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Temporal trends in millet consumption in northern China

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ABSTRACT

Temporal trends in prehistoric millet consumption are investigated in two regions of northern China, in the Wei River valley and a northern zone that encompasses north-eastern Shaanxi, western Shanxi and south-central Inner Mongolia. By directly radiocarbon dating each sample investigated, inferences about the timing of dietary shifts inferred from stable carbon and nitrogen isotope compositions can be made with a high degree of precision. Evidence presented here indicates that humans living around 4000 years ago in both the Wei River valley and the northern zone were heavily dependent on millet for their subsistence. By ca. 2500 cal. yr BP, a major diversification of diet had occurred in the Wei River valley, with some consuming much larger proportions of C3 foods than previously. These C3 foods may have included the western-derived cereals – wheat, barley and oats – and also rice.

1. Introduction

The means by which populations procure food has broad-ranging impacts on how societies develop and how the landscapes in which they live evolve. Few regions of the world have as long a history of agriculture as the middle and lower reaches of the Yellow River valley and few regions are dealing with impacts on land and water resources, related to agricultural activities, that are on such a grand scale (Sato et al., 2008; Saito et al., 2001; Liu and Xia, 2004; Tong et al., 2004).

Farming commenced in the Yellow River valley when the Asian millets began to be cultivated there around 10,000 years ago (Lu et al., 2009). Neolithic cultures persisted in that region until state-level societies and bronze age cultures were established at around the commencement of the second millennium BC (Liu and Chen, 2003, 2012). Neolithic cultures of the region utilised a mix of food sources. Archaeological investigations find remains of the Asian millets (*Panicum miliaceum* and *Setaria italica*) alongside remains of harvested and hunted wild foods such as nuts (*Corylus*, *Castanea*), molluscs and deer (e.g. Bettinger et al., 2010; Li et al., 2012, 2007b; Liu, 2004). Of the domestic animals present in this region, pig and dog remains are dominant for the Neolithic period, however remains of other domestic animals such as sheep/goat and cattle are also encountered (Barton et al., 2009; Chen et al., in press; Flad et al., 2007).

The suite of cultigens available to Neolithic farmers in northern China expanded with time. Seed assemblages indicate that rice (*Oryza sativa*), which has an origin in the Yangtze River valley to the south, had been adopted in the Wei River valley and lower Yellow River region by ca. 3000 BC (Lee et al., 2007). Buckwheat (*Fagopyrum* sp.) and soy bean (*Glycine* sp.), which may or may not have been a domestic variety, also appear to have been farmed (Li et al., 2007a). Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and oats (*Avena* sp.), which originate in western Eurasia, are present in seed assemblages from Neolithic sites in northern China. The oldest firm evidence of these cereals come from sites in Gansu, Xinjiang and possibly Shandong, and date to around the mid to late third and early second millennia BC (Jin et al., 2011 in Betts et al., in press; Dodson et al., 2013; Flad et al., 2010; Li et al., 2011, 2007a). Recent reviews have explored potential routes by which these cereals were transmitted there (Betts et al., in press; Dodson et al., 2013; Flad et al., 2010).

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By the time that state-level societies were established in the Wei River valley, commencing with the Erlitou (ca. 1900–1500 BC), a broadened suite of cultigens were available to farmers. Both archaeobotanical surveys (Lee et al., 2007) and stable isotope studies of human remains (Hou et al., 2012) indicate a gradual diversification of diet, away from a high dependence on millet, through pre-dynastic and early dynastic time periods. However, these periods have not received large amounts of attention by researchers interested in dietary reconstruction. This study aims to further understanding of temporal changes in millet consumption, from the Neolithic period to the later dynasties, and in parallel understand how the appearance of new C3 cultigens in the Yellow River valley affected diets. Unlike previous stable isotope studies focused on reconstructing diet, this study emphasises the importance of directly dating each bone sample analysed, in order to identify more precisely when large dietary shifts occurred. By directly dating the bone specimens themselves, precision surrounding sample age increases. With a high degree of certainty for the radiocarbon age of a sample, variability in stable isotope signatures can be better assessed to identify influencing factors, such as geographic location or social factors such as migration or gender.

2. Use of stable carbon isotope analysis to reconstruct diet in northern China

Stable carbon isotope analysis of bone remains is particularly useful for assessing past subsistence practices in northern China, as the principle prehistoric cultigens – the Asian millets – are C4 plants and thus contrast with the other pre-historic plant foods in their carbon isotope composition. Millet consumers can be distinguished by the ^{13}C-enriched nature of their remains. The method becomes more complicated in the Inner Mongolian steppes, where wild C4 plants are more abundant and are utilised by grazing and browsing herbivores (e.g. Auerswald et al., 2009; Wang, 2003).

