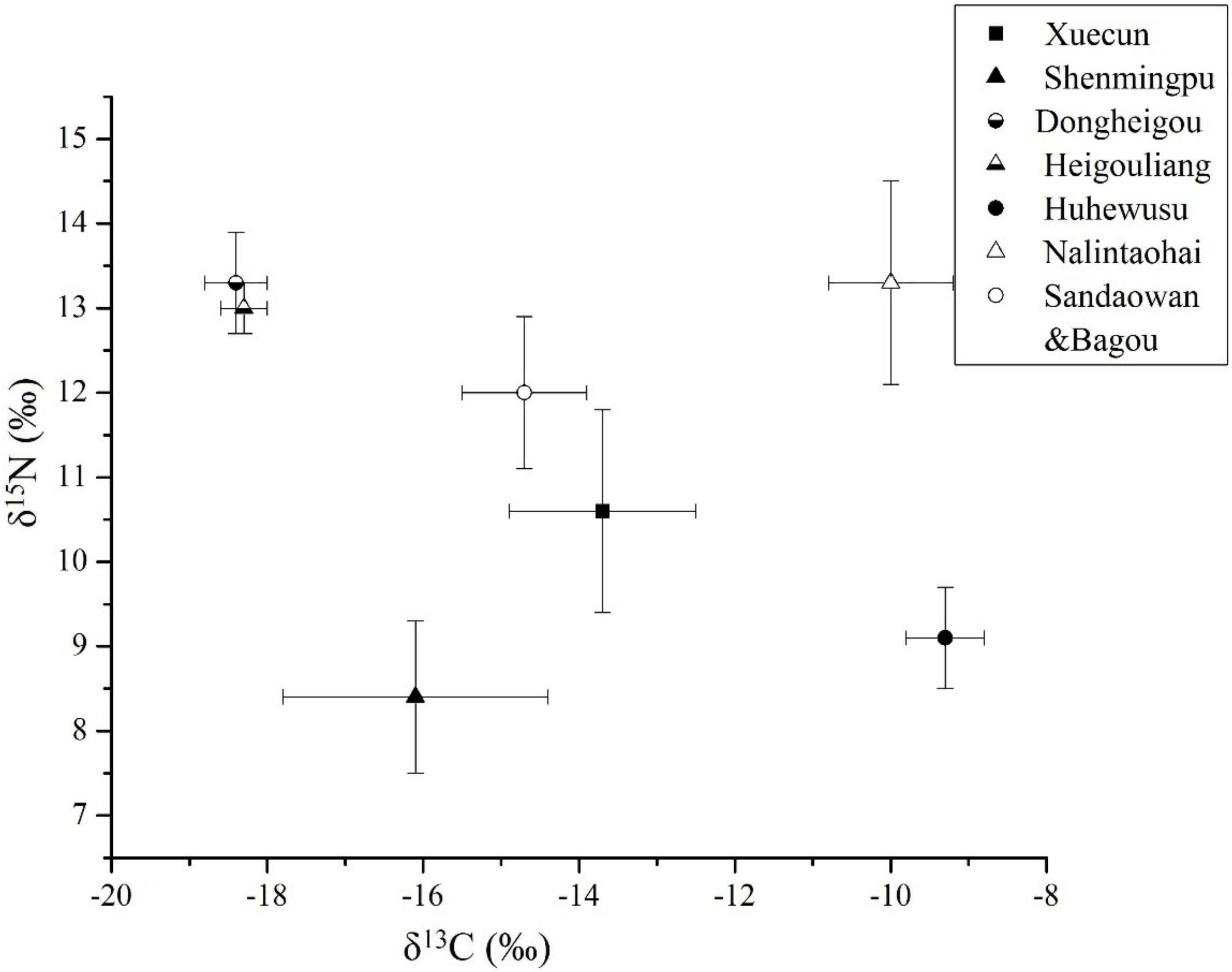


Figure 26. Isotopic comparison among sites dated to the Han Dynasty (Ave.± SD)

As Figure 25 shows, Huhewusu is in geographically close to Sandaowan and Bagou; however, Figure 26 demonstrates that these neighbouring populations are significantly dissimilar in stable isotope values. The Huhewusu were not likely pastoralists, given their low $\delta^{15}N$ value; they were probably peasants living on millet agriculture, as reflected in their high $\delta^{13}C$ values. Other lines of evidence support this surprising conclusion. Burial styles and funeral objects suggest that the Han Empire's expansion into the north is responsible for the Huhewusu remains (Wei, 1998, pp.1-3, 337-341); its residents were probably among the large number of agricultural communities that migrated to exploit the northern frontier. Here, dietary features have again served as preliminary indicators of human migration, and immigrant origins can indeed be proposed using isotopic dietary comparisons.

The above analyses of the Zhou and Han sites not only confirm dietary isotopes' potential for migrant identification, they also tell us that comparisons of dietary features can help pinpoint migrant origins. Given this, the possible immigrants from Yangdi, Chenjiagou, and Xuecun are plotted on the dietary map of the Zhou and Han dynasties respectively to see if new information about their origins can be obtained. Figure 27 shows the location of the three likely non-locals from Yangdi (YY-M5, YY-M6) and Chenjiagou (WC-M52) on the Eastern Zhou dietary map. They fall in an area of the graph with no similar isotopic data; thus, their origins cannot be immediately suggested, but it is less likely that they came from the north, east, or central regions based on a comparison to sites in those areas. The eastward relocation of the royal court at the beginning of the Eastern Zhou caused a wave of west-to-east migrations from regional states such as Zheng; if this process involved massive migrations of commoners from the west, it could be the clue to solving migratory puzzles in this special context.

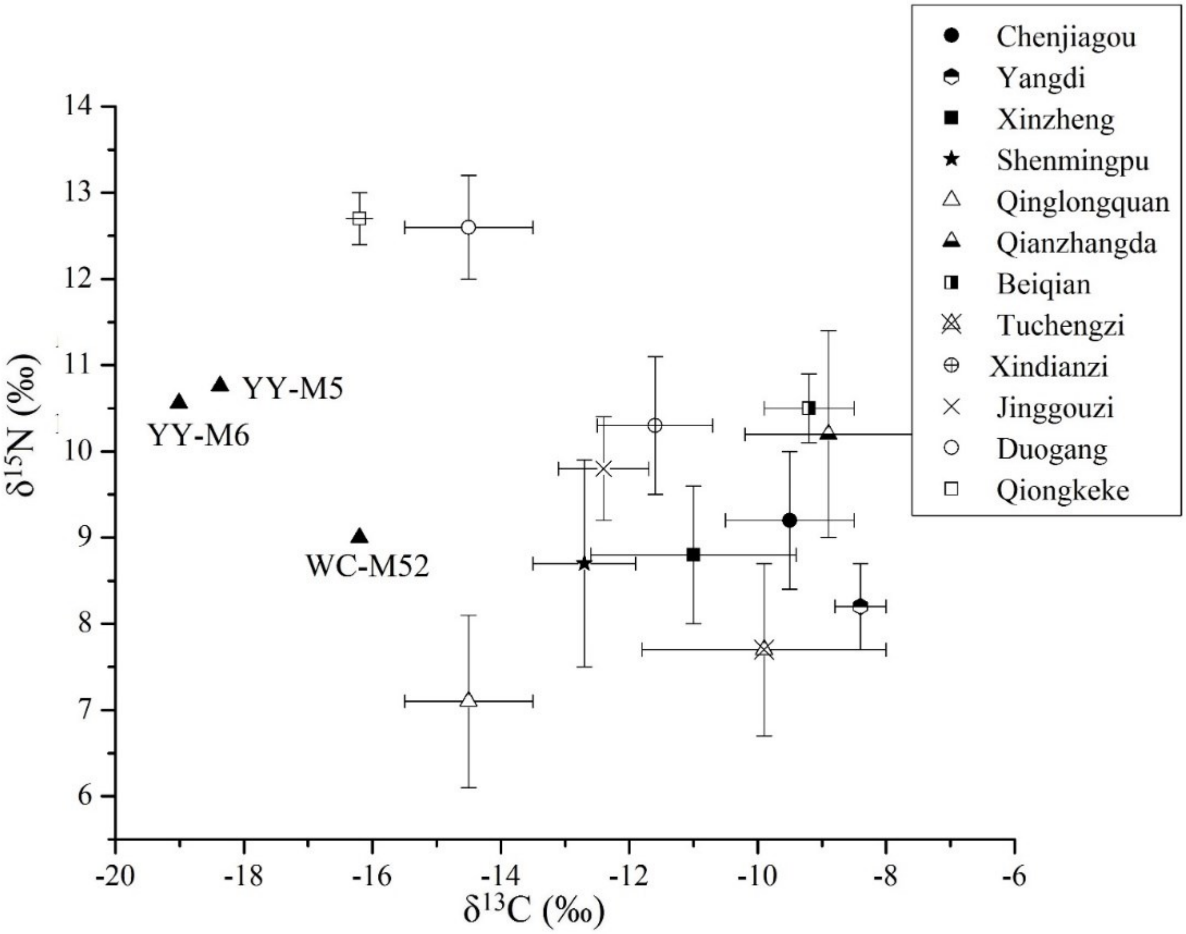


Figure 27. Possible immigrants from Yangdi and Chenjiagou plotted on the "dietary map" of the Zhou dynasty

Figure 28 plots the two Xuecun immigrants identified by both burial style and isotopic signature (XC2-M50:R, XC2-M80:R) as well as the two individuals with extreme values (XC1-M15, XC1-M20); it also plots the mean values from other sites. Surprisingly, individual XC1-M15 falls within the isotopic range of Huhewusu, where people likely moved to the northern steppe from an agricultural area. This does not suggest that the Huhewusu people themselves were from the plains, because individual XC1-M15 does not isotopically resemble the local plains people. Instead, it suggests that XC1-M15 and residents of Huhewusu were migrants with similar origins but different destinations. Accordingly, this hint of an origin could be investigated further using Sr, O isotope analysis, or other techniques such as aDNA or craniometrics.

