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Isotopic Results Reveal Possible Links between Diet and Social Status in Late Shang Dynasty (ca. 1250–1046 BC) Tombs at Xiaohucun, China

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Abstract: Here, we present evidence of possible links between diet and social status using carbon and nitrogen stable isotope ratios at the site of Xiaohucun in the Central Plains, China. This pilot study from a rescue excavation yielded humans ($n = 12$) identified to the late Shang Dynasty (ca. 1250–1046 BC), which was a warm climatic period. The population consumed a predominately C_4 diet (millets) and no difference was observed between the $\delta^{13}C$ results of individuals ($n = 7$) buried with ($-9.1 \pm 2.8\text{‰}$) and without ($n = 5$) bronze vessels ($-8.2 \pm 0.7\text{‰}$). However, individuals buried with bronze vessels ($10.3 \pm 1.6\text{‰}$) were found to have significantly higher $\delta^{15}N$ values (one-way ANOVA; $p = 0.015$) compared to individuals buried without bronze vessels ($8.0 \pm 0.9\text{‰}$), providing evidence that possible elite members consumed more animal protein (dog, pig, cow, sheep/goat). Isotopic results were also examined for social status in relation to the number of burial coffins that an individual had: double ($n = 6$), single ($n = 3$), or no coffin ($n = 3$). No difference was found in the $\delta^{13}C$ values, but variations were observed in the $\delta^{15}N$ values: double coffin ($10.2 \pm 1.7\text{‰}$) > single coffin ($8.8 \pm 1.8\text{‰}$) > no coffin ($8.0 \pm 1.3\text{‰}$), again possibly showing increased animal protein consumption linked to social status. Finally, isotopic results and status were studied by looking at the number of coffins and tomb size. Again, no correlation was observed for the $\delta^{13}C$ results, but a strong linear correlation ($R^2 = 0.85$) was observed for the $\delta^{15}N$ values of the individuals buried in two coffins vs. tomb size.

Keywords: human diet; hierarchy; bronze age; carbon and nitrogen stable isotope ratios

1. Introduction

Ancient China was a complex and highly socially stratified society [1–4]. Vast disparities existed between the nobility and the common people in areas such as rights, ownerships, diet, customs, behavior etc. These differences were chronicled in various historical works such as: Li Ji “礼记” which described how criminal law did not apply to senior officials and that etiquette did not apply to common people [5]. This social hierarchy of the living was also extended to the treatment of the dead, and the phrase: “Honor the dead as the living”, recorded by Xun Zi “荀子”, was and still is an important concept that is intertwined through the fabric of Chinese society [6,7]. Social status could also be maintained in the afterlife by the size and the scale of the tomb, and the quantity and quality of the grave goods interred with an individual [8–12].

Stable isotope ratio analysis has been successfully applied to examine dietary patterns in past populations from many societies across the globe [13–24]. Isotopic results of bone collagen primarily reflect the protein component of the diet averaged over the entire lifetime of an individual, including a large

portion of collagen synthesized during later childhood and adolescence [25,26]. Briefly, stable isotope ratios are defined as the ratio of the heavier to the lighter isotope (e.g., $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$) and are compared in terms of δ values in parts per 1000 or “per mil” (‰) in relation to internationally defined standards for carbon (Vienna Pee Dee Belemnite, VPDB) and nitrogen (ambient inhalable reservoir, AIR) [27]. In Chinese archaeological research, $\delta^{13}\text{C}$ measurements of human and animal collagen allow for an examination of the contribution of C_3 (rice, wheat, barley etc.) and C_4 foods (millets) to the diet. These studies have been vital for the reconstruction of a coarse time scale for the spread of different forms of agriculture in China [28–35] and for understanding animal husbandry practices [36–39]. The $\delta^{15}\text{N}$ results can be used as an estimation of the trophic level of a human or animal in a foodweb and are based on the observation of an increase of about 3‰–5‰ from the food to the consumer tissue [14,40,41]. Thus, levels of animal protein consumption can be examined with nitrogen isotope ratios. Modern human studies have found higher $\delta^{15}\text{N}$ values in omnivores compared to vegetarians and vegans [42,43]. However, an in-depth discussion on the intricacies of stable isotope ratios to reconstruct past diets is beyond the focus of this paper and the reader should consult the reviews of Katzenberg [44], Ambrose and Krigbaum [45], and Lee-Throp [46].

