Journal of Archaeological Science 40 (2013) 2344–2351

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Human subsistence strategy at *Liuzhuang* site, Henan, China during the proto-Shang culture (~2000–1600 BC) by stable isotopic analysis

Liangliang Hou [a,b], Yaowu Hu [a,b,*], Xinping Zhao [c], Suting Li [c], Dong Wei [d], Yanfeng Hou [c], Baohua Hu [d,e], Peng Lv [f], Tao Li [g], Guoding Song [a,b], Changsui Wang [a,b]

[a] *Lab of Human Evolution, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, PR China*
[b] *Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences, Beijing 100049, PR China*
[c] *Henan Provincial Institute of Cultural Relics and Archaeology, Zhengzhou 450000, PR China*
[d] *Research Center for Chinese Frontier Archaeology, Jilin University, Changchun 130012, PR China*
[e] *School of History, Wuhan University, Wuhan 430072, PR China*
[f] *Institute of Archaeology, Chinese Academy of Social Sciences, Beijing 100710, PR China*
[g] *Department of Anthropology, University of Pittsburgh, PA 15260, USA*

A R T I C L E I N F O

Article history:
Received 1 August 2012
Received in revised form
2 January 2013
Accepted 4 January 2013

Keywords:
The proto-Shang culture
Liuzhuang site (LZS)
Zhangdeng site (ZDS)
Subsistence strategy
$\delta^{13}C$ and $\delta^{15}N$

A B S T R A C T

Since the discovery of the proto-Shang culture, created mostly by ancestors of the Shang clan from the late Neolithic Age to the early Shang period (~2000–1600 BC), the subsistence strategy and lifestyle of humans in China during their movement southwards have been a great focus. Chinese literature and archaeological findings suggest that the proto-Shang societies were composed of different cultural groups and had various subsistence strategies. For example, at the *Liuzhuang* site, three types of burials, *i.e.*, stone coffin, wooden coffin and earthen shaft-pit, are found. The wooden coffin and earthen shaft-pit burials had been adopted locally in the Central Plains since the Neolithic Age while the stone coffin burials were usually used by people living in Northeast China and had never been found in the Central Plains before. In this study, stable carbon and nitrogen isotopic analyses were performed on human bones from the *Liuzhuang* site and animal bones from *Zhangdeng* site in Henan province, China to determine whether different social groups had various accesses to food resources and whether their dietary difference was related to inequality in social status. Humans have mean $\delta^{13}C$ and $\delta^{15}N$ values of $-7.6 \pm 0.6‰$ and $9.6 \pm 1.0‰$ ($n = 19$) respectively, which strongly indicates that humans rely primarily on C_4-based food. The main contribution of C_4-based food in their diet is from millet agriculture or animals that consume millet by-products. The isotopic spacing of carbon and nitrogen isotopic values between pigs and humans, between dogs and humans, and between cattle and humans, all imply that these animals were the main meat resources for humans. Surprisingly, the $\delta^{13}C$ values and $\delta^{15}N$ values of humans with different types of burials are quite close, indicating that they had equal access to food resources. This result suggests that the proto-Shang humans had adapted to the local subsistence strategy, and the local cultural factors in the Central Plains were very well integrated into proto-Shang culture.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Due to rich written records and abundant archaeological discoveries related to the Shang Dynasty (1600–1046 BC), it has been widely accepted that the Shang Dynasty is an early state of ancient China (Chang, 2002; Zhu, 2007). Since the first important discovery of the Shang remains in central China in 1920s, intensive discussions have been made on the social and political organizations, subsistence strategy, and ritual ideology in the Shang societies (e.g., Chang, 1983, 2002). To better understand how the Shang clan came into being, more and more studies have turned to the precursor of the Shang Dynasty, proto-Shang culture (Li, 1989; Tsou, 1980).

The proto-Shang culture was defined as the culture created primarily by the Shang clan from the late *Longshan* period to the early Bronze Age (~2000–1600 BC) in the Central Plains of China (Li, 1989). Current researches indicate that the proto-Shang cultural remains were distributed mainly in northern Henan and southern Hebei along the east side of the *Taihang* Mountains (Hu

* Corresponding author. Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences, Beijing 100049, PR China. Tel.: +86 010 8825 6417.
E-mail addresses: liangliang_hou@eva.mpg.de (L. Hou), ywhu@gucas.ac.cn (Y. Hu).

0305-4403/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2013.01.005

and Wang, 2012; Wang and Hu, 2011) (Fig. 1). So far four variants of the proto-Shang culture have been suggested, including *Baobei* (Shen, 1991), *Zhanghe* (Tsou, 1980), *Huiwei* (Tsou, 1980) and *Lutaigang* (Wei, 1999). The distribution of each variant is illustrated in different colors in Fig. 1 (in the web version). According to studies of pottery typology, the dates of the *Baobei* and *Zhanghe* were earlier than that of *Huiwei*, which was followed successively by *Lutaigang* (Hu and Wang, 2012; Li, 1989; Tsou, 1980; Wang and Hu, 2011).

It is argued mostly by Chinese historians that the subsistence strategy of the proto-Shang societies from the emergence of the Shang clan to the setup of Shang Dynasty underwent a fundamental change, from nomadic to semi-nomadic and semi-agricultural, and then to completely agricultural (Wang, 2010; Zhu, 2007). For example, Ding (1988) proposed that the ancestors of the Shang people lived a completely nomadic life based on the records of literature, *Taiping huanyuji*, which described an animal herding scene. Later, they were gradually influenced by the agricultural practices in central China as they interacted more frequently with the farmers during their migration southwards. For instance, the early Chinese literature, *i.e.*, *Guanzi Qingzhongwu*, recorded the setup of *Zaolao*, a specific place for raising livestock. More importantly, the naming pattern of two famous chiefs, *Hai* and his grandson *Shangjiawei*, was adopted by the Heavenly-stem and Earthly-branch system, which was widely used for agricultural production in China in ancient times (Zhu, 2007). By 1600 BC when the Shang Dynasty was founded, agriculture was highly developed and flourishing, which can be inferred from the records of *Mencius Tengwengong Xia* and *Shangshu Tangshi.*

In addition, more and more evidence on the subsistence strategy can be seen from the artifacts and archaeological contexts unearthed in proto-Shang sites from northern Henan and southern Hebei (Fig. 1). Archaeological artifacts, such as stone tools used for hunting and fishing, were found from early proto-Shang sites mostly located in northern Hebei like the *Yabazhuang* site (CPAMHP and CPAMCC, 1992), supporting the idea that the early proto-Shang societies lived a nomadic life. At sites during the Early to Middle