The close isotopic similarity between another two identified immigrants (XC2-M50:R, XC2-M80:R) and the Nalintaohai people implies possible linkage between them. Additionally, one study compares cranial morphological features of northern populations dated to Han and later times; it demonstrates that among the 18 population groups analyzed, Nalintaohai is the closest group to Xuecun (Sun, 2013, p, 111), suggesting that the two groups were genetically close to each other. Thus, dietary isotopic results on the origins of XC2-M50:R and XC2-M80:R are seconded by physical anthropological evidence, although the exact migration pattern still requires study. Human migration in the Han Dynasty was very complex; the emperor sent many troops to the northern border to defend against the Xiongnu (the Huns) and encouraged large agricultural populations to exploit its uncultivated land. Although individual XC1-M20 (with a $\delta^{15}N$ value higher than all currently known populations) has no certain origin at this time, the potential of dietary isotopes to take part in preliminary assessments of human migration cannot be denied.

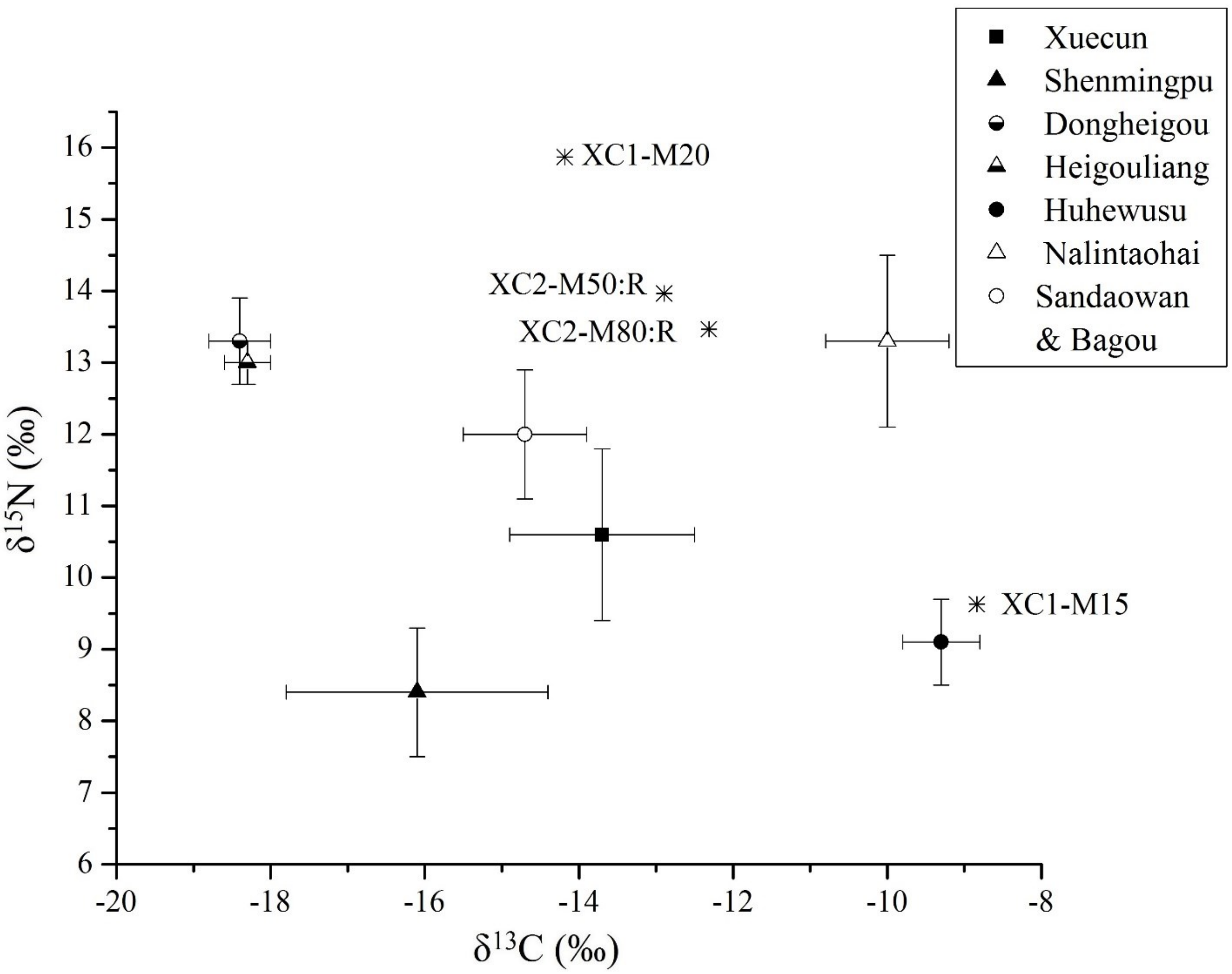


Figure 28. Possible immigrants from Xuecun plotted on the "dietary map" of the Han dynasty

This study has compared its results with previously published data to reveal the dietary diversity of both the Zhou and Han dynasties, and it has used dietary maps alongside geographical distributions to demonstrate that each region appears to feature specific human dietary patterns. This has enabled us to identify two migrating population groups (Tuchengzi and Huhewusu), which is unusual because most migration studies reveal only a few migrating individuals. Further comparisons between individual isotopic signatures and different sites have pointed out potential origins for some of the apparent non-locals in the current study. This not only confirms the potential of using dietary isotopes in human migration studies, but also raises intriguing questions for future studies. For example, how are we to avoid mistaking a moving human group as locals for lack of internal isotopic variation? Due to technological and geological constraints, tracing isotope analysis using elements such as Sr and O is not always possible. In contrast, dietary isotope analysis is inexpensive and easily accessible. Therefore, its potential is worth exploring, and the results of this study should point to areas for future exploration in the study of human migration using tracing isotopes or DNA.

Migration studies should, however, apply dietary SIA with caution for several reasons. Dietary features within a population are always variable, and it is difficult to differentiate non-locals from locals using dietary isotope values alone unless there is a very clear discrepancy. Furthermore, it takes a considerable amount of isotopic data to make dietary diversity visible, and the borderlines of dietary isotopic trends overlaid with geographical areas may not always be clear. Studies should always conduct a comparison of dietary features among co-occurring sites to avoid the effects of different time periods. Finally, to fully explore the potential of C and N isotopes as tools for migration and origin analysis without falling into the trap of over-interpretation, it is always necessary to keep an eye on other lines of evidence such as archaeological context and physical anthropology.

6.8 Socio-economic Change and Human Diet on the Central Plains

The period of transition from the Eastern Zhou to the Han Dynasty witnessed transformative changes throughout multiple aspects of Chinese society. The Central Plains suffered a high frequency of wars in the Eastern Zhou, but soon afterwards they experienced the prosperity of the Han Empire. This study will compare human isotopic data from the plains across these two contexts in order to analyze the effect of socioeconomic changes on daily life from the unique perspective of diet.

There are 119 Eastern Zhou individuals from three sites and 53 Han Dynasty individuals from one, all plotted together against their $\delta^{13}C$ and $\delta^{15}N$ values in Figure 29. Surprisingly, the dietary differences between these two groups are so clear that there is no overlap in their isotopic data with the exception of one likely immigrant at Xuecun. Figure 30 further clarifies these differences by comparing the average and SD values of the two populations; it demonstrates that the Han differed substantially from the Eastern Zhou in both $\delta^{13}C$ and $\delta^{15}N$ values. This is also supported by statistical tests ($\delta^{13}C$ t-test: $t=10.4$, $p<0.05$; $\delta^{15}N$ t-test: $=-10.4$, $p<0.05$). The average $\delta^{13}C$ of the Han individuals from Xuecun ($\delta^{13}C=13.7\pm1.2‰$) is 3.1‰ lower than that of the Eastern Zhou samples ($\delta^{13}C=10.6\pm2‰$), and this study argues that these figures indicate a substantial increase in wheat consumption (section 5.6.1). Conversely, the increase in $\delta^{15}N$ from Eastern Zhou ($\delta^{15}N=8.9\pm0.8‰$) to Han ($\delta^{15}N=10.6\pm1.3‰$) cannot be confidently attributed to an overall change in meat consumption (of quantity or type) before other possible interpretations are excluded.

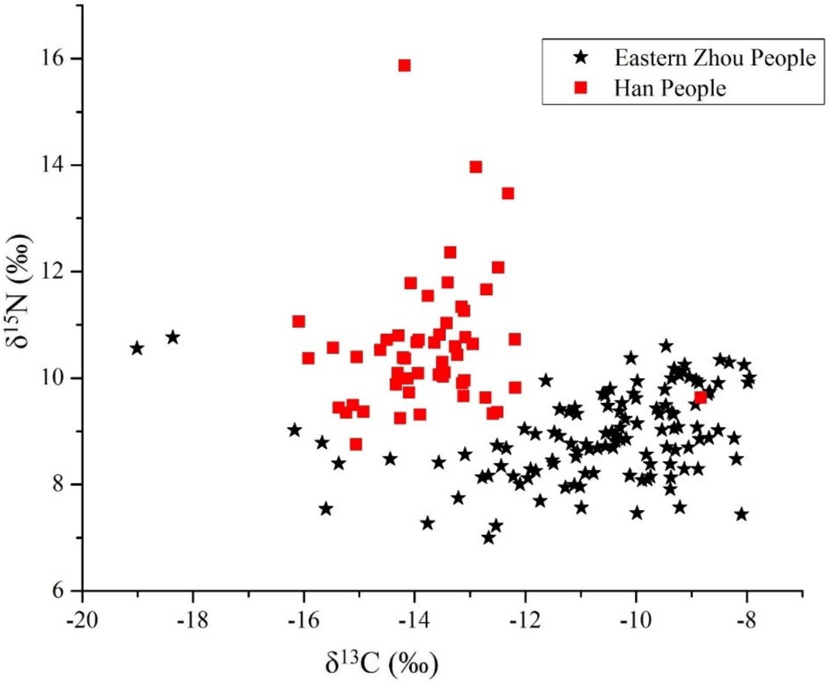


Figure 29. Comparison between the diet of Zhou and the Han people.