Increasingly, this technique is used to directly document dietary differences between social classes, e.g., elites vs. common people [47–52], and the reader is directed to consult Twiss [53] for a review of food and social diversity in archaeological and isotopic research. However, relatively little research has focused on the use of stable isotope ratios to directly determine dietary differences related to social status in China [54–58]. It is widely accepted that the Shang Dynasty (1600–1046 BC) is an early Chinese era based on abundant written records and the rich archaeological evidence [59–64]. Thus, this period is an extremely important phase in the development of the earliest Chinese civilization, and the formation of the ritual systems of power, class, and hierarchy [3]. Here, we present results of a small pilot study that examines dietary patterns related to social status for burials that date to the late Shang Dynasty (ca. 1250–1046 BC). Humans ($n = 12$) from the site of Xiaohucun and animals ($n = 11$) from the nearby contemporaneous site of Guandimiao in Henan Province were available for study due to a rescue excavation. The results of this research will be the focus of this work [65].

2. Background of Ritual Systems in Ancient China

China has a long and vibrant tradition of organized rituals and hierarchy, and this is especially evident for dining practices as well as the type of food consumed [66–70]. A separate system of dining was very popular for the elite members of society. At dinner, individuals knelt next to an Aiji “案几” (a kind of little table) and a selection of tableware was placed next to each person for holding cereals, meat, water, beverages, and liquor. The type, quality, and number of the dishes served were determined by the status and the age of the diners. Elders and people of high social status had the right to use more bronze vessels [69,71]. According to written accounts and archaeological data, the most important tableware in China were Ding “鼎” (an ancient vessel for cooking or holding meat) and Gui “簋” (an ancient vessel for holding grains), and a combination of both is the Chinese characters for banquet “飧宴”, which was a symbol associated with nobility [72] (Figure 1). The number of Ding and Gui that a person could use in life was consistent with their social status, and this was also reflected in the combination of these items that were buried with the dead (Table 1). In addition, the consumption of meat was a privilege of the nobility and elders of a family before the Qin Dynasty (Table 1). The work Li Ji “礼记” recorded that “If there is not an important reason, the princes shouldn’t kill cattle to eat, senior officials shouldn’t kill sheep to eat, junior officers shouldn’t kill dogs and pigs to eat, and the common people should not eat meat [5]. Thus, meat was a luxury dietary item that was generally reserved for elites and only for special occasions such as festivals or banquets. In addition, analysis of ceramics from the early Shang Dynasty site of Yanshi determined different structures and behaviors of dining between the palace elites and the individuals that made pottery [73]. Reinhart determined that the Yanshi elites engaged in large-scale exclusionary feasting in contrast to the simpler and home cooked meals of the potters.

Figure 1. Bronze ritual vessels discovered in tomb M22 of Xiaohucun site (a = Ding, b = Gui, c = All bronze grave goods).

There were also strict rules for the maintenance of social status for the deceased in ancient China. Tomb size and burial depth (representing wealth and labor consumption) and the quantity and quality of the coffins used were some of the most important criteria reflecting social status (Table 1) [74,75]. The writings of Xun Zi “荀子” described that the number of coffins used for the Emperor was seven, for a prince was five, for senior nobility was three, and for junior nobility was two [6]. Furthermore, there were strict codes for the materials, size, thickness, as well as the internal and external decoration patterns of coffins, and this was related to hierarchy in Chinese society (Table 1). In addition, the type and quality of grave goods was an important manifestation of the status of the deceased. At least from the Zhou Dynasties, the combination of the number of bronze ritual vessels (Ding and Gui) played a very important role in the status of a tomb owner (Table 1) [3,72]. However, it is important to note that there is a chronological lag between these historical sources and the Shang period and that these works might be biased by the views of the writers. Thus, caution and some skepticism are advised in the use of these textual sources, and they should not be viewed as undisputed fact.

Table 1. Summary of selected differences based on social class in ancient China. This information is referenced from Li Ji “礼记” [5] except for “coffin number” which was referenced from Xun Zi “荀子” [6]. Note: Readers are advised that care must be taken with the accuracy of this information as it is compiled from historical sources which could be subject to the biases of the writers.