The use of stable isotope analysis to distinguish millet consumption amongst prehistoric inhabitants of northern China has been described in detail by previous authors (e.g. Atahan et al., 2011; Barton et al., 2009; Chen et al., in press; Pechenkina et al., 2005). While estimating absolute proportions of millet plants or millet fed animals in ancient diets using bone $\delta^{13}C$ values can be problematic, due to the uncertainty surrounding isotopic composition of each food available to the individual during life. The method is useful for assessing changing proportions of dietary components through time and within populations. General categories for describing C3 and C4 food consumption in northern China have been developed: individuals with bone collagen $\delta^{13}C$ values $\leq -18‰$ are typically interpreted to be mainly C3 food consumers; those with $\delta^{13}C$ values between $-18‰$ and $-12‰$ are interpreted to be mixed C3 and C4 food consumers; and those with $\delta^{13}C$ values $\geq 12‰$ are interpreted to be mainly C4 consumers (Barton et al., 2009; Ma et al., 2014; Pechenkina et al., 2005).

3. Study regions

3.1. Wei River valley

The Wei River is the largest tributary of the Yellow River. It flows from west to east across modern-day Gansu and Shaanxi Provinces, before its confluence with the Yellow River near Tongguan. The Wei River valley is bordered to the south by the Qinling Mountains and to the north by the Loess Plateau. The climate of the area is characterised by cold dry winters and moist warm summers. Precipitation is strongly influenced by the East Asian Monsoon, and averages around 500–600 mm/year.

The earliest settled agriculturalists in the Wei River valley belonged to the Laoguantai Culture (ca. 8000–7000 BP). A low number of sites discovered to date result in relatively little being known about them, however existing evidence indicates that they were cultivating millet to provision both themselves and their domestic dogs and pigs with food (Barton et al., 2009; Bettinger et al., 2010). The Neolithic Yangshao (ca. 7000–5000 BP) and Longshan (ca. 5000–4000 BP) periods followed, after which the region was incorporated into the broad-reaching Erlitou state which had a centre in the Yiluo Basin to the east (Liu and Chen, 2012). The Wei River valley has played important political and cultural roles through the Chinese Dynasties. During the Western Zhou Dynasty (ca. 1100 BCE – 770 BCE), the capital was located at Fenghao to the south of modern-day Xi'an; and then during the Qin (221 – 206 BCE), Sui (581–618 CE), Tang (618–907 CE) and parts of the Han (206 BCE – 220 CE) Dynasties, the capital was located near to or at Xi'an (Lu and Yan, 2005; Xu, 2005). Currently large numbers of people inhabit the fertile alluvial plains of the Wei River, and many of these currently reside in large cities such as Xi'an and Baoji.

Samples from the Wei River valley region in the present study derive from six archaeological sites: Fenggeling, Lintong, Lixian, Xungyi, Yuhuazhai and Zhanguo. Small samples of bone were obtained from Northwest University's Institute of Archaeology collection. Site locations are shown in Fig. 1.

3.2. Northern zone

The northern zone here broadly refers to land following the southwards flowing section of the middle Yellow River, incorporating north-eastern Shaanxi, western Shanxi and south-central Inner Mongolia. The region has deeply incised river valleys and alluvial plains, sandy and loess dominated arid areas and elevated steppes. A strong precipitation gradient occurs from the southeast to the northwest of the region, spanning from around 500–600 mm/yr in the southeast and to around 300–400 mm/yr in the northwest.

Occasionally referred to as 'The Northern Frontier', this region is considered to have been a cultural and ecological transition zone since at least the emergence of state-level societies and bronze age cultures around 4000 years ago. Settled agricultural economies have traditionally dominated the climatically more moderate areas to the south, and nomadic pastoral or agro-pastoral economies have dominated the more arid steppe areas to the north (Huang and Su, 2009). The location of the boundary between these distinctly different economies appears to have been responsive to past changes in climate, whereby during moist periods when the summer monsoon was strengthened, agricultural societies expanded northwards, while during periods of drought or unstable conditions, the boundary moved southwards (Huang et al., 2002, 2003; Huang and Su, 2009; Zhou et al., 2012).

Bone samples from the northern zone were collected from five sites during part of a broader study on the ecological history of the region. The location of these sites – Dakou, Shimao, Xinhua, Xinhuacun and Zhukaigou – are shown on Fig. 1. Information about archaeological remains has previously been provided by Dodson et al. (2014), Flad et al. (2007), Linduff (1995) and Liu and Chen (2012).

4. Methods

4.1. Collagen preparation

Bone collagen from 27 samples of human bone was prepared for isotope analysis using the ultrafiltration method described by Brock et al. (2007), Bronk Ramsey et al. (2004), Brown et al. (1988) and