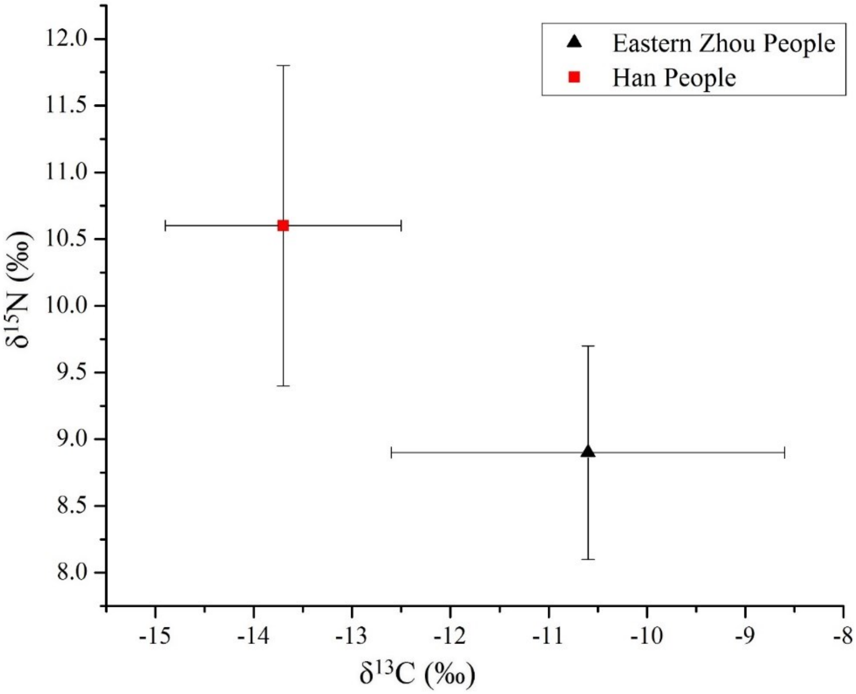


Figure 30. Isotopic comparison between Zhou and Han people (Ave.± SD)

In regards to potential changes in meat consumption, there are other options that must be considered first. The Han Dynasty featured a highly developed agricultural system (Hsu, 2005), and related activities could have affected human collagen $\delta^{15}N$ values. Among them, manuring is the most likely factor that would cause elevation in $\delta^{15}N$ (Choi et al., 2002; Bogaard et al., 2007; Fraser et al., 2011). However, the $\delta^{15}N$ manuring effect depends on manuring levels and frequency (Bogaard et al., 2007). Long-term experiments producing a substantial effect had to apply 20 to 35 tons of manure, which amounts to the annual manure production of two to three cattle, to one hectare of field every year or every second year (Bogaard et al., 2007). This high manuring level is very unlikely for ancient China. Taking the Han Dynasty as an example, a normal household of five people cultivated about two hectares of land (Ning, 1980). A few pigs, dogs, and chickens would have produced the manure for each family, because large animals like cattle were usually raised by specialized households (Wen, 2007). Thus, there was a limited amount of animal manure applied to most land. Moreover, it is unlikely that manuring levels were improved remarkably in the Han Dynasty, because farmers fertilized their fields in a way similar to that of Zhou times (Hsu, 1984a; Hsu, 2005, pp. 217-219). With these considerations in mind, the possibility that manuring caused the marked elevation of $\delta^{15}N$ in the Han sample seems to be very low.

As all four sites are located in close proximity to each other on the same floodplain, ecological factors that might elevate $\delta^{15}N$ values, such as leaching, aridity, and salinity (Heaton, 1987; Hartman, 2011; Handley and Raven, 1992) can also be excluded. The era from the Eastern Zhou to the former period of the Han was relatively warm and humid without significant variation (Zhu, 1972); this also excludes the possibility that the shift in human collagen isotopic values resulted from climate change rather than dietary variation (Fenner et al., 2014).

Having excluded these potential anthropogenic, ecological, and climatic factors, we can plausibly state that the elevation in $\delta^{15}N$ values from the Eastern Zhou to the Han Dynasty likely resulted from changing meat consumption. In addition to an increase in wheat use, this is the other feature of significant dietary change between the two eras.

While wheat consumption appears to have increased substantially during the Han Dynasty, this grain was still not preferred by those with the luxury to choose, as reflected by both isotopic evidence (section 5.6.3) and textual records (see Yu, 1977 for a review). This may indicate that the substantial increase in wheat consumption was not a natural trend following dietary changes initiated in the Eastern Zhou, but rather an adaptive strategy in response to food pressure in special historical context (Peng, 2010). After the establishment of the Han Empire, a more peaceful life and prosperous economy ensued as did population growth; during the first seven decades (202-134 BC) of the empire the population almost doubled (Ge, 1991, pp.113-114). This rapid growth lasted throughout the Western Han Dynasty, and the population increased from about 15-18 million in 202 BC to about 60 million in 2 AD (Ge, 1991, p.113). For any society, the most direct consequence of rapid population growth is often food scarcity. In contrast to the Eastern Zhou wherein food crises seemed to only affect urban areas, food supply pressure in the Han Dynasty might have threatened the whole society. Thus, it is not surprising to see that the first governmental promotion of wheat cultivation in ancient China took place around 100 BC (Ban, 1962, pp. 1137[1st century AD]), during the first population explosion of the imperial period. Aside from population-triggered food pressure, wheat's higher per-unit yield than the traditional grain, millet, might have also promoted its expansion (Peng, 2010). Given this historical background, the presence of substantial wheat in human diets of the Han Dynasty is to be expected, even though the people of the time might not have accepted this grain very readily and still regarded it as inferior to millet.

In contrast to elevated wheat consumption, which seems to have been an adaptive or passive strategy in response to external pressures, the change in the role of meat in human diets was more likely a positive, active change. Some Han era scholars complained that "now [during the Han Dynasty] there are butchers everywhere and it is common to see people using millet to trade for meat", and that "on sacrificial events, the rich ones killed cattle, the middle class ate sheep and dogs, and even the poor had pigs and chickens to eat" (Wang, 1992, pp.351-352). These comments suggest that improved animal husbandry and commerce allowed meat to be traded freely on the market without restraint; the population likely welcomed this development, because they could use millet to trade for meat.

There is a lack of urban isotopic data for the Han Dynasty; so it is currently difficult to know whether the rural-to-urban dietary discrepancy observed in the Eastern Zhou changed or not. However, the absence of significant sex-related, temporal, and economic variations within the Han sample (section 6.4) suggests that human diets became more stable and homogeneous in this period. This might indicate that a change in social structure enabled relatively equal access to food resources for the majority of the population in the empire.

Overall, the significant dietary change from the Eastern Zhou to the Han Dynasty seems to reflect two trends: adaptive strategies in response to population-triggered food scarcity, and active strategies benefiting from the development of animal husbandry and free trade. Socioeconomic changes during this transformational period therefore had profound effects on human diet. The passive and active aspects of this dietary change are both related to historical context and the requirements of a fast-growing population. The decrease in internal dietary variation further suggests a modification of social structure and redistribution of resources after the establishment of the Han Empire, in a way that benefited the majority of the people, particularly the commoners. Based on these considerations, the dietary change from the Eastern Zhou to the Han Dynasty was unquestionably positive for much of the population.

6.9 The First Major Dietary Change on the Central Plains since Late Neolithic Times

This study has established that the Central Plains' dietary change from the Eastern Zhou to the Han Dynasty was undoubtedly substantial. However, whether this change had significant meaning and profound influence when contextualized by the full agricultural history of the region cannot be determined without a review of long-term dietary fluctuations since Neolithic times.

Before beginning the review of historical and pre-historical materials, it is necessary to clarify two geographical terms in order to avoid any possible confusion. As introduced in section 2.5, the term 'Central Plains' mainly refers to Henan Province (Editorial Committee, 1996, p.133), but the two do not exactly equal each other in geographical range. 'Central Plains' only refers to the plains portion of Henan Province and does not include the mountainous area in the southwest (section 2.5, Figure 1). There are sixteen sites from this province that have been analyzed for dietary studies (Figure 31, Table 19), fourteen of which are located on the plains (Table 19, from Jiahu to Gu'an) and two of which are located in the mountainous area (Table 19: Gouwan, Shenmingpu). The following discussion will first focus on the sites from the plains, and briefly cover the mountainous sites towards the end in order to show the dietary differences between these two regions.

Figure 32 lays out all sites dating from Middle Neolithic times (7500-5000BC) to the Eastern Wei and Northern Qi Dynasties (534-577 AD), with the exceptions of three sites with no $\delta^{15}N$ values and one site with limited and uninterpretable $\delta^{15}N$ (Table 19). It includes the average isotopic values and SD for these ten remaining sites.

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Figure 31. Isotopically analyzed sites in Henan Province

Table 19. Human stable isotope values from different sites located in the Henan Province

Site	N	Date	$\delta^{13}C$(‰) (Ave.±SD)	$\delta^{15}N$(‰) (Ave.±SD)	Reference
Jiahu	14	7500-5000 BC	-20.3±0.5	8.9±0.9	Hu et al., 2006
Xishan	39	5000-3000 BC	-8.2±1.5	9±0.8	Zhang XL et al. 2010
Xipo	31	5000-3000 BC	-9.7±1.1	9.4±1	Zhang XL et al. 2010
Xinzhai	8	1870-1720 BC	-9.6±1.4	9.0±1	Wu et al., 2007
Erlitou*	22	1735 -1530 BC	-9.3±2.4	11.9±3.8	Zhang XL et al., 2007
Liuzhuang	32	2000-1600 BC	-7.6±0.6	9.6±1	Hou et al., 2013
Nanzhai	9	2000-1600 BC	-9.6±1.2	----	Zhang XL et al., 2003
Yanshi	3	1600-1260 BC	-7.6±0.6	----	Zhang XL et al., 2003
Yin Xu	39	1300-1046 BC	-8.2±2.4	----	Zhang XL et al., 2003
Chenjiagou	39	770-221BC	-9.7±1.4	9.2±0.8	Current study
Yangdi	3#	770-221BC	-8.4±0.4	8.2±0.5	Current study
Xinzheng	75	770-221BC	-11±1.6	8.8±0.8	Current study
Xuecun	53	141BC-220 AD	-13.7±1.2	10.6±1.2	Current study
Gu'an	26	534-577AD	-11.5±1.2	10.0±0.6	Pan, 2009
Gouwan	41	5000-3000 BC	-14.3±1.9	8.3±1.1	Fu et al., 2010
Shenmingpu1	14	475-221BC	-12.7±0.8	8.7±1.2	Hou et al., 2012
Shenmingpu2	19	206BC-220 AD	-16.1±1.7	8.4±0.9	Hou et al., 2012

Note:

*** Only five of the twenty-two samples from this site were analyzed for nitrogen isotope and no background information was provided. So the unusual δ^{15}N values is hard to interpret currently and is not plotted on Figure 32.**