Status	Diet		Sacrifice	Travel		Burial		
	Tableware and Courses per Meal	Meat in Diet	Bronze Vessels (Ding) in Ritual Activities	Carriage Number	Horse per Carriage	Coffin Number	Coffin Material	Ding + Gui Combination
Emperor	26	Yes	7	NA	6	7	N/A	9 & 8
Prince	12–16	Yes	5	7	4	5	Pine	7 & 6
Senior Nobility	8	Yes	4	5	3	3	Cypress	5 & 4
Junior Nobility	6	Yes	1	3	2	2	Miscellaneous	3 & 2
Common People	3–6	Only older people	N/A	N/A	1	N/A	N/A	N/A

3. Site of Xiaohucun, Henan Province, China

The Xiaohucun site, dating to the late Shang (ca. 1250–1046 BC) and Western Zhou Dynasty (ca. 1046–771 BC), was the focus of a partial rescue excavation in 2006 by the Henan Provincial Institute of Cultural Relics and Archaeology. The site is situated to the northeast of Xiaohu Village in Xingyang City, which is about 20 km from Zhengzhou, the capital of Henan Province, China (Figure 2) [76]. This unique location is situated in the core of the Central Plains, which was the origin of many early civilizations of China, and also the political and economic center of the early Shang Dynasty. Based on archaeobotanical and isotopic research, the inhabitants of the Central Plains mainly relied on millet cultivation (rice and wheat were also present to some extent) and animal husbandry (pig, cattle, etc.) for subsistence [1,3,34,66,77–80].

Figure 2. Map of China showing the location of the (a) Xiaohucun site and (b) Guandimiao site. Note: Zhengzhou is the capital of Henan Province.

A total of 58 tombs from the late Shang Dynasty (ca. 1250–1046 BC) were excavated from an area of 400×200 meters. All tombs are pits and rectangular in shape, and most had a platform consisting of: inner coffin, outer coffin, waste pit, sacrificial dogs, and various types of grave goods. Unfortunately, many tombs have been looted and destroyed and only 21 of them could be studied in any detail. According to the preliminary report from this site, all the 21 tombs can be divided into three styles, equivalent to the phases of the Yin Ruins II, III, and IV [81]. No radiocarbon dates are available from the site, but examination of the tomb style, grave goods, and the writing on the bronze vessels suggest that the cemetery was a family plot that belonged to the *She* “舌” family from the late Shang Dynasty. Many of the individuals were from the junior nobility class, but a number of common people were also interred here.

4. Materials and Methods

For the 21 tombs at Xiaohucun, bone samples consisting of long bone fragments were obtained from 12 late Shang Dynasty individuals for stable isotope ratio analysis. Osteological analysis, including sex determination and age estimation, was carried out according to standard methods [82]. Unfortunately, due to poor preservation and looting many of the skeletons were destroyed or incomplete and only 5 out of 12 individuals could be positively identified to gender and 9 out of 12 aged (Table 2). In addition, since Xiaohucun was a cemetery site, faunal samples were not available for study. However, we were able to obtain animal bones ($n = 11$) from the nearby (15 km) and contemporaneous site of Guandimiao (ca. 1250–771 BC) which serves as a baseline estimation for the human diets (Table 3).

Collagen was extracted at the Key Laboratory of Vertebrate Evolution and Human Origins of the Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology in Beijing, China, using the protocol outlined by Richards and Hedges [83]. The extracted collagen was well preserved and the majority of samples had collagen yields of over 1% and C: N between 3.0–3.2 (11/11 animals; 12/12 humans), which is indicative of collagen suitable for isotopic analysis [84]. The samples were measured with an Isoprime 100 IRMS coupled with Elementar Vario. Standard material for testing the carbon and nitrogen content was sulfonamides. For every 10 samples, we interpolated one IEAE-CH-6, IEAE-N-2, and IEAE-600 to make data corrections. The measurement precision for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results is $\pm 0.2\text{‰}$. SPSS 20.0 and Origin 8.0 were used for statistical analysis.

Table 2. Isotopic results and sample information for all humans from the Xiaohucun site, Henan Province, China.