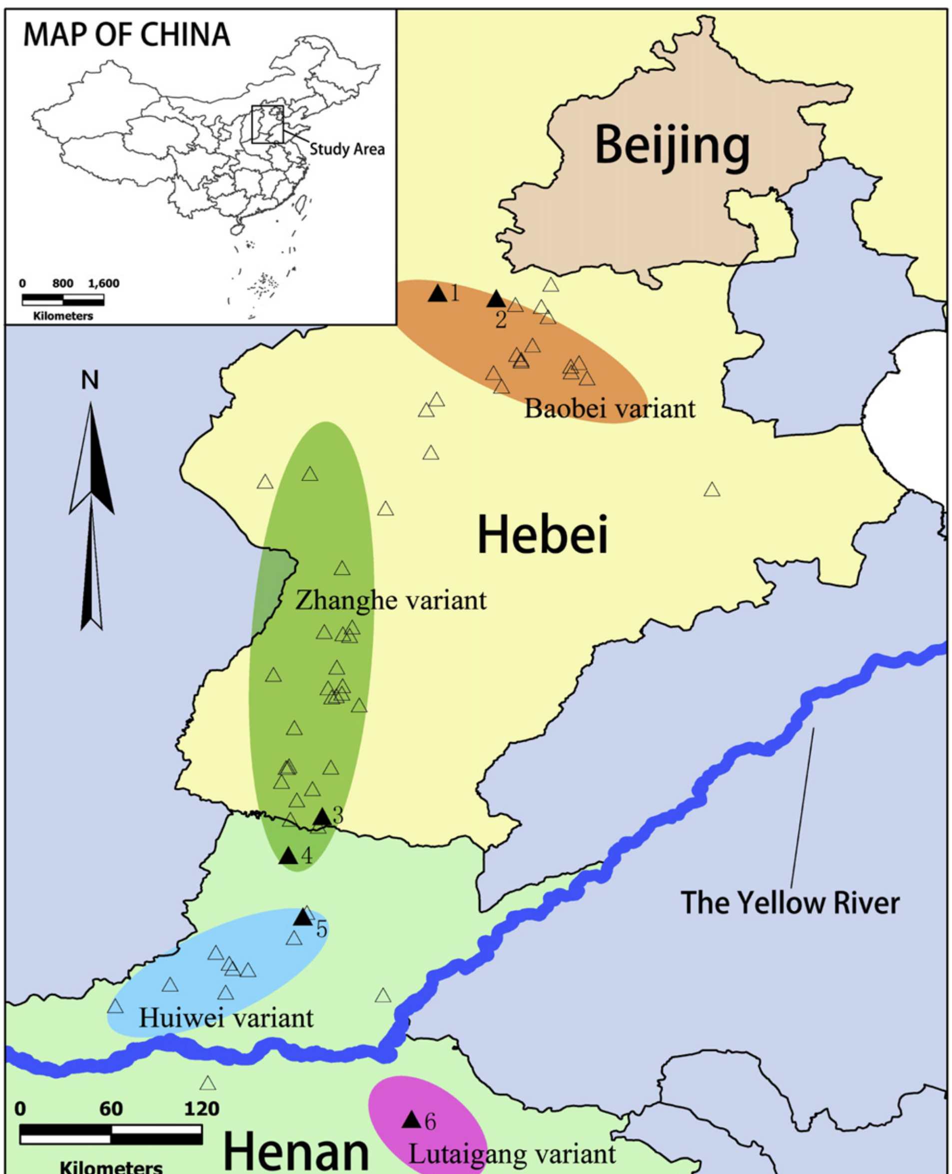

Fig. 1. Location of archaeological sites of the proto-Shang culture marked by triangles, among which the solid triangles with numbers are referring to sites mentioned in the context (1. *Yabazhuang*; 2. *Xiayuegezhuang*; 3. *Xiaqiyuan*; 4. *Zhangdeng*; 5. *Liuzhuang*; 6. *Lutaigang*).

proto-Shang period, such as *Xiayuegezhuang* (Duan et al., 2008; JAT, 1988), *Xiaqiyuan* (CPAMHP, 1979), *Zhangdeng* (Hou et al., 2009), and *Liuzhuang* (HPICRA, 2007, 2010; Zhao and Han, 2006) etc., archaeologists found different types of tools widely used for agricultural life, such as stone sickles, stone shovels, and pottery (*Ding*, *Ge* and *Yan*) for cooking and serving food. Domestic animal bones (pigs, dogs, cattle and sheep/goats) were also found, indicating that proto-Shang people always raised livestock for meat resources or animal power (mostly for transportation) (Hou et al., 2009, in press). There were a large number of pottery artifacts, domestic animals bones, and semi-subterranean house architecture found in *Lutaigang* site during the late proto-Shang period (SAMZU et al., 1994; SAMZU and ATKC, 2000), indicating a sedentary lifestyle.

The *Liuzhuang* site (LZS), located in northern Henan, was classified as the *Huiwei* variant and elected as one of the *Top Ten New Archaeological Discoveries of China* in 2005 (Fig. 1). The site may have been occupied during the Middle to Late proto-Shang period (~1750–1600 BC) (HPICRA, 2007, 2010; Zhao and Han, 2006). As one of the most important sites along the path of the proto-Shang people's southward movement, this site offers a cultural bridge to connect the northern and southern sites geographically. Three hundred and thirty-eight burials can be identified as one of three types – a stone coffin burial, a wooden coffin burial, or an earthen shaft-pit burial (HPICRA, 2007, 2010; Zhao and Han, 2006). The wooden coffin and earthen shaft-pit burials had been adopted locally in the Central Plains since the Neolithic Age, while the stone coffin burials were usually used by people living in Northeast China and had never been found in the Central Plains before (Zhou, 2006). Apparently, the residents in LZS were quite complex and may be representative of different social groups. Did they have differential access to food resources? Were differences in their diet related to inequality in social status?

To answer the above questions, stable carbon and nitrogen isotopic analyses of human skeletal remains from the LZS as well as animal bones from the *Zhangdeng* site (ZDS) (Hou et al., 2009) were undertaken to explore the similarities or dissimilarities in subsistence strategy among people from this region. This comparative study will allow us to not only explore the differences in human diets and subsistence strategy but it will also help to clarify the relationship between the social organization, burial practices, and social identity of the proto-Shang people at the LZS.

2. Materials and methods

2.1. Materials

Thirty-two human bones from the LZS were selected for stable isotope analysis. Since animal bones from the LZS are currently not available, 49 animal bones including pigs, dogs, cattle and sheep/goats were sampled from the ZDS (Hou et al., 2009), contemporary to and near the LZS. The exact location of LZS and ZDS is illustrated in Fig. 1. More details about the human skeletons and animal bones can be seen in Tables 1 and 2.

2.2. Collagen extraction

Collagen was extracted from the human and animal bone samples based on a slightly modified version of the protocol outlined by Jay and Richards (2006). Bone samples weighing 2–3 g were mechanically cleaned to remove outer and inner contaminants. The bone samples were then demineralized in 0.5 mol/L HCl at 4 °C. The liquid was refreshed every 2 days until the samples turned soft and no bubbles came out. Then the residues were washed by deionized water until neutral, rinsed in 0.125 mol/L

Table 1
Archaeological context of humans and C and N contents and isotopic data from LZS.