 # Possible non-locals from Yangdi (n=2) not included.

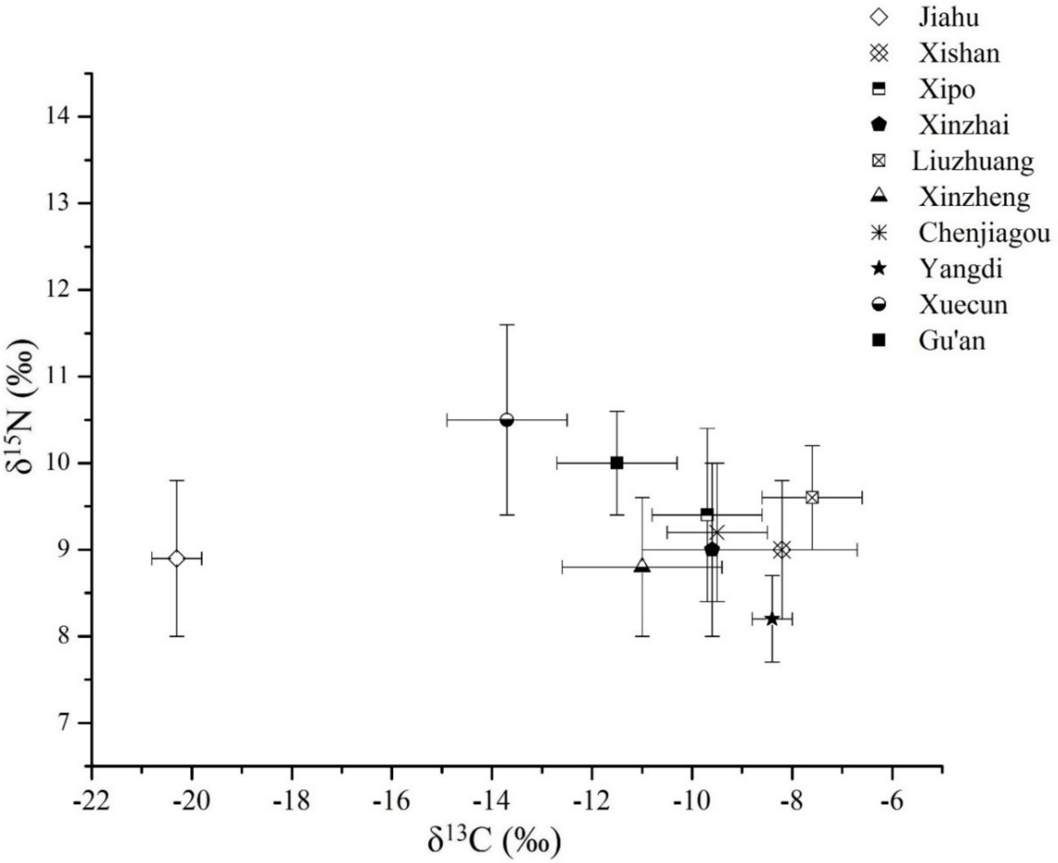

Figure 32. Isotopic comparison of sites on the Central Plains (Ave.± SD)

In Figure 32, Middle Neolithic Jiahu is the site that most clearly distinguishes itself from all the others with a distinctively low δ^{13}C value. Jiahu is the earliest site on the Central Plains that shows strong evidence for early agriculture, and it has shed light on this subsistence transition in northern China (Hu et al., 2006). Interestingly, these earliest farmers practiced rice agriculture despite their location in an area known for a long history of millet cultivation; this is supported by both the archaeobotanical evidence and human isotopic data (Kong et al., 1996; Hu et al., 2006). The wide discrepancy between the δ^{13}C values of Jiahu and those of other sites demonstrates that the Jiahu's rice agriculture disappeared suddenly. The C3-based human diet was not inherited by later generations who apparently grew and ate millet instead. The agricultural shift from rice to millet in this area might have been a consequence of climate change from the humid early Holocene to the drier middle Holocene, but this possibility is not well-supported because there are no clear diachronic trends observed between 9000 and 7800 BP at Jiahu (Hu et al., 2006). The dramatic shift has long remained a mystery. Almost no-one so far has considered the possibility that Jiahu's people could have been immigrants from somewhere outside the plains, even though strontium isotope analysis has demonstrated high population mobility in this site throughout time (Yin et al., 2008). A theory based on immigration has been broached very recently. Some archaeologists have analyzed the composition of plant remains and compared pottery morphology, and they insightfully propose that the earliest Jiahu people were likely immigrants from the Yangtze River valley in southern China where rice agriculture originated (Zhang and Hung, 2013). Their conclusion sheds light on the Jiahu agricultural mystery. It also supports the possibility proposed in section 6.7, confirming that dietary patterns can be valuable indicators of human mobility. Once again, this has raised the question of how to identify an entire migrating population, as most isotopic studies of human mobility target moving individuals and depend on isotopic differences between them and the majority of site values.

All the other analyzed sites postdate the rice-growing Jiahu (probably occupied by immigrants from the south) and date from Late Neolithic times to the Bronze Ages (from Xishan to Liuzhuang in Table 19). They display a relatively compact distribution of both $\delta^{13}C$ and $\delta^{15}N$ values on Figure 32, reflecting a consistent millet-based human diet with limited meat food over a time period of over 2000 years. This stable situation changed during the Eastern Zhou when human diet differed noticeably between the rural and urban areas. The two rural sites, Yangdi and Chenjiagou, still fall within the isotopic range of former locations; however, the urban site Xinzheng differentiates itself with lower $\delta^{13}C$ values, where the dietary influence of C3 foods became visible for the first time (see also Figure 18 in section 6.1). The shift toward C3 food intensified in the Han Dynasty, as demonstrated by the wide discrepancy between the $\delta^{13}C$ value of Xuecun and those of other sites. This is accompanied by an elevation in $\delta^{15}N$, which may have been a consequence of changed meat consumption (section 6.8). The substantial decline in $\delta^{13}C$ and noticeable increase in $\delta^{15}N$ make Xuecun the second most distinctive sites on the plains, after Jiahu.

After Late Neolithic times and the adoption of agricultural subsistence, human diets on the Central Plains remained stable for a very long time period without much apparent change in either staple food or meat consumption (see also Figure 18 in section 6.1 and Figure 19 in section 6.2). This would seem to reflect a conservative agricultural tradition that was not much affected by the introduction of a new crop, wheat, into northern China around 3000-2000 BC (Jin, 2007), as well as a relatively simple pattern of animal husbandry with no substantial changes for thousands of years. Against this background, the dietary change initiated in the urban Eastern Zhou and intensified during the Han Dynasty was not simply a short-term fluctuation in human diet. Rather, the dietary changes illustrated in this study mark the first substantial subsistence change in the area since Late Neolithic.

This significant dietary transition is only evident in the plains area. The mountainous region in the southwest of the plains shows a different history: the influence of the southern rice agricultural tradition was visible in human diets of the Late Neolithic site Gouwan (Fu et al., 2010). Furthermore, the presence of rice was still discernible during the Eastern Zhou and Han Dynasties, as reflected by the $\delta^{13}C$ discrepancy between Shenmingpu and contemporary sites on the plains (see Figure 24 and 26). A glance at $\delta^{13}C$ values of Gouwan and the two periods of Shenmingpu (Table 19) reveals an increase from -14.3‰ to -12.7‰ during the period from the Later Neolithic times to the Eastern Zhou, and then a sharp decline to -16.1‰ in the Han

Dynasty. Fluctuations in staple food compositions probably resulted from the shifting influences of the southern and northern agricultural traditions. In contrast, the mountains' consistently low $\delta^{15}N$ values imply very limited meat consumption without much change from the Neolithic times to the Han Dynasty. The trends in both $\delta^{13}C$ and $\delta^{15}N$ in the mountainous area are distinctive from those of the plains, demonstrating a geographical influence on agricultural traditions and consequently human diet. Given this, the mountainous sites must not be included in analyses of the plains area, even though they belong to the same province.

Although C3 resources in the Central Plains area gained popularity during the dietary shift from the Eastern Zhou to the Han Dynasty, this does not mean that they could quickly replace millet as the predominant grain in human diets. The isotopic data from Gu'an site (534-577 AD) indicates a decrease in the dietary proportion of C3 resources compared to that of Xuecun: the increased role of wheat in human diet was not yet fully established, and wheat's dietary importance fluctuated throughout the early centuries following the Han Dynasty. However, C3 resources *do* remain visible in Gu'an, and $\delta^{15}N$ values are very close to Xuecun and earlier sites. Both of these observations suggest that Han Dynasty dietary changes had lasting influence.

Later dynasties were influenced by significant dietary changes in many ways. These changes involved both passive adaptation and active change (section 6.8); the Han and following dynasties obviously benefited greatly from both changes. Dietary adaptive strategies were evidently successful, as seen in the population increases and stable human diets throughout the Han Dynasty. A comparative study on the mortality of ancient people on the Central Plains has revealed that mortality of young children, adolescents, and adults living in the Han and later dynasties was clearly lower than that of people predating the Qin Dynasty (Sun, 2013, pp.17-18). Although there is no evidence indicating that wheat is nutritionally superior to millet, sufficient animal meat in the diet would benefit general health by providing not only added protein but also more of several important vitamins and minerals (Bender, 1992). The correlation between lower mortality and dietary change allows us to see the profound influence of Han era dietary changes from a broader perspective. It has also inspired a follow-up study (to be completed in the near future) on the health conditions of the human remains analyzed in this study, which might tell us more about the direct effects of this dietary change on human health.

Millet, the predominant grain, indigenous to northern China, finally lost its place to the imported C3 grain wheat in some point after the sixth century AD (Zhou and Garvie-Lok, 2015). The beginning of this shift on the Central Plains was marked by dietary changes in the transformational period from the Eastern Zhou to the Han Dynasty. Long-term trends in human stable isotope values confirm that this dietary shift was the first major change in human consumption on the Central Plains since Late Neolithic times. Adaptive food strategies successfully relieved pressure from food scarcity during the Han Dynasty by adding wheat into human diets. Dietary changes shaped the following dynasties and may have improved human health by elevating animal protein intake for the first time in the agricultural history of ancient China.