Lab ID	Location	Sex	Age	Open Size (m ²)	Depth (m)	Coffin Type	# Grave Goods	Bronze Vessels	# Bronze Vessels	# Jade & other Objects	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C:N
1	M8	Male	45–50	7.35	4.30	double	6	yes	6	-	−8.8	12.8	29.9	11.5	3.0
2	M24	Male	55 ±	5.52	1.80	double	8	yes	7	1	−8.1	10.7	38.6	14.0	3.2
3	M27	?	55 ±	5.61	2.60	double	8	yes	3	5	−7.8	10.3	41.0	14.9	3.2
4	M30	?	?	4.57	2.00	double	7	yes	6	1	−15.2	7.6	42.1	15.3	3.2
5	M39	?	40–45	3.92	1.00	none	-	no	-	-	−8.6	6.7	40.2	14.9	3.1
6	M46	?	35 ±	2.60	0.90	single	-	no	-	-	−8.8	7.5	39.7	14.4	3.2
7	M47	?	25–30	1.92	1.60	single	-	no	-	-	−7.5	8.2	38.4	14.1	3.2
8	M52	?	?	6.80	3.58	double	11	yes	5	4 (1 cowrie shell & 1 wooden object)	−6.4	10.9	41.4	15.2	3.2
9	M89	?	50–55	2.30	0.70	none	1	no	-	1	−7.4	8.2	41.2	15.2	3.2
10	M90	Male	40–45	3.95	0.66	single	4	yes	2	1 (1 cowrie shell)	−9.3	10.8	39.6	14.7	3.2
11	M105	Male	?	4.91	2.25	double	5	yes	4	1	−8.0	9.2	40.0	14.8	3.1
12	M116	Female	45 ±	1.54	1.40	none	1	no	-	(1 cowrie shell)	−8.5	9.2	37.5	13.5	3.2

Table 3. Isotopic results and sample information for all fauna from the Guandimiao site, Henan Province, China.

Lab ID	Location	Species	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C:N
a 1	H28	Pig (<i>Sus scrofa domestica</i>)	−8.2	7.8	35.1	13.0	3.2
a 2	H26	Pig (<i>Sus scrofa domestica</i>)	−9.9	8.6	31.6	12.0	3.1
a 3	H26	Deer (<i>Cervus nippon</i>)	−20.5	4.9	36.2	13.0	3.2
a 4	H741	Pig (<i>Sus scrofa domestica</i>)	−6.7	6.6	41.8	15.0	3.2
a 5	H932	Pig (<i>Sus scrofa domestica</i>)	−9.3	7.6	41.0	14.8	3.2
a 6	H932	Dog (<i>Canis lupus familiaris</i>)	−7.6	8.6	37.3	13.7	3.2
a 7	H1309	Cattle (<i>Bos primigenius taurus</i>)	−9.0	5.7	41.9	15.2	3.2
a 8	H1250	Pig (<i>Sus scrofa domestica</i>)	−11.6	8.8	22.2	9.0	2.9
a 9	H1251	Deer (<i>Cervus nippon</i>)	−15.0	7.6	40.0	14.3	3.3
a 10	J20	Sheep/Goat (<i>Caprinae</i>)	−10.7	7.5	39.8	14.3	3.2
a 11	G7	Dog (<i>Canis lupus familiaris</i>)	−7.5	7.6	37.4	13.8	3.2

5. Results

Sample information and the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for humans and animals are presented in Tables 2 and 3. Given the work at the Xiaohucun site was a rescue excavation, and many tombs were looted, we fully acknowledge that the number of humans available for study was relatively small, but this collection serves as a pilot study and the first opportunity to gain a glimpse into possible isotopic dietary differences related to status during the late Shang Dynasty (ca. 1250–1046 BC) in the Central Plains of China.

5.1. Faunal Isotope Results

In Figure 3 the isotopic results of the humans and animals are presented. The $\delta^{13}\text{C}$ values for pigs ($n = 5$), dogs ($n = 2$), cow ($n = 1$), sheep/goat ($n = 1$) range from −6.7‰ to −11.6‰, which indicates that all of these animals had a diet predominately, if not exclusively, based on C_4 dietary protein sources. Past archaeological and isotopic research has revealed that millet agriculture was important to the residents of the Central Plains [1,28,77,78,85], and that the livestock were mostly consuming millet or its byproducts during the Shang Dynasty [39]. In contrast to the domestic animals, the two deer had $\delta^{13}\text{C}$ values that indicated either a mixed C_3/C_4 (−15.0‰) or exclusive C_3 (−20.5‰) diet. The finding of a deer with the mixed diet is interesting as this could suggest that this animal lived near