Lab. id.	Location	Type	Sex	Age	Wt. %C	Wt. %N	C:N	Col%	δ^{13}C ‰	δ^{15}N ‰
LZS1	M5	A	F	25–30	34.6	11.8	3.4	0.5	−7.0	9.8
LZS2	M13	A	?	20±	30.2	10.5	3.4	0.6	−8.0	10.0
LZS3	M14	B	M	?	32.9	11.5	3.3	1.6	−7.7	10.3
LZS4	M15	B	F	20±	38.9	13.6	3.3	0.8	−7.6	8.9
LZS5	*M16*	*A*	*?*	*25±*	*13.8*	*4.1*	*3.9*	*1.6*	*−9.5*	*13.1*
LZS6	*M17*	*A*	*M*	*20–25*	*8.7*	*2.3*	*4.4*	*0.3*	*−10.7*	*14.6*
LZS7	*M23*	*A*	*M*	*30–35*	*16.3*	*5.0*	*3.8*	*0.2*	*−10.0*	*11.8*
LZS8	M34	B	F	35±	23.8	9.4	2.9	0.4	−8.3	10.1
LZS9	*M38*	*A*	*F*	*35–40*	*9.6*	*2.7*	*4.1*	*0.2*	*−10.6*	*14.3*
LZS10	M58	A	M	25±	27.7	9.7	3.3	0.3	−7.7	12.0
LZS11	M85	A	?	41±	32.3	11.6	3.2	0.3	−7.9	9.6
LZS12	M136	A	?	25±	35.4	12.1	3.4	0.5	−8.2	9.8
LZS13	*M139*	*B*	*F*	*25–30*	*16.0*	*4.8*	*3.9*	*0.1*	*−9.1*	*12.9*
LZS14	M152	A	?	25–30	7.2	2.9	2.9	0.3	−12.2	14.3
LZS15	M153	B	M	25–30	36.0	12.7	3.3	0.6	−7.4	10.4
LZS16	*M169*	*A*	*?*	*?*	*3.5*	*1.5*	*2.8*	*0.3*	*−24.9*	*16.3*
LZS17	M172	C	M	25–30	23.1	7.9	3.4	0.2	−7.4	9.8
LZS18	*M193*	*C*	*M*	*40–45*	*6.8*	*1.2*	*6.8*	*0.3*	*−21.4*	*7.8*
LZS19	M195	C	F	?	35.0	12.4	3.3	0.3	−7.1	10.3
LZS20	*M211*	*A*	*?*	*25–30*	*3.4*	*0.5*	*8.0*	*0.2*	*−16.9*	*9.3*
LZS21	M217	C	?	?	37.2	13.4	3.3	0.2	−6.9	9.0
LZS22	M227	A	M	40–45	33.5	12.7	3.1	0.3	−6.9	8.5
LZS23	M231	A	?	?	33.0	12.2	3.2	0.3	−6.8	8.9
LZS24	M233	A	M	?	19.4	6.6	3.4	0.2	−8.5	9.5
LZS25	M234	C	?	30–35	32.1	10.8	3.5	0.5	−7.6	9.9
LZS26	M236	C	F	40–45	20.3	7.4	3.2	0.3	−9.0	7.2
LZS27	*M254*	*C*	*M*	*35±*	*2.8*	*1.5*	*2.2*	*0.3*	*−23.6*	*−0.7*
LZS28	*M256*	*A*	*?*	*30–35*	*6.2*	*1.5*	*4.9*	*0.3*	*−20.4*	*8.4*
LZS29	M274	A	?	?	37.7	12.9	3.4	0.9	−7.8	8.4
LZS30	M302	A	F	20–25	21.3	7.2	3.4	0.3	−15.1	6.8
LZS31	*M308*	*A*	*?*	*40–45*	*6.5*	*1.1*	*7.0*	*0.3*	*−15.8*	*9.2*
LZS32	M330	A	?	40±	26.7	8.6	3.6	0.4	−7.5	10.0

Note: wt% C and wt% N are of collagen; A = Earthen shaft-pit burial, B = Simple stone coffin burial, C = Wooden coffin burial; M = male, F = female; ? = sex not known or age not known; the italic means the samples has been contaminated, italicized C:N data indicate unusable data.

Table 2
Archaeological context of animals and C and N contents and isotopic data from ZDS.