7. Conclusion

Stable isotope studies of human and animal skeletal remains have gained momentum and become a mainstay in paleodietary studies over recent decades, as evidenced by the explosive increase in publications that use these methods (Pestle et al., 2014; Makarewicz and Sealy, 2015). This has resulted in a growing body of isotopic data that has provided valuable information on the history of human diet worldwide; these published data should never be ignored when interpreting newly generated data. In this study, for example, most of the nine topics discussed in chapter 6 benefited greatly from detailed comparisons with published data from over 20 other sites in China. Inter-laboratory variability in the results of SIA has been a topic of concern recently (Pestle et al., 2014). So, it is necessary to state here that except for a very few sites whose samples were analyzed in other facilities (Wang et al., 2012, 2014; Zhang XL et al., 2012; Wu et al., 2007), the majority of the cited studies of sites in China had their samples analyzed in the same laboratory (AESIL, CAAS, director Dr. Li Yuzhong), as did the current study. This laboratory applies consistent standards, and precision is always within the accepted range (± 0.2 ‰ for both $\delta^{13}C$ and $\delta^{15}N$). Accordingly, comparisons among different data groups from this laboratory are reliable, and the patterns reflected by inter-site variations are meaningful.

7.1 Expanding the Prospects of Stable Isotope Research in the Context of Published Data

Makarewicz and Sealy (2015) have recently called for efforts to expand the aspects of stable isotope research in archaeological studies. They suggest many new research prospects, all aimed at optimising the information that stable isotopes can provide. This study mainly focuses on the stable carbon and nitrogen isotopes that are most commonly used as dietary indicators. Along with dietary information about staple food composition and patterns of meat consumption, discussions in this study have shown that dietary isotopes are also able to provide valuable wide-scale information.

Chapter 6 covers a number of topics that are neither considered nor systematically investigated by most paleodietary studies based on stable carbon and nitrogen isotopes. These topics arise from contextual research on the Eastern Zhou and Han Dynasties, and the Chapter 6 discussion generates important implications for populations beyond the 172 human individuals and 14 animals from the five sites analyzed in this study. This paper draws conclusions such as the proposed bottom-up model of wheat's expansion into human diets, the dietary role of soybeans, gendered food behaviour in ancient Chinese agricultural societies, and the possibility of using dietary isotopes to study human migration, All of these insights are made possible by a detailed comparison with the large body of published isotopic data across China.

It would be fruitless to investigate the dietary significance of a specific crop, such as millet, wheat, or soybean, without knowing its role in human diets of ancient times. Fortunately, a comparison with existing isotopic data allows this study to create a timeline of human diets from the Middle Neolithic times to the sixth century AD. In addition, chronological comparisons of human collagen $\delta^{13}C$ values reveal the slow progress of wheat's expansion into northern Chinese diets in a typical bottom-up model. All of this evidence points to a conservative human dietary tradition and agricultural pattern from the Late Neolithic era. A similar comparison of human collagen $\delta^{15}N$ values casts doubts on long-held beliefs about the dietary roles of soybean in ancient China by revealing that despite the literary emphasis on this crop, it has never served as a primary protein staple. Additionally and unexpectedly, the chronological analysis of $\delta^{15}N$ values exposes a fundamental animal husbandry strategy that existed without substantial development for over 2000 years.

Nearly every study with relevant data discusses sex-related dietary differences, but these discussions are generally limited to individual sites and are usually very brief. In this paper, statistically significant sex differences are seen in only two of the four sites; however, when the data from the four sites are considered together, a unidirectional isotopic difference becomes visible. Females are always lower than males for both $\delta^{13}C$ and $\delta^{15}N$ values, even though some of the discrepancies are not statistically significant. This intriguing phenomenon is clarified further when the comparison based on isotopic data from all sites of the same era demonstrates that the unidirectional isotopic differences between males and females appear to be specific to agricultural groups. Such differences are thus very likely related to subsistence pattern and sexual divisions of labor in agricultural societies.

This study’s investigation of human diet and migration based on the context of published data is a first attempt, but it has produced exciting results. Human isotopic data from different sites dating to the Zhou and Han Dynasties are plotted together in order to observe regional dietary diversity from each of these two periods. Values display considerable diversity in human diets within each era, and the mean isotopic values and SD from different regions can be used to form a “dietary map” that mirrors this spatial diversity. Two populations with non-local dietary features become visible on the maps as possible immigrant communities. Archaeological and physical anthropological evidence reinforce these conclusions and demonstrate the potential of dietary stable isotope analysis in human migration research.

This study’s dietary maps also plot possible immigrants from each site. The three non-local individuals from Yangdi and Chenjiagou are more likely from the west or south, and their movement could be related to the wave of migration following the Eastern Zhou royal court's relocation to the east. On the Han Dynasty dietary map, two non-locals from Xuecun fall very close to a population of the northern steppe; physical anthropological evidence also supports the origin suggested by the chart. Xuecun's third non-local falls within the isotopic range of a population of peasants from a millet-growing area. Additionally, this study conducts a chronological comparison of human stable isotope values on the Central Plains. It reveals that the earliest agricultural population in this area is distinct from all of the later ones; this is consistent with recent archaeological evidence suggesting that this special group of people were immigrants from the rice-growing south.

Dietary isotopic data has proved invaluable in studies of ancient migration. Migration studies can use these methods to great effect and consider new approaches such as identifying entire groups as migrating populations, even though the approach of using distinctive diet to identify migrants traditionally focuses on individuals. Detailed comparisons to published data optimise each study's stable isotope values, and allow the prospects of stable isotope research to be expanded.

7.2 Significant Potential of SIA in Historical Contexts

Human dietary studies using stable isotope analysis are rare in historical China, probably because researchers assume that abundant textual records leave only limited space for new scholarship. However, a clear scenario of human diet in historical times cannot be illustrated using only biased literary documents and fragmentary archaeological evidence (as discussed in Chapter 2). Thus, this study uses history and archaeology as context to analyze stable isotope data for 172 human remains from four sites and 14 animals from one site. With this method, it has generated new insights into human diet in a key area during the profound transition from territorial state to centralized empire.

The Eastern Zhou dynasty experienced the fading of the royal court, state military competition, and five centuries of warfare. This history impacted human diet differently in urban and rural areas. In urban regions, people did not benefit much from prosperous trade and the handicraft industries in terms of diet; all classes had few animal resources. A high frequency of military attacks and high urban population likely caused food scarcity, which forced people of the lowest status to accept wheat as a supplementary staple food. In contrast, rural commoners cultivated their own land and were less affected. Their diet was millet-based and similar to that of earlier periods. The amount of meat in the rural diet was slightly higher than in the city, and rural communities likely lived better lives in this respect than urban residents during this chaotic period.

The Han Empire made the Central Plains almost warfare-free for about four centuries and was a time of development and prosperity. Wheat, initially eaten only by the poor in the Eastern Zhou, was widely incorporated into the diets of people of different statuses (despite evidence that it was still not regarded as equal to millet). This quick and substantial change may have been an adaptive strategy for a fast-growing population at the end of long-lasting chaos.

The dietary change from state to empire featured a substantial increase in the importance of wheat as well as a notable change in meat consumption: the isotopic data and literary records indicate that people of all classes had a relative abundance of meat to eat. This study reviews regional dietary isotopes since the Late Neolithic and demonstrates that this is the first major isotopically visible change in human diet on the Central Plains for millennia. A millet-based diet lasted for over 2000 years; meat consumption also apparently remained at a limited level during this long period. The change first appears in the Eastern Zhou when the urban poor eat a significant amount of wheat due to food scarcity. Wheat's influence on human diet on the plains becomes isotopically visible for the first time, marking the start of a dietary change that gains momentum during the Han Dynasty. When the dietary proportion of wheat is quickly elevated to almost equal that of millet, meat consumption also changes substantially for the first time in the long agricultural history of this region. The Han Dynasty thus sees profound reform in agricultural patterns as well as a jump in animal husbandry strategies, probably driven by government policy. Populations employed successful adaptive strategies in response to population-triggered food pressure and this shaped human dietary patterns thereafter. These changes may also have improved regional human health.

This study has solved several issues previously debated or ignored by text-based research. Stable isotope data illustrates a clear picture of wheat's introduction into human diet on the Central Plains through a bottom-up model. Text based scholarship demonstrates wheat's importance in the Han Dynasty, but isotopic evidence does not support its predominant role in human diets. The myths in the literature about soybeans have also been unravelled. Isotopic evidence suggests that soybean was never the staple food, not even for the poor, during Zhou or Han times; instead, it was likely a supplementary protein source or vegetable. Additionally, this study discovers that rural individuals in the Eastern Zhou ate better than urban residents, and that low-rank nobles had a similar diet to well-off commoners. These facts problematize the noble-commoner dietary dichotomy presented by historical documents.

Despite the abundant literary records of the Eastern Zhou and the Han Dynasty, isotopic analysis has provided new details on human diet and social transition. Stable isotope research has great potential in the study of ancient China: it has demonstrated the significance of dietary change during this period and provided a unique historical window.

7.3 Planned Work in the Future

This study's analyses have provided valuable information about the human dietary patterns during a period of social transition, but it also leaves much work to be done. The absence of Han era faunal samples makes it difficult to determine whether the substantial increase in human collagen $\delta^{15}N$ values from the Eastern Zhou to the Han era resulted from increased meat consumption or a change in meat eating patterns. Thus, a follow-up analysis of Han era faunal samples will be conducted when materials are available. Additionally, an increased wheat consumption in the urban Eastern Zhou area has been observed using the human bone collagen $\delta^{13}C$ values, which can only reflect substantial changes in main grain use. In the future, tooth samples from the same individuals for carbonate $\delta^{13}C$ values will be analyzed; this data can be compared with bone collagen $\delta^{13}C$ values to detect subtle grain use. Hopefully, this process will illustrate a much clearer scenario of wheat's expansion into ancient human diets on the Central Plains. This study has also investigated the potential of using dietary isotopes to study human migration. The possible immigrants, identified based on their distinctive dietary isotope values, will be further studied using dietary isotopes such as Sr and O in the future. This will assist in narrowing down their origins. Finally, this study suggests that the significant dietary changes discussed also affected human health conditions; this requires a detailed health study of the same human individuals analyzed here.

7.4 Social Transition and Human Diet

I conclude by referring back to the questions raised at the end of the introduction (Chapter 1), where it is asked whether this period of transition was an era of instability or development, and if its social changes brought about suffering or prosperity. As food and diet are directly related to the quality of human lives, the dietary patterns revealed in the current study give us some tentative answers.