the settlement and grazed on the millet fields or that it was possibly kept as pet. Similar results for deer were found at the Xia Dynasty (2070–1600 BC) site of Xinzhai, also in Henan Province, and these ^{13}C -enriched deer were thought to have been possibly raised for the purposes of hunting by the elites of the society [86]. The dog (8.1‰), pig ($7.9 \pm 0.9\text{‰}$), and sheep/goat (7.5‰) all had similar $\delta^{15}\text{N}$ values, suggesting feeding at a similar trophic level, whereas the deer (6.3‰) and cow (5.7‰) were lower. However, this site was closed to the Yellow river, so we could not eliminate the possibility of ingesting freshwater or marine fish resources by human.

Figure 3. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results for humans from the Xiaohucun site and animals from the Guandimiao site Henan Province, China.

5.2. Human Isotope Results

The human $\delta^{13}\text{C}$ results range from -15.2‰ to -6.4‰ and show that most individuals had a predominately C_4 diet based on millet (Figure 3). The exception was individual M30 (-15.2‰) who had a mixed C_3/C_4 diet that was likely a combination of rice and/or wheat and millet [79,87]. The human $\delta^{15}\text{N}$ results range from 6.7‰ to 12.8‰ , indicating there was likely significant individual variation in the consumption of protein at the site. A comparison of the human and faunal isotopes values indicate that pigs, dogs, cattle, and sheep/goats were all likely dietary protein sources, while deer played a minor role (Figure 3). Thus, the diet of the individuals was predominately millet based with some possible inputs of rice and/or wheat, but there were large differences in $\delta^{15}\text{N}$ values that we ascribe to variations in animal protein consumption, as discussed in the next section.

6. Discussion

6.1. Burials and the Classification of Social Status during the Late Shang Dynasty

In order to determine a possible correlation between social status and dietary differences at the Xiaohucun site, it is important to understand how social status may have influenced the tomb type and value. In ancient China, tombs and burials can be graded and valued based on the human labor costs and materials used for construction, the size and shape of the structure, as well as the number and type of graves goods reflecting symbols of power and wealth interred with individuals [55,71]. Since the shapes of all the late Shang Dynasty burials at Xiaohucun were rectangular, the preliminary grading scale of the 12 tombs was classified by number of coffins, tomb depth, and size, and by the presence of

bronze funerary objects and this information is listed in Table 1 and plotted in Figure 4. Tomb sizes ranged from 1.54 m² to 7.35 m² (4.25 ± 1.9 m², $n = 12$), the burial depth was between 0.66 m to 4.3 m (1.93 ± 1.1 m, $n = 12$), which could suggest that the cemetery was under a type of burial management based on social hierarchy. More importantly, the burial depth and tomb size were found to have a linear correlation ($R^2 = 0.67$, $p = 0.001$) with clear differences between the number of coffins used and whether a burial contained bronze vessels.

Figure 4. Plot of burial depth (m) vs. tomb size (m²) for individuals buried in different coffin types with and without bronze funerary vessels at the Xiaohucun site, Henan Province, China.

In addition, past studies developed a specific classification system for Shang Dynasty tombs [3,71], where they can be divided into three different categories (A, B, C) with seven subdivisions (Aa, Ab, Ac, Ba, Bb, Bc, C) (Table 4). Using this system, seven of the tombs (M8, M52, M27, M24, M105, M30, M90) at Xiaohucun are assigned to type Bb. Thus, the owners of these seven tombs are presumed to be junior nobility: six had double coffins and all seven were buried with bronze funerary vessels. Four other tombs (M47, M46, M116, M89) were matched to the Bc category, an indication that the occupants were common people (Table 4). A single tomb (M39) gave somewhat conflicting results. The tomb size was large (3.92 m²) indicating the owner could have been a noble, but the individual was found to be buried without coffins or bronze funerary objects which is an indication this individual was of the lower class (Table 4). It is important to recognize that these classifications are based on information from the royal Shang capital at Anyang and may not be directly applicable at Xiaohucun. However, their use here provides an important starting point from which to explore the relationship between dietary differences and social status during the late Shang Dynasty.