Lab. Id.	Location	Species	Wt. %C	Wt. %N	C:N	Col %	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰
D1	T9 H7	Dog (*Canis lupus familiaris*)	34.7	12.9	3.1	3.1	−7.6	7.6
D2	T01310 H21:8	Dog (*Canis lupus familiaris*)	39.4	14.5	3.2	5.4	−8.8	6.7
D3	T10 H22:49	Dog (*Canis lupus familiaris*)	38.9	14.3	3.2	3.3	−6.7	7.3
D4	T17 H68:10	Dog (*Canis lupus familiaris*)	38.9	14.3	3.2	1.3	−7.4	7.7
S1	T9 H18: 146	Sheep/goat (Caprinae)	39.9	14.6	3.2	4.0	−14.2	8.4
S2	T01310H21:11	Sheep/goat (Caprinae)	39.1	14.5	3.2	2.3	−16.3	6.6
S3	T23 H42:2	Sheep/goat (Caprinae)	40.9	15.0	3.2	3.6	−17.1	8.7
S4	T12 H44:5	Sheep/goat (Caprinae)	37.6	14.2	3.1	1.3	−10.7	7.4
S5	T20 H89	Sheep/goat (Caprinae)	37.2	14.0	3.1	1.4	−13.1	8.0
S6	T17 H86:34	Sheep/goat (Caprinae)	42.0	15.3	3.2	7.2	−13.8	8.5
S7	T13 H69:11	Sheep/goat (Caprinae)	41.0	15.1	3.2	4.5	−21.4	7.1
S8	T01310 H21:34	Sheep/goat (Caprinae)	43.6	16.0	3.2	6.1	−15.8	6.3
S9	T01310 T21 H64	Sheep/goat (Caprinae)	39.7	14.6	3.2	3.7	−15.1	5.8
S10	T13 H69:17	Sheep/goat (Caprinae)	42.1	15.2	3.2	1.5	−19.0	8.3
S11	T14 H50:25	Sheep/goat (Caprinae)	39.8	14.5	3.2	2.0	−13.9	8.2
S12	T19 H47:1	Sheep/goat (Caprinae)	40.5	14.8	3.2	3.5	−15.2	10.2
S13	T10 H22:47	Sheep/goat (Caprinae)	43.8	16.0	3.2	6.9	−14.1	6.9
P1	T4 H1:2	Pig (*Sus scrofa domestica*)	38.5	14.5	3.1	1.9	−6.5	7.7
P2	T4 H2:2	Pig (*Sus scrofa domestica*)	39.7	14.6	3.2	2.9	−8.8	7.1
P3	T10 H17:1	Pig (*Sus scrofa domestica*)	40.6	14.8	3.2	2.6	−7.1	7.6
P4	T9 H18:39	Pig (*Sus scrofa domestica*)	40.8	14.7	3.3	1.4	−9.2	7.8
P5	T10 H22:9	Pig (*Sus scrofa domestica*)	41.0	15.2	3.1	1.7	−6.9	7.1
P6	T13 H27:4	Pig (*Sus scrofa domestica*)	40.0	14.9	3.1	0.9	−11.2	7.9
P7	T13 H35:8	Pig (*Sus scrofa domestica*)	43.4	15.8	3.2	6.1	−6.8	7.5
P8	T13 H70:4	Pig (*Sus scrofa domestica*)	40.3	14.8	3.2	1.4	−9.1	7.7
P9	T17 H86:25	Pig (*Sus scrofa domestica*)	41.8	15.2	3.2	3.2	−6.5	8.1
P10	T9 H11:153	Pig (*Sus scrofa domestica*)	42.4	15.7	3.2	3.2	−6.4	7.4
P11	T9 H18:88	Pig (*Sus scrofa domestica*)	41.0	15.0	3.2	1.9	−8.8	8.0
P12	T3 H32:4	Pig (*Sus scrofa domestica*)	43.0	15.7	3.2	4.6	−8.0	6.6
P13	T9 H7:4	Pig (*Sus scrofa domestica*)	42.5	15.6	3.2	3.9	−6.6	8.4
P14	T22 H69	Pig (*Sus scrofa domestica*)	38.4	14.4	3.1	0.6	−6.9	8.3
P15	T9 H4:4	Pig (*Sus scrofa domestica*)	41.0	14.8	3.2	1.8	−7.5	8.2
P16	T9 H7:23	Pig (*Sus scrofa domestica*)	36.4	13.3	3.2	0.8	−6.4	7.6
P17	T9 H18:169	Pig (*Sus scrofa domestica*)	38.3	14.4	3.1	1.3	−7.3	7.1
P18	T10 H6:13	Pig (*Sus scrofa domestica*)	36.4	13.7	3.1	0.7	−8.1	7.6
P19	T23 H82:9	Pig (*Sus scrofa domestica*)	36.6	13.6	3.1	0.5	−7.3	7.8
C1	T21 H64:4	Cattle (*Bos primigenius taurus*)	37.6	13.8	3.2	2.0	−9.6	5.3
C2	T13 H69	Cattle (*Bos primigenius taurus*)	42.8	15.5	3.2	2.5	−7.5	5.6
C3	T3 H32:4	Cattle (*Bos primigenius taurus*)	44.0	16.0	3.2	6.6	−7.7	8.1
C4	T9 H10:14	Cattle (*Bos primigenius taurus*)	40.4	14.6	3.2	1.3	−6.2	8.3
C5	T9 H4	Cattle (*Bos primigenius taurus*)	39.7	14.4	3.2	1.3	−6.8	5.6
C6	T01310 H21:29	Cattle (*Bos primigenius taurus*)	43.2	15.7	3.2	5.3	−18.9	4.0
C7	T9 H11:3	Cattle (*Bos primigenius taurus*)	40.3	14.7	3.2	0.7	−12.3	7.2
C8	T10 H22:56	Cattle (*Bos primigenius taurus*)	41.3	15.0	3.2	6.0	−10.7	8.7
C9	T9 H18	Cattle (*Bos primigenius taurus*)	43.6	15.8	3.2	4.9	−7.7	6.1
C10	T9 H7:42	Cattle (*Bos primigenius taurus*)	44.1	16.0	3.2	6.4	−11.1	7.6
C11	T17 M86:96	Cattle (*Bos primigenius taurus*)	43.0	15.5	3.2	5.2	−10.4	7.1
C12	T10 H17:1	Cattle (*Bos primigenius taurus*)	41.4	15.1	3.2	2.3	−6.7	6.2
C13	T21 H64	Cattle (*Bos primigenius taurus*)	44.4	16.1	3.2	4.2	−10.8	6.2

Note: wt% C and wt% N are of collagen.

NaOH for 20 h at 4 °C, and finally washed by deionized water again. Afterward, the remains were rinsed in 0.001 mol/L HCl, gelatinized at 70 °C for 48 h, and filtered. Then the residues were freeze-dried for 48 h to get the collagen. Finally, the collagen content was calculated through the dried collagen weight divided by the bone sample weight (Tables 1 and 2).

2.3. Measurement of C and N contents and their stable isotope ratios

The contents of C, N and the C, N stable isotope ratios of collagen were measured in an Isoprime 100 IRMS coupled with Elementary Vario at the Measuring Center of the Institute of Agricultural Environment and Substantial Development, Chinese Academy of Agricultural Sciences. The standard for measuring the content of C, N is Sulfanilamide. IEAE-N-1 and USGS 24 were used as standards to normalize N_2 (AIR as standard) and CO_2 (PDB as standard) in steel bottles respectively. In addition, after every 10 samples, a standard laboratory made collagen with a $\delta^{13}C$ value of $-14.7 \pm 0.2‰$ and a $\delta^{15}N$ value of $6.8 \pm 0.2‰$ was inserted into the sample list for calibration. The precision of carbon and nitrogen isotope ratios is $\pm 0.2‰$ and $\pm 0.2‰$, respectively. Stable isotopic data are shown in Tables 1 and 2 too.

Generally speaking, the collagen contents of all samples are very low (0.1%–7.2%), with an average of 2.0%, which is much lower than the average (about 20%) of modern bones (Ambrose et al., 1997). In addition, the amount of C (2.8%–44.4%) and N (0.5%–16.1%) in collagen is also lower than that found in modern collagen (C: 41%; N: 15%) (Ambrose, 1990), indicating that the majority of bone collagen had been decomposed to some extents during its long-term burial. However, the atomic ratios of C to N in collagen ranged from 2.9 to 3.6 (DeNiro, 1985), so the samples can still be considered well-preserved for stable isotopic analysis. In this study, 11 samples (LZS5, LZS6, LZS7, LZS9, LZS13, LZS16, LZS18, LZS20, LZS27, LZS28 and LZS31) were excluded for further analysis due to their abnormal C:N atomic ratios (Tables 1 and 2).

3. Results and discussions

3.1. Animal diets

Fig. 2 presents the scatter plot of δ^{13}C and δ^{15}N values in bone collagen extracted from animals (cattle, sheep/goats, pigs and dogs) at the ZDS. For convenience, the animals are divided into two groups for further discussion, *i.e.*, herbivore (cattle and sheep/goat), and omnivore (pig) or carnivore (dog).

In Fig. 2, the δ^{13}C values of all cattle except one (C6) range from −12.3‰ to −6.2‰ with an average of −9.0 ± 2.1‰ ($n = 12$), implying that they mainly ate C_4 plants. The δ^{15}N values of cattle have a quite wide range (5.3‰–8.7‰) with an average of 6.8 ± 1.2‰ ($n = 12$). However, the outlier, C6, has a much lower δ^{13}C value (−18.9‰) and δ^{15}N value (4.0‰) than the others, implying that it had a diet with more ^{15}N-deficient C_3 plants. The range of δ^{13}C values of sheep/goats (−21.4‰ to −10.7‰), is much wider than that of cattle, indicating that they had more diverse plants resources. All sheep/goats except S12 have δ^{15}N values ranging from 5.8‰ to 8.7‰, S12, however, has an abnormally high δ^{15}N value (10.2‰), which might be influenced greatly by the milk consumption effect (Balasse and Tresset, 2002; Makarewicz and Tuross, 2006; Ogrinc and Budja, 2005) or water stress (Ambrose, 1991; Pearson et al., 2007; Thompson et al., 2008).