Compared with the Central Plains populations that predated the Zhou Dynasty, human diets during the Zhou period were affected by constant warfare and instability. It was during this time that the regional millet-based diet changed for the first time in millennia. The dietary change was intensified during the Han Dynasty, involving both passive adaptive strategies and active change. However, population increases and prosperity in the Han Empire, as well as improved health conditions in the Han Dynasty and thereafter, all indicate that both society and individuals benefited greatly from these changes.

Human diet and agricultural patterns on the Central Plains were highly conservative for over 2000 years before the Eastern Zhou: chaos and suffering triggered the first significant dietary change. Just as the social transition from state to empire brought about stability and prosperity, dietary changes during this transformative period were successful and of profound influence, echoing positive socioeconomic changes from a parallel perspective.

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Appendices

Appendix 1: Detailed information for animal samples from Tianli site

Sample no.	Species	δ13C (‰)	δ15N (‰)	C%	N%	C/N	Yield
TL- M47	pig	-13.9	5.3	39.8	14.5	3.2	5.7%
TL- M49	pig	-7.9	7.7	40.1	14.7	3.2	5.0%
TL- M46	pig	-14.4	6.1	40.5	14.6	3.2	8.3%
TL- M8	pig	-13.5	6.2	39.9	14.4	3.2	2.9%
TL- M56	dog	-9.4	7.3	40.9	14.8	3.2	5.7%
TL- M142	cattle	-6.8	7.6	41.4	15.1	3.2	17.4%
TL- M152	cattle	-10.4	7.7	41.5	15.3	3.2	5.6%
TL- M128	cattle	-11.2	7.1	41.8	15.2	3.2	14.1%
TL- M142	sheep	-16.6	7.9	41.3	15.0	3.2	2.4%
TL- M128	sheep	-14.0	10.7	41.7	15.2	3.2	11.8%
TL- M55	sheep	-14.9	8.6	41.2	15.1	3.2	9.0%
TL- M165	sheep	-18.6	9.9	41.6	15.1	3.2	12.6%
TL- M142	sheep	-17.0	6.6	41.7	15.3	3.2	9.7%
TL- M152	sheep	-13.1	10.2	41.1	15.1	3.2	11.6%

NOTE: TL is short for the Tianli Food Factory cemetery; M (e.g. M47) indicates the specific burial number at the site.

Appendix 2: Detailed information for human samples from Yangdi Site

Sample no.	Sex	Age	Funeral objects	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C%	N%	C/N	Yield
YY-M5	F	Adult	shells	-18.4	10.8	36.8	13.4	3.2	2.0%
YY-M6	M	Adult	shells	-19.0	10.6	40.1	14.7	3.2	3.7%
YY-M7	M	Adult	shells	-8.2	8.5	40.3	14.6	3.2	6.2%
YY-M8	F	Adult	none	-8.1	7.4	40.5	14.9	3.2	14.0%
YY-M9	M	Adult	shells	-9.1	8.7	40.5	14.9	3.2	6.7%

NOTE: YY stands for Yuzhou Yangdi site; M (e.g. M5) stands for the tomb number at the site

Appendix 3: Detailed information for human samples from Chenjiagou site

Sample no.	Sex	Age	Funeral objects	Coffin	δ^{13}C (‰)	δ^{15}N (‰)	C%	N%	C/N	Yield
WC-M1	?	12-15	none	none	-12.7	8.2	40.7	14.8	3.2	4.7%
WC-M3	?	?	pottery	single	-8.7	9.7	39.2	14.3	3.2	2.1%
WC-M5	?	＜15	none	single	-11.1	8.5	40.2	14.7	3.2	8.3%
WC-M6	M	31-34	none	none	-10.6	9.7	40.0	14.4	3.2	3.5%
WC-M7	?	＜10	none	none	-9.4	7.9	41.2	15.0	3.2	5.8%
WC-M8	?	50±	pottery	single	-9.3	9.1	40.6	14.1	3.4	2.9%
WC-M9	?	10	none	none	-9.7	8.4	40.6	14.7	3.2	6.0%
WC-M10	?	12-15	pottery	none	-8.2	8.9	39.5	14.3	3.2	4.7%
WC-M13	?	＞60	Pottery jade	single	-9.8	8.1	40.5	14.7	3.2	3.2%
WC-M14	M	40-45	pottery	none	-8.9	9.5	38.3	13.8	3.2	2.5%
WC-M15	?	11-12	none	none	-9.3	8.6	27.4	9.8	3.3	4.0%
WC-M17	M	60±	pottery	single	-8.9	8.8	41.4	15.1	3.2	13.8%
WC-M18	F	50-55	pottery	single	-9.2	7.6	39.0	14.1	3.2	5.2%
WC-M20	F	35-40	none	none	-11.6	10.0	38.8	14.1	3.2	1.4%
WC-M23	M	20±	none	single	-8.5	9.0	40.7	14.7	3.2	5.4%
WC-M26	M	50±	pottery	single	-8.9	9.9	41.1	15.0	3.2	8.6%
WC-M27	?	45±	pottery	single	-9.6	9.3	40.6	14.7	3.2	8.4%
WC-M28	M	40±	none	single	-9.1	8.3	39.7	14.5	3.2	4.2%
WC-M31	M	50±	none	none	-9.8	8.6	40.8	14.9	3.2	11.0%
WC-M38	F	adult	stone	double	-9.4	8.7	38.0	13.9	3.2	3.5%
WC-M39	M?	30-35	jade	single	-8.7	9.7	41.0	15.0	3.2	9.5%

Sample no.	Sex	Age	Funeral objects	Coffin	δ^{13}C (‰)	δ^{15}N (‰)	C%	N%	C/N	Yield
WC-M40	M	45±	pottery	single	-8.9	10.0	40.3	14.7	3.2	11.6%
WC-M41	M	45±	none	single	-8.7	8.9	40.6	14.8	3.2	4.4%
WC-M42	?	adult	none	single	-8.5	10.3	40.8	14.8	3.2	8.9%
WC-M44	F	30-35	none	double	-11.1	9.3	40.4	14.7	3.2	6.8%
WC-M45	M	55-60	pottery	single	-9.2	10.1	40.8	14.9	3.2	7.6%
WC-M46	?	adult	jade	single	-8.0	9.9	40.6	14.8	3.2	5.8%
WC-M48	M	＞35	none	none	-8.1	10.2	40.5	14.8	3.2	7.5%
WC-M50	M	50±	pottery	double	-9.4	10.0	41.0	15.0	3.2	6.0%
WC-M51	M	50-55	pottery	double	-10.6	9.0	39.1	14.2	3.2	6.3%
WC-M52	?	adult	none	single	-16.2	9.0	41.8	15.3	3.2	20.5%
WC-M62	M	45±	pottery	single	-8.3	10.3	40.4	14.7	3.2	10.2%
WC-M71	?	adult	none	single	-9.4	8.4	40.4	14.7	3.2	3.3%
WC-M73	M	51-60	pottery	single	-9.5	10.6	40.6	14.8	3.2	4.2%
WC-M79	?	adult	jade	none	-9.4	8.1	41.0	14.9	3.2	4.7%
WC-M86	?	50-55	pottery jade	single	-10.3	9.5	37.3	13.4	3.2	3.1%
WC-M90	M	60±	pottery	single	-10.6	9.7	41.2	15.1	3.2	7.5%
WC-M102	?	adult	pottery	double	-9.6	9.4	40.8	15.1	3.2	7.4%
WC-M108	?	adult	pottery	single	-10.2	8.9	40.9	14.9	3.2	7.5%

NOTE:

1. **WC stands for Wenxian Chenjiagou site, M (e.g. M1) refers to specific burial number.**
2. **In the Coffin column, “single” and “double” refer to the layers of coffin.**

Appendix 4: Detailed information for human remains from ancient Xinzheng city

Sample no.	Sex	Age	Funeral objects	Phase	Coffin	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C%	N%	C/N	Yield
TP-M5	M	20-24	p	3	s	-11.4	9.4	41.7	15.2	3.2	19.4%
TP-M23	F	35-39	p	1	s	-10.3	8.8	41.0	15.0	3.2	17.2%
TP-M24	F	30-34	p	2	s	-12.7	7.0	42.2	15.3	3.2	3.0%
TP-M27	F	adult	p+r+j	3	d	-13.2	7.7	41.5	15.0	3.2	17.6%
TP-M35	F	adult	p	1	s	-10.0	7.5	41.1	15.0	3.2	14.6%
TP-M36	F	young adult	n	n	s	-9.4	9.3	41.0	15.1	3.2	13.3%
TP-M40	M	35-39	r	2	s	-10.2	9.2	41.1	15.0	3.2	18.0%
TP-M48	F	30-34	p+j	2	d	-10.6	8.7	40.3	14.8	3.2	21.2%
TP-M55	F	adult	p+j	2	d	-11.5	8.4	41.6	15.1	3.2	13.1%
TP-M56	M	40-49	p	3	d	-11.3	7.9	42.0	15.2	3.2	17.0%
TP-M58	F	35-44	n	n	s	-12.0	8.1	40.8	14.8	3.2	6.1%
XH-M1	F	35-39	p+j	2	d	-11.1	8.6	39.1	14.0	3.3	6.2%
XH-M3	F	30-34	p+j	3	s	-12.0	9.0	40.7	14.8	3.2	16.0%
XH-M4	F	60+	p	1	d	-10.5	9.5	41.4	15.0	3.2	11.6%
XH-M6	F	40-44	p	1	s	-11.0	7.6	32.8	11.4	3.4	1.4%
XH-M11	M	35-39	p+w	2	s	-9.3	10.2	40.7	14.7	3.2	9.6%
XH-M18	F	35-39	p	1	s	-11.1	8.0	41.0	14.7	3.3	10.2%
XH-M19	M	35-39	r+w	3	d	-11.1	9.4	41.1	14.9	3.2	12.0%
XH-M21	F	30-34	p	2	s	-10.9	8.2	41.7	15.1	3.2	14.6%
XH-M22	F	adult	p	2	s	-9.7	8.1	40.7	14.7	3.2	9.7%
XH-M25	F	35-45	p	1	s	-8.9	8.3	40.6	14.8	3.2	12.8%
XH-M28	M	30-34	p	2	s	-10.7	8.7	41.2	15.0	3.2	13.6%