6.2. Diet and Social Status

No difference is observed between the $\delta^{13}\text{C}$ results of the perceived elites ($n = 7$) buried with bronze vessels ($-9.1 \pm 2.8\text{‰}$) and the individuals ($n = 5$) buried without bronze vessels ($-8.2 \pm 0.7\text{‰}$), and this indicates that all classes of the population relied heavily on a millet based diet (Figure 5a). However, individuals buried with bronze vessels ($10.3 \pm 1.6\text{‰}$) were found to have significantly higher $\delta^{15}\text{N}$ values (one-way ANOVA; $p = 0.015$) compared to individuals buried without bronze vessels ($8.0 \pm 0.9\text{‰}$). This finding suggests that the elite during the late Shang Dynasty were consuming a diet with possibly more animal protein or fish than the commoners. Subtle similar patterns have also been noted at the sites of Xipo (ca. 4000–3300 BC) and Qianzhangda (ca. 1000 BC) [54,56]. In particular,

at Qianzhangda, a tomb owner associated with a larger grave was found to have a higher $\delta^{15}\text{N}$ result compared to the other tomb owners with smaller sized burials, and tomb owners were also found to have higher $\delta^{15}\text{N}$ results than sacrificed individuals. Zhang et al. [56] concluded that these elevated nitrogen results of the elites with larger tombs were related to increased meat consumption. However, the results presented here are the first to suggest a possible direct isotopic link between diet and social status at a middle Shang Dynasty site from the Central Plains of China.

Table 4. Classification of social status for burials from the Shang and Zhou Dynasties. Note: Information is referenced from IA CASS [3].

Type	Sub-Type	Tomb Passage	Size (m ²)	Inner & Outer Coffins	Grave Goods	Human Sacrifice	Owner Status
A	a	4	>100	always	abundant	always	Emperor
	b	2	>20	always	abundant	always	Prince
	c	1	20–70	always	abundant	always	Prince or senior nobility
B	a	0	>10	always	abundant	mostly	Prince or senior nobility
	b	0	3–10	mostly	ordinary	rarely	Junior nobility
	c	0	<3	rarely	little or absence	absence	Common people
C	a	0	N/A	absence	absence	absence	Unprivileged people

Figure 5. (a) $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results showing the differences between individuals buried with and without bronze vessels at the Xiaohucun site, Henan Province, China. The $\delta^{15}\text{N}$ results are statistically significant (one-way ANOVA; $p = 0.015$); (b) $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results for individuals buried in a double, single, or without a coffin at the Xiaohucun site, Henan Province, China. The $\delta^{15}\text{N}$ results were not found to be statistically significant using one-way ANOVA tests (double vs. single, $p = 0.288$; double vs. none, $p = 0.095$).

In addition, the isotopic values of the tombs were examined by coffin type: double coffin, single coffin, and no coffin (Figure 5b). No differences in $\delta^{13}\text{C}$ were observed for the double ($-9.1 \pm 3.1\text{‰}$), single ($-8.5 \pm 0.9\text{‰}$), and no coffin ($-8.2 \pm 0.7\text{‰}$) burials. Yet again, there were differences in the $\delta^{15}\text{N}$ values: double ($10.2 \pm 1.7\text{‰}$) > single ($8.8 \pm 1.8\text{‰}$) > no coffin ($8.0 \pm 1.3\text{‰}$) suggesting that possible differences in animal protein consumption were present during the lifetime of these individuals. However, while these results are interesting, they must be viewed with the utmost caution as they were not found to be statistically significant using one-way ANOVA tests (double vs. single coffins, $p = 0.288$; double vs. no coffins, $p = 0.095$).

We further examined the isotopic results of the burials in relation to the number of coffins and tomb sizes since a larger size might equate to higher social status based on the increased labor costs of construction. This permitted an investigation of possible dietary differences within the same social class; specifically did individuals with larger tombs have diets different from individuals with smaller tombs? As with the previous measures of status, the $\delta^{13}\text{C}$ values show little correlation with the size of the tombs, and the entire population, regardless of status, was focused on the consumption of millet (Figure 6a). The $\delta^{15}\text{N}$ results of the individuals with a single or no coffin burial show little