As Fig. 2 shows, the δ^{13}C values of all pigs except one (P6) are quite close and range from −9.2‰ to −6.4‰ with a mean of −7.5 ± 1.0‰ ($n = 18$), implying that they mainly consumed C_4-based foods. As omnivores, the pigs have the mean δ^{15}N value of 7.7 ± 0.5‰ ($n = 19$). Compared to others, the δ^{13}C value (−11.2‰) of P6 is much lower, indicating that its diet included more C_3 based foods. Although dogs are generally considered carnivores, in this study their average δ^{13}C and δ^{15}N values are −7.6 ± 0.9‰ ($n = 4$) and 7.3 ± 0.5‰ ($n = 4$), respectively, similar to those of the pigs, which implies that the dogs might be fed by the same food.

3.2. Human diets

Fig. 3 presents the scatter plot of δ^{13}C and δ^{15}N values of bone collagen of humans from LZS as well as an error bar plot of the isotopic data from the ZDS animals after exclusion of the outliers (C6, S12).

The δ^{13}C values of the samples, excluding LZS14, LZS30, are relatively consistent. The average value is −7.6 ± 0.6‰ ($n = 19$), suggesting that the humans at LZS mainly ate C_4 based foods. The mean δ^{15}N value of these people is 9.6 ± 1.0‰ ($n = 19$), indicating that their food contained high amounts of animal protein. Therefore, the high δ^{13}C and δ^{15}N values of these people (Fig. 3) strongly indicate that high amounts of C_4-based animal protein were consumed by the proto-Shang people.

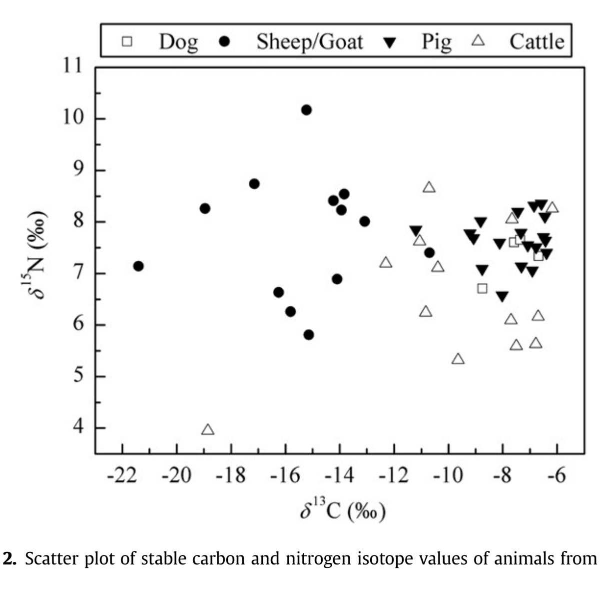

Fig. 2. Scatter plot of stable carbon and nitrogen isotope values of animals from ZDS.

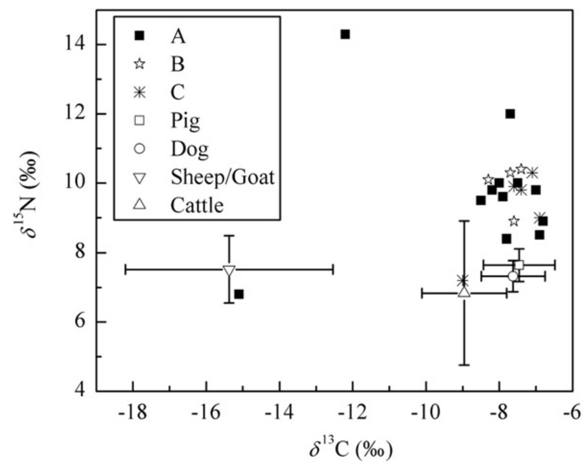

Fig. 3. Scatter plot of stable carbon and nitrogen isotope values of humans from the LZS and error bar plot of those of animals from the ZDS (A = Earthen shaft-pit burial, B = Simple stone coffin burial, C = Wooden coffin burial).

The source of animal protein in human diets can be easily traced further back by comparing the human isotopic data to the animal isotopic data. To do this comparison, the isotopic fractionation of carbon and nitrogen along the trophic level is used. As Fig. 3 shows, the δ^{13}C and δ^{15}N values of pigs, dogs and cattle are closer to that of humans than to that of other animals. The isotopic spacing of δ^{13}C mean value between pigs and humans, dogs and humans, cattle and humans, is −0.1‰, 0‰, and 1.4‰, respectively. Obviously, they are all not beyond the range of the C isotopic enrichment (1‰–1.5‰) in one trophic level (Ambrose and Norr, 1993; Hedges and Reynard, 2007). Meanwhile, the small isotopic spacing of δ^{15}N mean value between pigs and humans (2.0‰), dogs and humans (2.3‰), cattle and humans (2.8‰) does not exceed the range of the N isotopic enrichment (3‰–5‰) in one trophic level (Ambrose and Norr, 1993; Hedges and Reynard, 2007) either. Based on the above, it is obvious that the main animal protein in human diets may come from pigs, dogs, and cattle.

However, the relationship between sheep/goats and humans is very different. As Fig. 3 shows, the isotopic spacing of the mean δ^{13}C value between sheep/goats and humans is as large as 7.8‰, which is much higher than the range of the C isotopic enrichment (1‰–1.5‰) in one trophic level (Ambrose and Norr, 1993; Hedges and Reynard, 2007). It seems that humans did not like to consume the meat from sheep/goats. So what was the purpose of raising sheep/goats? Were they used for wool? Were they milked? To better answer these questions, more work should be done to reveal the role that sheep/goats played in human society.

One outlier, LZS30 (Table 1), has the lowest δ^{13}C (−15.1‰) and δ^{15}N (6.8‰) values among the humans sampled, indicating that large quantities of C_3 plants were part of her diet. The highest δ^{15}N value (14.3‰) is found in the human LZS14, the other outlier, which suggests that the largest proportion of animal protein or aquatic resources was his or her diet. Moreover, the comparison with C and N isotopic data of the animals will give greater clarity to what was the type of animal resources in their diet.

The isotopic spacing of the mean δ^{15}N value (7.5‰; 6.8‰; 6.6‰; 7‰) between the above-mentioned domestic animals (cattle; sheep/goats; pigs; dogs) and LZS14 is much higher than the range of N isotopic enrichment (3‰–5‰) in one trophic level (Ambrose and Norr, 1993; Hedges and Reynard, 2007), indicating that the human LZS14 did not consume meat from these domestic animals, but probably did consume meat from aquatic resources (Richards et al., 2005). An alternative interpretation is that the individual may have come from a more arid area, which can cause abnormality of N metabolism (Ambrose, 1991; Pearson et al., 2007; Thompson et al., 2008). The low δ^{13}C (−15.1‰) and δ^{15}N (6.8‰) values of LZS30 suggest that the individual ate primarily C_3 plant foods, quite different from the other humans tested. Therefore, these two outliers might be immigrants rather than local residents.