Sample no.	Sex	Age	Funeral objects	Phase	Coffin	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C%	N%	C/N	Yield
XH-M29	F	25-29	p	2	s	-10.3	9.1	41.4	14.9	3.2	12.1%
XH-M30	F	40-44	p	3	d	-10.0	9.9	41.4	15.0	3.2	16.5%
XH-M31	F	35-39	p	2	s	-10.8	8.7	41.2	14.9	3.2	10.1%
XH-M35	F	35-39	r	2	t	-10.5	9.8	40.2	14.5	3.2	4.6%
XH-M36	M	45+	shell knife	n	d	-9.9	8.1	40.7	14.9	3.2	9.0%
XH-M39	M	adult	p	2	s	-10.4	8.8	40.5	14.7	3.2	8.6%
XH-M41	M	adult	p	2	s	-10.0	9.7	40.3	14.6	3.2	9.9%
XH-M45	F	adult	p	3	s	-12.8	8.1	39.7	14.3	3.3	6.0%
XH-M46	F	50-59	p	3	s	-14.4	8.5	39.5	13.8	3.4	1.1%
XH-M48	F	35-39	n	n	n	-12.3	8.7	40.5	14.8	3.2	6.8%
XH-M51	?	adult	p	2	d	-11.8	8.9	39.0	14.1	3.2	3.2%
XH-M52	M	40-44	p	2	d	-9.2	9.1	40.5	14.7	3.2	6.7%
XH-M53	F	45-49	p	2	d	-12.1	8.0	40.7	14.8	3.2	17.2%
XH-M54	F	old adult	p	3	d	-12.5	8.7	39.9	14.4	3.2	15.4%
XH-M55	F	50-59	p	1	s	-8.9	9.1	40.7	14.8	3.2	15.1%
XH-M56	F	40-44	p	2	s	-10.1	8.2	23.2	8.1	3.4	3.6%
XH-M57	F	40-44	p	3	s	-11.5	8.5	41.5	15.0	3.2	11.4%
XH-M59	M	40-44	n	n	s	-9.2	10.1	40.7	14.8	3.2	14.7%
XH-M60	F	50-59	p	2	s	-11.4	8.9	39.3	14.2	3.2	5.2%
XH-M63	F	50-59	p	2	s	-10.4	8.7	40.9	14.8	3.2	16.2%
XH-M64	F	40-44	p+j	2	s	-9.5	9.5	41.1	14.8	3.3	11.9%
XH-M69	M	40-44	r	3	s	-9.5	9.0	40.6	14.7	3.2	10.0%
XH-M71	F	40-44	p	3	s	-11.9	8.3	41.3	14.9	3.2	12.3%

Sample no.	Sex	Age	Funeral objects	Phase	Coffin	δ^{13}C (‰)	δ^{15}N (‰)	C%	N%	C/N	Yield
XH-M73	M	45-49	p	3	n	-13.1	8.6	40.4	14.7	3.2	10.9%
XH-M80	M	35-39	n	n	s	-11.2	9.4	39.8	14.5	3.2	8.0%
XH-M83	F	50+	n	n	s	-13.6	8.4	39.2	14.2	3.2	13.7%
XH-M87	M	35-39	n	n	n	-15.6	7.5	38.5	14.0	3.2	8.0%
XH-M89	F	40-49	n	n	n	-15.4	8.4	39.7	14.3	3.2	7.7%
XH-M90	F	40-44	other	n	s	-12.2	8.2	40.7	14.8	3.2	10.0%
XH-M92	?	adult	p	2	s	-11.5	9.0	40.6	14.7	3.2	11.9%
XH-M93	F	35-39	p	n	n	-9.1	10.3	41.1	14.9	3.2	12.9%
XH-M98	F	60+	n	n	s	-10.4	9.0	40.9	14.8	3.2	16.0%
XH-M103	M	adult	p	2	s	-9.0	10.0	40.5	14.6	3.2	13.5%
XH-M104	F	45-49	p+j	1	s	-10.4	8.9	39.9	14.5	3.2	5.8%
XH-M112	M	40-44	p	2	s	-9.3	9.3	41.1	15.0	3.2	12.5%
XH-M113	F	50-59	p	3	s	-11.0	8.0	40.7	14.8	3.2	9.3%
XH-M115	?	young adult	n	n	s	-11.8	8.3	40.3	14.7	3.2	9.0%
XH-M116	?	adult	n	n	n	-15.7	8.8	38.0	13.7	3.2	5.0%
XH-M117	M	25-29	n	n	n	-13.8	7.3	39.8	14.5	3.2	10.7%
XH-M122	?	?	p+j	n	d	-8.5	9.9	40.7	14.7	3.2	10.4%
XH-M123	M	35-44	p	2	d	-8.0	10.0	40.9	14.8	3.2	11.8%
XH-M125	M?	40-44	p	2	d	-10.0	9.6	41.0	14.9	3.2	12.1%
XH-M126	M	45-49	p	2	s	-10.3	9.4	40.4	14.7	3.2	9.1%
XH-M127	M	40+	p	2	s	-10.1	8.2	40.0	14.4	3.3	1.7%
XH-M128	?	adult	p	1	s	-11.2	8.8	40.8	14.9	3.2	12.1%
XH-M133	F	30-34	p	2	d	-11.7	7.7	40.8	14.8	3.2	6.5%

Sample no.	Sex	Age	Funeral objects	Phase	Coffin	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C%	N%	C/N	Yield
XH-M136	F	40-44	r	n	s	-10.9	8.8	40.7	14.6	3.2	8.5%
XH-M137	F	40-44	r	n	s	-10.0	9.1	41.1	15.1	3.2	9.0%
XH-M140	M	40-44	p	2	s	-10.1	10.4	39.9	14.4	3.2	4.3%
XH-M145	F	40-44	p	3	s	-10.8	8.2	41.5	15.1	3.2	10.8%
XH-M149	F	35-39	r	n	d	-12.4	8.3	41.4	15.2	3.2	11.5%
XH-M150	F	25-29	r	n	s	-12.5	7.2	41.1	15.0	3.2	11.9%
XH-M152	M	adult	p	3	s	-9.5	9.8	40.9	15.0	3.2	13.9%

Notes:

1. **Sample no.:** TP is short for Thermal Power Plant, XH for Xinghong Gardern, and M (e.g. M5) stands for the specific burial number at the site.
2. **Funeral objects:** “p” is short for pottery, “j” for jade, w for weapon, “r” for ritual vessels (bronze or imitation), and “n” for none.
3. **Phase 1, 2, and 3** are new divisions based on the original chronology in the report; see section 4.1.3 for explanation. “N” is short for "not sure"
4. **Coffin:** “s” is short for single layer, “d” for double, “t” for triple, “n” for non

Appendix 5: Detailed information for human remains from Xuecun Site

Sample no.	Sex	Age	Tomb structure	Funeral objects	Phase	District	δ^{13}C (‰)	δ15N (‰)	C%	N%	C/N	Yield
XC1-M11:E	F	30-34	b-4	p+m+f	2	A	-13.2	10.4	39.3	14.2	3.2	1.9%
XC1-M11:B	M?	adult	b-4	p+m+f	2	A	-13.5	10.0	41.7	15.0	3.2	14.7%
XC1-M15	?	adult	b-3	p+m+f	2	A	-8.8	9.6	41.0	15.0	3.2	16.4%
XC1-M17: E	M?	young adult	b-4	p+w	1	A	-12.5	12.1	8.1	2.9	3.2	5.8%
XC1-M20	?	adult	b-4	p+w	2	A	-14.2	15.9	40.2	14.6	3.2	8.2%
XC1-M25: W	M	adult	b-2	p+w	1	A	-14.1	11.8	40.6	14.9	3.2	4.7%
XC1-M29: S	M?	40-44	b	p+w+m+f	2	A	-12.5	9.4	41.4	15.2	3.2	13.4%
XC1-M57	?	adult	e	p+w	1	A	-13.8	11.5	41.1	15.2	3.2	10.8%
XC1-M59	M	young adult	e	p	2	A	-15.1	8.8	39.4	14.5	3.2	4.4%
XC1-M63	?	adult	b	p+w	2	A	-13.6	10.8	40.3	14.9	3.2	7.3%
XC1-M76: W	M	old adult	b	p	2	A	-13.1	10.0	40.0	14.6	3.2	3.2%
XC2-M5:1	M	adult	b-2	p	2	C	-13.6	10.1	41.3	15.1	3.2	9.9%
XC2-M5:2	M	25-29	b-2	p	2	C	-13.0	10.6	41.0	15.0	3.2	10.4%
XC2-M5:3S	M	35-39	b-2	p	2	C	-13.3	10.6	40.4	14.8	3.2	3.8%

Sample no.	**Sex**	**Age**	**Tomb structure**	**Funeral objects**	**Phase**	**District**	**$\delta^{13}C$ (‰)**	**δ15N (‰)**	**C%**	**N%**	**C/N**	**Yield**
XC2-M5:4S	M	young adult	b-2	p	2	C	-14.2	10.4	40.7	14.9	3.2	4.7%
XC2-M11	F?	adult	e	p	2	C	-16.1	11.1	41.2	14.8	3.2	10.3%
XC2-M17	M	adult	e	none	n	C	-14.3	10.1	40.3	14.7	3.2	9.2%
XC2-M43:R	F	adult	e	p	2	C	-15.4	9.4	39.0	14.2	3.2	4.3%
XC2-M50:L	?	9.5+	e	p	2	C	-13.4	11.0	40.3	14.8	3.2	9.4%
XC2-M50:R	M	35-45	e	p	2	C	-12.9	14.0	39.9	14.5	3.2	5.4%
XC2-M80:L	M	50-59	e	p	2	C	-12.2	10.7	41.0	15.1	3.2	11.9%
XC2-M80: R	F	old adult	e	p	2	C	-12.3	13.5	40.5	14.5	3.3	10.1%
XC2-M134	F	adult	e	p	2	C	-13.5	10.3	41.0	15.0	3.2	13.6%
XC2-M168	M	25-29	b	p	1	C	-13.6	10.7	40.6	14.9	3.2	7.4%
XC2-M206: N	?	adult	b-3	p+m+f	2	B	-12.2	9.8	40.3	14.8	3.2	5.4%
XC2-M206:S	F	35-39	b-3	p+m+f	2	B	-14.3	9.2	41.2	14.9	3.2	9.3%
XC2-M217	M	adult	e	other	1	C	-13.2	11.3	39.5	14.4	3.2	6.7%
XC2-M281: E	M	adult	b-3	p+w+m+f	2	B	-12.7	9.6	40.7	15.0	3.2	11.3%
XC2-M281: BE	F	adult	b-3	p+w+m+f	2	B	-13.1	9.7	40.6	14.8	3.2	14.6%