correlation with tomb size (Figure 6b). In contrast, a significant positive linear correlation ($R^2 = 0.84$) is observed for the $\delta^{15}\text{N}$ values between the individuals buried in two coffins and the tomb size. This is possible evidence that owners that were wealthy/powerful enough to build bigger tombs had diets that contained increasing amount of animal products, and the largest tomb (M8) had an occupant that consumed the most animal protein (Figure 6b). While these findings are intriguing and agree with the historical accounts described in Zhou Li “周礼” (Rites of the Zhou Dynasty by Zhou Gong “周公”, ca. 1100 BC [88]) and Chunqiu Gongyang Zhuan “春秋公羊传” (Gongyang’s Commentary on Spring and Autumn Annals by Gongyang Gao “公羊高”, ca. 507 BC [89]) extreme caution is warranted as the sample size is unfortunately small.

Figure 6. (a) $\delta^{13}\text{C}$ results vs. tomb size (m²) for individuals buried in a double, single, or without a coffin at the Xiaohucun site, Henan Province, China; (b) $\delta^{15}\text{N}$ results vs. tomb size (m²) for individuals buried in a double, single, or without a coffin at the Xiaohucun site, Henan Province, China.

It is noteworthy that the $\delta^{15}\text{N}$ values of some burials did not correlate with the corresponding tomb size although a general relationship between the two variables was observed as mentioned above. The reasons for this are complex and unknown but could be related to the slow turnover rate of bone collagen which averages the general dietary protein isotope signatures of the last decades of life [25,26]. If an individual fell on financial or social misfortune and their social standing was diminished during the later years of their life, this could account for a difference in the social status of their burial vs. Their lifetime diet. For example, the $\delta^{15}\text{N}$ result (10.8‰) of M90 was high and he was buried with some bronze funerary objects suggesting a possible elevated social standing during life, but the small size of his tomb (3.95 m²), shallow burial depth (0.66 m), and the fact that he was only buried in a single coffin could imply that his social status or personal fortunes declined later in life. In addition, the reverse scenario could be envisioned for the M30 burial. This individual had a $\delta^{13}\text{C}$ value (−15.2‰) which was radically different than the rest of the population and the lowest $\delta^{15}\text{N}$ value (7.6‰) of all the perceived elite burials. This is possible evidence that this person was a commoner that immigrated to the Xiaohucun community, and that this individual was not born into elite status but acquired it later in life, possibly through marriage, accumulation of wealth, or behavior (bravery in battle). However, all of these possibilities are speculative scenarios and additional research is necessary (ancient DNA, sulfur and strontium stable isotope ratios, etc.) to better understand these patterns, and variables such as age and sex should also be considered in future studies that examine Shang Dynasty sites for social stratification with stable isotope ratio analysis.

7. Conclusions

Here, we applied isotopic measurements as a direct technique to determine dietary patterns related to social class at the site of Xiaohucun, Henan Province, China. For the most part, the population was found to be consuming a predominately C₄ diet (millets), although a single individual (M30) was found

to have a mixed C₄/C₃ diet and could have been an immigrant to the community. No difference was found in the $\delta^{13}\text{C}$ results of the individuals buried with bronze vessels ($-9.1 \pm 2.8\text{‰}$) and the individuals buried without bronze vessels ($-8.2 \pm 0.7\text{‰}$) but significant differences were present in the $\delta^{15}\text{N}$ values: individuals buried with bronze vessels ($10.3 \pm 1.6\text{‰}$) vs. individuals buried without bronze vessels ($8.0 \pm 0.9\text{‰}$). Isotopic results were then compared by the number of burial coffins that an individual had: double, single, or without coffin. No difference was found in the $\delta^{13}\text{C}$ values, but variations were observed in the $\delta^{15}\text{N}$ values: double ($10.2 \pm 1.7\text{‰}$) > single ($8.8 \pm 1.8\text{‰}$) > no coffin ($8.0 \pm 1.3\text{‰}$), possible evidence of increased animal protein consumption with higher social status. Lastly, isotopic results and status were examined by the number of coffins and tomb size. Again, no correlation was seen with $\delta^{13}\text{C}$, but a linear correlation ($R^2 = 0.85$) was found for the $\delta^{15}\text{N}$ values of the elites. Thus, additional social stratification could have existed among the elites with owners' wealthy/power enough to build larger tombs and possibly consuming more animal protein in their diets. These preliminary results of this pilot study offer a glimpse of the social hierarchy that existed during the late Shang Dynasty.

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