3.3. Dietary difference among humans

Previous work shows that the study of dietary difference in humans can provide valuable clues to understanding the equality/inequality of human social status (e.g., Ambrose et al., 2003; Jay and Richards, 2006; Jørkov et al., 2010; Linderholm et al., 2008; Richards et al., 1998). Statistical analysis of carbon and nitrogen isotopic values of humans with different ages and sexes suggest that humans shared similar foods no matter what age or gender they were. Thus, more focus was put toward determining dietary variation of humans with different burial styles. A standard deviation plot of δ^{13}C and δ^{15}N values of humans with three types of different burials is drawn in Fig. 4, excluding the two outliers (LZS14 and LZS30).

Generally speaking, human isotopic values in Fig. 4 are quite close no matter to which burial they belonged. A represents stone coffin burials, B represents wooden coffin burials, and C represents earthen shaft-pit burials (Fig. 4). The mean δ^{13}C values of A (-7.6 ± 0.6‰, $n = 10$), B (-7.8 ± 0.4‰, $n = 4$) and C (-7.6 ± 0.8‰, $n = 5$) are almost the same. The mean δ^{15}N values of A (9.7 ± 1.0‰, $n = 10$), B (9.9 ± 0.7‰, $n = 4$), and C (δ^{15}N = 9.2 ± 1.2‰, $n = 5$) are also very similar. Moreover, the independent *t*-test statistical analyses of the mean δ^{13}C values (A vs B is $t = 0.380$, $P > 0.05$; B vs C is $t = -0.331$, $P > 0.05$; A vs C is $t = -0.083$, $P > 0.05$) and the mean δ^{15}N values (A vs B is $t = -0.492$, $P > 0.05$; B vs C is $t = 0.984$, $P > 0.05$; A vs C is $t = 0.688$, $P > 0.05$) show that there was no significant difference in diet, suggesting that humans had similar access to the different types of food, even though they may have belonged to different clans.

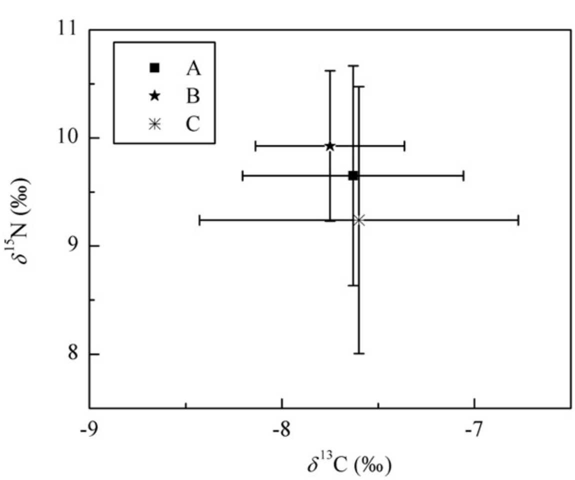

Fig. 4. Error bar of human average stable carbon and nitrogen isotope values from different types of burials (A = Earthen shaft-pit burial, B = Simple stone coffin burial, C = Wooden coffin burial).

3.4. Human subsistence strategy and animal management during proto-Shang culture period

Carbon isotopic analysis of palaeosol in North China indicates that C_3 plants were dominant during the Holocene (Liu et al., 2011). C_4 plants are rare in North China, and are mainly composed of the *Gramineae* and *Chenopodiaceae* (Liu et al., 2011). The only C_4 plant used as a cultigen used in North China is millet (Barton et al., 2009; Hu et al., 2008; Liu et al., 2011).

The domestication of foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*) in North China can be traced back to 11,000 years ago (Yang et al., 2012), and millets, including foxtail millet and broomcorn millet, have been cultivated extensively since the *Yangshao* culture (~5000–3000 BC) (Hu et al., 2008; You, 2008; Zhao, 2005a). Afterward, other crops, such as rice, wheat, soybean, and hemp appeared, but millets still played a great role in the human diet from the *Longshan* culture (~2350–1950 BC) to the three dynasties (Xia, Shang, and Zhou) (Chen, 2007; Zhao, 2005b). During the proto-Shang culture, many millet remains have also been found by flotation at the LZS (Wang et al., 2010) and the ZDS (Liu, 2010).

Previous study shows that δ^{13}C values of modern millet are about −11.7‰ (McGovern et al., 2004). Talking into account the fossil-fuel effect (approximately 1.5‰) (Marino and McElroy, 1991), the δ^{13}C values of millets in the prehistory should be around −13.2‰. The δ^{13}C values of human or animals consuming 100% millet products would be around −7.2‰ if the enrichment in bone collagen of δ^{13}C value (5‰ or so) from foods (DeNiro and Epstein, 1978) is considered.

The very high δ^{13}C values of pigs (-7.5 ± 1.0‰, $n = 18$) and dogs (-7.6 ± 0.9‰, $n = 4$) suggest that they were fed large amount of millet by-products or human leftovers. Since cattle are large herbivores, their high δ^{13}C values (-9.0 ± 2.1‰, $n = 12$) suggest that cattle were fed more millet by-products such as the stem, stalk, leaves, etc. However, the δ^{13}C values of sheep/goats (-15.4 ± 2.8‰, $n = 18$) are substantially lower, indicating that they relied more on wild C_3 plants. In this study, humans are all of high δ^{13}C values (-7.6 ± 0.6‰, $n = 19$), indicating that their food came mainly from the contribution of millet agriculture or animals consuming millet by-products.

Just as mentioned in the introduction, the earthen shaft-pit burials and the wooden coffin burials were the traditional burial forms found in the Central Plains (Ye, 1994), while stone coffin burials were popularized in Northeast China, and also appeared in the adjacent areas, such as northern Hebei province (Zheng, 2002; Zhou, 2006). Stone coffin burials were only found in LZS during the time of the proto-Shang culture (Zhou, 2006). However, most of the stone coffin burials were more simplified than before (HPICRA, 2007, 2010; Zhao and Han, 2006), indicating that this archaeological culture shrunk and adapted when it moved southwards. Most importantly, the artifacts in the stone coffin burials were similar to those found in the other two types of burials. Moreover, the stable carbon and nitrogen isotopic analyses of human bones show that all humans had quite similar dietary patterns no matter what type of burial they had. Therefore, based on the above discussions, we can conclude that the proto-Shang clan adapted to local cultural and agricultural systems very quickly during the migration from north to south, although some original cultural factors were retained. Obviously the adaptation to local culture and environment, and the integration of local people help to make the proto-Shang culture more vigorous and creative, which might have played an active role in the establishment of the Shang Dynasty.