Sample no.	Sex	Age	Tomb structure	Funeral objects	Phase	District	$\delta^{13}C$ (‰)	δ15N (‰)	C%	N%	C/N	Yield
XC2-M281: BW	M	40-44	b-3	p+w+m+f	2	B	-13.4	12.4	38.2	13.7	3.3	3.0%
XC3-M1	M	45-59	b-3	p	2	A	-14.6	10.5	41.3	15.1	3.2	14.7%
XC3-M14	?	adult	e	p	2	A	-14.9	9.4	37.4	13.6	3.2	14.8%
XC4-M1	F	25-29	b	p	2	C	-14.1	9.7	41.0	15.1	3.2	9.5%
XC4-M3: E	F	30-34	e	p	2	C	-13.9	10.7	40.3	14.6	3.2	1.6%
XC4-M10: N	M	30-34	e	p+w	2	C	-13.5	10.1	40.8	15.0	3.2	7.1%
XC4-M10: S	M	adult	e	p+w	2	C	-15.1	9.5	41.1	14.9	3.2	7.8%
XC4-M45	?	adult	e	p	1	C	-15.2	9.3	41.5	15.2	3.2	11.8%
XC4-M56: N1	M	adult	e-2	p	2	B	-13.4	11.8	40.9	14.7	3.2	1.9%
XC4-M56: N2	F	adult	e-2	p	2	B	-14.3	10.8	41.0	15.0	3.2	8.9%
XC4-M59	M	40-44	e	p	1	C	-13.1	10.8	40.6	14.9	3.2	11.4%
XC4-M62	?	adult	b-4	p+w	2	B	-13.1	9.9	41.2	15.1	3.2	5.9%
XC4-M66	?	adult	e	p	2	B	-13.1	11.3	39.7	14.5	3.2	5.4%
XC4-M74	?	adult	e	none	n	C	-14.3	9.9	39.9	14.4	3.2	7.4%
XC4-M84	M	adult	e	p+m+f+w	2	B	-15.9	10.4	40.5	14.7	3.2	3.6%
XC4-M91	?	child	b	p+w	1	C	-14.2	10.4	40.6	14.8	3.2	7.7%

Sample no.	Sex	Age	Tomb structure	Funeral objects	Phase	District	$\delta^{13}C$ (‰)	δ15N (‰)	C%	N%	C/N	Yield
XC4-M92	F	adult	e	p	1	C	-13.9	10.1	40.5	14.8	3.2	8.2%
XC4-M96	M	35-45	e	p	1	C	-13.9	9.3	40.9	15.1	3.2	10.0%
XC4-M99	M	young adult	e	p+w	2	C	-14.1	10.0	41.5	15.3	3.2	12.4%
XC4-M100	?	adult	e	p	1	C	-12.7	11.7	40.6	14.8	3.2	6.5%
XC4-M108	?	adult	e	p	1	C	-12.6	9.3	38.2	13.9	3.2	6.3%
XC4-M111: W	M	35-44	e	p+w	1	C	-14.0	10.7	39.5	14.3	3.2	3.1%
XC4-M111: E	F	adult	e	p+w	1	C	-15.0	10.4	40.8	15.0	3.2	16.8%
XC4-M114	F	adult	e	p	1	C	-15.5	10.6	40.7	14.8	3.2	10.4%

Note:

1. **Sample no.:** XC1 refers to Xuecun site region 1, M (e.g. M11) is the specific burial number. The following letter or number represents a specific individual in multiple burials.
2. **Tomb structure**: “e” is short for earthen pit, “b” for brick chamber, followed by the number of chambers if more than one.
3. **Funeral objects**: “p” for pottery, “w” for weapon, “m” for models, “f” for figurine
4. **Phase:** the division is based on original typological sequence, see section 4.1.4. “N” is short for "not sure".
5. **District:** see Figure 5 for this internal division**.**

Appendix 6. Standardized $\delta^{13}C$ and $\delta^{15}N$ values of males and females from the four sites.

Males Sample No.	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)	Females Sample No.	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
YY-M6	-6.5	1.4	YY-M5	-5.9	1.6
YY-M7	4.3	-0.7	YY-M8	4.4	-1.8
YY-M9	3.5	-0.5	WC-M18	0.5	-1.6
WC-M48	1.6	1.0	WC-M38	0.3	-0.5
WC-M62	1.4	1.1	WC-M44	-1.4	0.1
WC-M23	1.2	-0.2	WC-M20	-1.9	0.8
WC-M39	1.0	0.5	TP-M23	0.7	0.0
WC-M41	1.0	-0.3	TP-M24	-1.7	-1.8
WC-M17	0.8	-0.4	TP-M27	-2.2	-1.1
WC-M26	0.8	0.7	TP-M35	1.0	-1.3
WC-M40	0.8	0.8	TP-M36	1.6	0.5
WC-M14	0.8	0.3	TP-M48	0.4	-0.1
WC-M28	0.6	-0.9	TP-M55	-0.5	-0.4
WC-M45	0.5	0.9	TP-M58	-1.0	-0.7
WC-M50	0.3	0.8	XH-M1	-0.1	-0.2
WC-M73	0.2	1.4	XH-M3	-1.0	0.2
WC-M31	-0.1	-0.6	XH-M4	0.5	0.7
WC-M51	-0.9	-0.2	XH-M6	0.0	-1.2
WC-M6	-0.9	0.5	XH-M18	-0.1	-0.8
WC-M90	-0.9	0.5	XH-M21	0.1	-0.6
TP-M5	-0.4	0.6	XH-M22	1.3	-0.7
TP-M40	0.8	0.4	XH-M25	2.1	-0.5
TP-M56	-0.3	-0.9	XH-M29	0.7	0.3
XH-M11	1.7	1.4	XH-M30	1.0	1.1
XH-M19	-0.1	0.6	XH-M31	0.2	-0.1
XH-M28	0.3	-0.1	XH-M35	0.5	1.0
XH-M36	1.1	-0.7	XH-M45	-1.8	-0.7

Males Sample No.	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)	Females Sample No.	$\delta^{13}C$(‰)	$\delta^{15}N$(‰)
XH-M39	0.6	0.0	XH-M46	-3.4	-0.3
XH-M41	1.0	0.9	XH-M48	-1.3	-0.1
XH-M52	1.8	0.3	XH-M53	-1.1	-0.8
XH-M59	1.8	1.3	XH-M54	-1.5	-0.1
XH-M69	1.5	0.2	XH-M55	2.1	0.3
XH-M73	-2.1	-0.2	XH-M56	0.9	-0.6
XH-M80	-0.2	0.6	XH-M57	-0.5	-0.3
XH-M87	-4.6	-1.3	XH-M60	-0.4	0.1
XH-M103	2.0	1.2	XH-M63	0.6	-0.1
XH-M112	1.7	0.5	XH-M64	1.5	0.7
XH-M117	-2.8	-1.5	XH-M71	-0.9	-0.5
XH-M123	3.0	1.2	XH-M83	-2.6	-0.4
XH-M125	1.0	0.8	XH-M89	-4.4	-0.4
XH-M126	0.7	0.6	XH-M90	-1.2	-0.6
XH-M127	0.9	-0.6	XH-M93	1.9	1.5
XH-M140	0.9	1.6	XH-M98	0.6	0.2
XH-M152	1.5	1.0	XH-M104	0.6	0.1
XC1-M59	-1.4	-1.8	XH-M113	0.0	-0.8
XC4-M96	-0.2	-1.3	XH-M133	-0.7	-1.1
XC1-M29: S	1.2	-1.2	XH-M136	0.1	0.0
XC4-M10: S	-1.4	-1.1	XH-M137	1.0	0.3
XC2-M281: ER	1.0	-1.0	XH-M145	0.2	-0.6
XC1-M76: W	0.6	-0.6	XH-M149	-1.4	-0.5
XC4-M99	-0.4	-0.6	XH-M150	-1.5	-1.6
XC1-M11:B	0.2	-0.6	XC2-M206:S	-0.6	-1.4
XC2-M5:1	0.1	-0.5	XC2-M43:R	-1.7	-1.2
XC2-M17	-0.6	-0.5	XC2-M281: BE	0.6	-0.9
XC4-M10: N	0.2	-0.5	XC4-M1	-0.4	-0.9

Males Sample No.	**$\delta^{13}C$(‰)**	**$\delta^{15}N$(‰)**	**Females Sample No.**	**$\delta^{13}C$(‰)**	**$\delta^{15}N$(‰)**
XC4-M84	-2.2	-0.2	XC4-M92	-0.2	-0.5
XC2-M5:4S	-0.5	-0.2	XC2-M134	0.2	-0.3
XC3-M1	-0.9	-0.1	XC4-M111: E	-1.3	-0.2
XC2-M5:3S	0.4	0.0	XC1-M11:E	0.5	-0.2
XC2-M5:2	0.7	0.0	XC4-M114	-1.8	0.0
XC2-M168	0.1	0.1	XC4-M3: E	-0.2	0.1
XC4-M111: W	-0.3	0.1	XC4-M56: N2	-0.6	0.2
XC2-M80:L	1.5	0.1	XC2-M11	-2.4	0.5
XC4-M59	0.6	0.2	XC2-M80: R	1.4	2.9
XC2-M217	0.5	0.7			
XC1-M25: W	-0.4	1.2			
XC4-M56: N1	0.3	1.2			
XC1-M17: E	1.2	1.5			
XC2-M281: BW	0.3	1.8			
XC2-M50:R	0.8	3.4			

Note:

1. The standardized value is obtained by subtracting the average $\delta^{13}C$ or $\delta^{15}N$ values of the site from the individual value.

2. Possible males (M?) or females (F?) are included into males and females respectively

3. YY refers to Yangdi site; WC refers to Chenjiagou site; XH and TP refer to the two cemeteries inside Ancient Xinzheng City; XC refers to Xuecun site.