4. Conclusion

The mean $\delta^{13}C$ and $\delta^{15}N$ values (-7.6 ± 0.6‰; 9.6 ± 1.0‰, $n = 19$) of humans at the LZS except for the two outliers (LZS14, LZS30) suggest that human diets were mainly comprised of C_4-based food, coming from the contribution of millets or animals consuming millet by-products. Based on the isotopic spacing between humans and animals (dogs, pigs, cattle, sheep/goats), we found that dogs, pigs, and cattle were humans' main animal protein resources but sheep/goats were not. Although humans were found in three types of burials, their diets were quite similar. This finding, in combination with the archaeological context, suggests that the proto-Shang humans had adapted to the local culture and environment in the Central Plains very well, and that they had integrated local cultural factors.

Finally, we suggest that a major cause of the integration of local or exotic culture by the proto-Shang clan might be human migration, as humans LZS14 and LZS30 in this study may have been immigrants. To better understand where they came from, other isotope analyses, such as sulfur, hydrogen, strontium, and oxygen, are under way.

Acknowledgments

We thank Melinda Yang (Department of Integrative Biology, University of California, Berkeley) for editing and improving our manuscript. We also thank Ma Ying (Department of Human Evolution, Max-Planck Institute for Evolutionary Anthropology, Leipzig), Guo Yi (Department of Cultural Heritage and Museology, Zhejiang University, Hangzhou), Zhang Guowen (College of History, Naikai University, Tianjin), Tao Dawei (College of History, Zhengzhou University, Zhengzhou) and Chen Xianglong (Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences, Beijing) etc. for the suggestions. We acknowledge the funding from the CAS Strategic Priority Research Program (gs1) (Grant No. XDA05130303, XDA05130501), the CAS Knowledge Innovation Directional Project (gs2) (Grant No. KZCX2-YW-Q1-04), the Chinese Academy of Sciences and the Max-Planck Institute Partnership Group Project (gs3) (Grant No. KACX1-YW-0830), and the Project Supported by National Science and Technology Ministry (gs4) (Grant No. 2010BAK67B03). At last, we are very grateful for the opinions and suggestions from four anonymous reviewers to improve the manuscripts.

References

Ambrose, S.H., 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. J. Archaeol. Sci. 17, 431–451.
Ambrose, S.H., 1991. Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs. J. Archaeol. Sci. 18, 293–317.
Ambrose, S.H., Buikstra, J., Krueger, H.W., 2003. Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone. J. Anthropol. Archaeol. 22, 217–226.
Ambrose, S.H., Butler, B.M., Hanson, D.B., Hunter-Anderson, R.L., Krueger, H.W., 1997. Stable isotopic analysis of human diet in the Marianas Archipelago, Western Pacific. Am. J. Phys. Anthropol. 104, 343–361.
Ambrose, S.H., Norr, L., 1993. Isotopic composition of dietary protein and energy versus bone collagen and apatite: purified diet growth experiments. In: Lambert, J.B., Grupe, G. (Eds.), Prehistoric Human Bone: Archaeology at the Molecular Level. Springer Verlag, Berlin, pp. 1–37.
Balasse, M., Tresset, A., 2002. Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios. J. Archaeol. Sci. 29, 853–859.
Barton, L., Newsome, S.D., Chen, F., Wang, H., Guilderson, T.P., Bettinger, R.L., 2009. Agricultural origins and the isotopic identity of domestication in northern China. Proc. Natl. Acad. Sci. U. S. A. 106, 5523–5528.
Chang, K., 1983. China in the Early Bronze Age. Sanlian Publishing House, Beijing.
Chang, K., 2002. Shang Civilization. Liaoning Education Press, Liaoning.
Chen, W., 2007. China Agricultural History-the Volume of Xia, Shang, Western Zhou Dynasties, and Spring and Autumn Period. China Agriculture Press, Beijing.
CPAMHP (Commission for the Preservation of Ancient Monuments, Heibei province), 1979. Excavations at the site of *Xiaqiyuan* in Cixian, Hebei Province. Acta Archaeol. Sin. (Kaogu Xuebao) (2), 185–214.
CPAMHP (Commission for the Preservation of Ancient Monuments, Heibei province), CPAMCC (Commission for the Preservation of Ancient Monuments of Cangzhou City), 1992. Excavations at the site of *Labazhuang* in Renqiu City, Hebei Province. Stories of Relics (Wenwu Chunqiu) (Suppl. 1), 89–97.
DeNiro, M.J., 1985. Post-mortem preservation of alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature 317, 806–809.
DeNiro, M.J., Epstein, S., 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochim. Cosmochim. Acta 42, 495–506.
Ding, S., 1988. Research on the History of Shang and Zhou Dynasties. Zhonghua Book Company, Beijing.
Duan, T., Tang, M., Zhu, L., 2008. A discussion and thinking of the studies of Xia archaeological culture in the region of Beijing, Tianjin and Baoding. Stories of Relics (Wenwu Chunqiu) (6), 6–10.
Hedges, R.E.M., Reynard, L.M., 2007. Nitrogen isotopes and the trophic level of humans in archaeology. J. Arch. Sci. 34, 1240–1251.
Hou, L., Hu, Y., Li, S., Hou, Y., LV, P., Song, G., Wang, C., Stable isotopes analysis of animals' bones from *Zhangdeng* site, Henan in China: the feeding strategies of domestic animals during poto-Shang culture. Huaxia Archaeol. (Huaxia Kaogu), in press.
Hou, Y., Li, S., Ma, X., Sun, L., 2009. The Exploitation of animal resources at *Zhangdeng* site in Anyang. Cult. Relics Central China (Zhongyuan Wenwu) (5), 38–47.
HPICRA (Henan Provincial Institution of Culture Relics and Archaeology), 2007. Excavation of the proto-Shang (*Xiaqiyuan*) culture cemetery on the *Liuzhuang* site in Hebi City, Henan. Huaxia Archaeol. (Huaxia Kaogu) (3), 22–30.
HPICRA (Henan Provincial Institution of Culture Relics and Archaeology), 2010. Burial custom and institution of the proto-Shang (*Xiaqiyuan*) culture cemetery at *Liuzhuang* in Hebi City, Henan. Huaxia Archeol. (Huaxia Kaogu) (3), 85–89.
Hu, B., Wang, L., 2012. Studies on the variations and periodizations of the proto-Shang culture. In: Aurora Central for Study of Ancient Cilizations, Peking University, Henan Provincial Insitute of Cultural Relics and Archaeology, Hebei Provincial Insitute of Cultural Relics, Zhengzhou Municipal Institute of Cultural Relics and Archaeology (Eds.), Collected Studies on the Early-Xia Culture and Proto-shang Culture (Aurora Central for Study of Ancient Civilizations, Peking University. Publication Series, No. 26). Science Press, Beijing, pp. 296–322.
Hu, Y., Wang, S., Luan, F., Wang, C., Richards, M.P., 2008. Stable isotope analysis of humans from *Xiaojingshan* site: implications for understand the origin of millet agriculture in China. J. Archaeol. Sci. 35, 2960–2965.
JAT (Jumahe Archaeological Team), 1988. Trial excavation of archaeological sites in Yixian and Laishui Counties, Hebei. Acta Archaeol. Sin. (Kaogu Xuebao) (4), 421–454.
Jay, M., Richards, M.P., 2006. Diet in the Iron Age cemetery population at Wetwang Slack, East Yorkshire, UK: carbon and nitrogen stable isotope evidence. J. Archaeol. Sci. 33, 653–662.
Jørkov, M.L.S., Jørgensen, L., Lynnerup, N., 2010. Uniform diet in a diverse society. Revealing new dietary evidence of the Danish Roman Iron Age based on stable isotope analysis. Am. J. Phys. Anthropol. 143, 523–533.
Li, B., 1989. Exploring the proto-Shang culture. In: The Team of the Proceedings for Celebration of Su Bingqi's Fifty Five Years Archaeological Work (Ed.), The Proceedings for Celebration of Su Bingqi 55 Years' Archaeological Work. Culture Relics Press, Beijing, pp. 280–293.
Linderholm, A., Jonson, C.H., Svensk, O., Lidén, K., 2008. Diet and status in Birka: stable isotopes and grave goods compared. Antiquity 82, 446–461.
Liu, H., 2010. Flotation results from the *Zhangdeng* site, Anyang County of Henan. In: The Abstract Proceedings for Celebration of the 10th Archaeometry Forum, Beijing, pp. 19–20.
Liu, L., Zhou, X., Yu, Y., Guo, Z., 2011. The natural vegetations on the Chinese Loess Plateau: the evidence of soil organic carbon isotope. Quat. Sci. (Disiji Yanjiu) 31, 506–513.
Makarewicz, C., Tuross, N., 2006. Foddering by Mongolian pastoralists is recorded in the stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of caprine dentinal collagen. J. Archaeol. Sci. 33, 862–870.
Marino, B.D., McElroy, M.B., 1991. Isotopic composition of atmospheric CO_2 inferred from carbon in C_4 plant cellulose. Nature 349, 127–131.
McGovern, P.E., Zhang, J., Tang, J., Zhang, Z., Hall, G.R., Moreau, R.A., Nuñez, A., Butrym, E.D., Richards, M.P., Wang, C., Cheng, G., Zhao, Z., Wang, C.S., 2004. Fermented beverages of pre- and proto-historic China. Proc. Natl. Acad. Sci. U. S. A. 101, 17593–17598.
Ogrinc, N., Budja, M., 2005. Paleodietary reconstruction of a Neolithic population in Slovenia: a stable isotope approach. Chem. Geol. 218, 103–116.
Pearson, J.A., Buitenhuis, H., Hedges, R.E.M., Martin, L., Russell, N., Twiss, K.C., 2007. New light on early caprine herding strategies from isotope: a case study from Neolithic Anatolia. J. Archaeol. Sci. 34, 2170–2179.
Richards, M.P., Hedges, R.E.M., Molleson, T.I., Vogel, J.C., 1998. Stable isotope analysis reveals variations in human diet at the Poundbury Camp Cemetery site. J. Archaeol. Sci. 25, 1247–1252.
Richards, M.P., Jacobi, R., Cook, J., Pettitt, P.B., Stringer, C.B., 2005. Isotope evidence for the intensive use of marine foods by Late Upper Palaeolithic humans. J. Hum. Evol. 49, 390–394.
SAMZU (School of Archaeology and Museology, Zhengzhou University.), ATKC (The Archaeological Team, Kaifeng City.), 2000. Excavation of Qi County Site, in Eastern Henan. Science Press, Beijing.
SAMZU (School of Archaeology and Museology, Zhengzhou University), ATKC (The Archaeological Team, Kaifeng City.), CPAMQC (The Commission for the

Preservation of Ancient Monuments of Qixian City.), 1994. Excavation of Lutaigang site in Qi County, Henan. Archaeology (Kaogu) (8), 673–682.

Shen, Y., 1991. Two Bronze cultures in the northern of Baoding in Xia Dynasty. Acta Archaeol. Sin. (Kaogu Xuebao) (3), 85–89.

Thompson, A.H., Chaix, L., Richards, M.P., 2008. Stable isotopes and diet at ancient Kerma, Upper Nubia (Sudan). J. Archaeol. Sci. 35, 376–387.

Tsou, H., 1980. Studies of the Hsia Culture, Essays on the Archaeology of the Hsia, Shang, Chou Dynasties. Culture Relics Press, Beijing.

Wang, C., Zhao, X., Jin, G., 2010. Flotation results from the *Liuzhuang* site, Hebi City of Henan. Huaxia Archaeol. (Huaxia Kaogu) (3), 90–99.

Wang, L., Hu, B., 2011. Studies of the proto-Shang culture. In: School of Archaeology and Museology, Peking University, The Center for the Study of Chinese Archaeology in Peking University (Eds.), A Collection of Studies on Archaeology (VIII)-Festschrift of the 5th Anniversary of Zou Heng's Death. Science Press, Beijing, pp. 179–193.

Wang, Z., 2010. The Origin of Shang Tribe and Social Changes in Proto-Shang Period. China Social Sciences Press, Beijing.

Wei, X., 1999. Studies on Lutaigang variant of the proto-Shang (*Xiaqiyuan*) culture. Archaeology (Kaogu) (5), 65–74.

Yang, X., Wan, Z., Perry, L., Lu, H., Wang, Q., Zhao, C., Li, J., Xie, F., Yu, J., Cui, T., Wang, T., Li, M., Ge, Q., 2012. Early millet use in northern China. Proc. Natl. Acad. Sci. U. S. A. 109, 3726–3730.

Ye, X., 1994. History of Development of Tombs in China. Guansu Culture Press, Lanzhou.

You, X., 2008. Chinese Agricultural History-the Volume of Pre-history Period. China Agriculture Press, Beijing.

Zhao, X., Han, C., 2006. Main results of the excavation during 2005 at Liuzhuang Site in Hebi City, Henan. In: Oriental Archaeology Research Center of Shangdong University (Ed.), Oriental Archaeology (Dongfang Kaogu), vol. 3. Science Press, Beijing, pp. 195–203.

Zhao, Z., 2005a. Studies on the original of agriculture and civilization: a paleo-ethnobotany perspective. Manage. Rev. Soc. Sci. (Shehui Kexue Guanli Yu Pinglun) 2, 82–91.

Zhao, Z., 2005b. Study on agricultural economy in Central Plains, China, from 2500 BC to 1500 BC. In: Yuan, J. (Ed.), The Proceedings for Archaeometry (2). Science Press, Beijing, pp. 1–11.

Zheng D., 2002. An archaeological Research on the Remains of Sarcophagus Burials in the Northeast of China During the Bronze Ages. A paper for the Doctor Degree of Institute of Archaeology. Chinese Academy of Social Sciences, Beijing.

Zhou J., 2006. An Analysis on Sarcophagus Burials in the Adjacent Areas of Inner Mongolia, Liaoning and Hebei Provinces During Shang and Zhou Dynasties. A Paper for the Master Degree of Minzu University of China, Beijing.

Zhu, Y., 2007. The Origin, Migration and Development of Shang Clan. The Commercial Press, Beijing.