Archaeological Research in Asia 4 (2015) 25–35

Contents lists available at ScienceDirect

Archaeological Research in Asia

journal homepage: www.elsevier.com/locate/ara

Isotopic evidence for the expansion of wheat consumption in northern China

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ARTICLE INFO

Article history:
Received 12 August 2015
Received in revised form 23 October 2015
Accepted 26 October 2015
Available online 12 November 2015

Keywords:
Northern China
Wheat
Agriculture
Dietary staples
Stable carbon isotopes

ABSTRACT

Flotation and carbon dating indicate that wheat was introduced into northern China, where millet agriculture had existed for thousands of years, around 3000–2000 BC. Wheat eventually replaced millet as the staple of northern Chinese diets, but it is still unclear how it was added to the established agricultural system and when millet finally lost its staple role to the imported crop. Because wheat and millet have distinct $\delta^{13}C$ values, stable isotope analysis offers an opportunity to answer these questions. Here, we review published stable isotope data for 645 human samples from 36 sites in northern China, dating from 3000 to 2000 BC to the sixth century AD, summarizing the current evidence for dietary changes since the appearance of wheat. The results indicate that wheat had little influence on human nutrition at its first appearance. The first possible evidence for wheat consumption is seen in Xinjiang about 1800 BC. Further east in Qinghai and Gansu, a shift from C4-based diets to mixed C4/C3-based diets occurred between 2000 and 1500 BC. In areas further east, millet continues to dominate human diets for the following two millennia, although wheat has been widely recovered in archeological contexts and its importance in agriculture was recorded in contemporary documents. It was only in the sixth century AD that C3 crops became important in human diets in the east of northern China. This is quite different from the scenario depicted by palaeobotanical studies, and illustrates the need for further stable isotope analysis of human and faunal remains to better characterize the millet-wheat transition in northern China.

1. Introduction

China has long been an agricultural society. Archeological evidence shows that the earliest agricultural communities appeared in northern China no later than 8000 years ago (Lu, 1999, pp. 132–133). Ever since its earliest stages, agriculture and diet in northern China and its contemporary southern part, the division of which is marked by the Qinling-Huaihe Line, developed different features due to varying geographical and environmental conditions. Most notably, while millet was the predominant staple food in Northern China for thousands of years after the advent of agriculture, the people of the south long preferred rice (Wang and Xu, 2003; Liu and Xiang, 2005).

Floral remains from archeological sites support the predominance of millet in northern China in Neolithic times. For example, at Cishan, dated to about 5300 BC, remains of stored millet were found in 88 pits with a thickness of deposition varying from 0.2 to 2.9 m and an estimated total weight exceeding 50 t (Sun et al., 1981; Tong, 1984), reflecting the maturity of millet agriculture at this site and the importance of this crop to its people. Dietary studies using stable isotope analysis of human and animal bones also reveal millet's significant contribution to ancient human diets in northern China (Pechenkina et al., 2005; Barton et al., 2009).

However, the current situation differs greatly from ancient times. In modern China northerners eat far less millet than their ancestors, focusing their diets instead on wheat-based foods including various types of noodles, dumplings, and breads (Huang, 2014). This is reflected in stable isotope measurements on modern hair, which indicate a diet focusing on C3 resources (Thompson et al., 2010). In contrast, people of the south still prefer rice as their ancestors did. Item 74 of Chapter 11 of The Seed Law of the People's Republic of China, issued in 2004, appointed wheat as one of the five main agricultural crops of the nation, the other four of which were the two staple crops rice and maize and two economic crops, cotton and soybeans. It is obvious that millet had lost its predominance as a staple food in modern China, while the role of wheat has been elevated to key importance. This raises two questions: when did the replacement of millet by wheat happen, and how did wheat expand in northern China?

In this study we assemble 645 published stable isotope values for human bones from 36 sites in northern China dated from 3000 BC to the sixth century AD, suggesting a shift in human diets in ancient

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http://dx.doi.org/10.1016/j.ara.2015.10.001
2352-2267/

northern China over this time. Following this, we investigate the process of wheat's introduction into human diets and the replacement of millet by wheat as the staple food by comparing the isotope data with archeological flotation studies and documentary evidence.

2. Evidence for wheat in ancient China

Archaeobotanical and genetic studies show that the earliest domestication of wheat took place about 10,000 years ago in the Fertile Crescent (Heun et al., 1997; Nesbitt and Samuel, 1998; Özkan et al., 2002). In China, whether wheat was initially an imported crop or was independently domesticated from local wild varieties was debated for decades. Although some have argued that wheat is an aboriginal crop in China (e.g. Li, 1980, 1993; Cao, 1983), now more are inclined to the opinion that the earliest wheat in China originated from Western Asia (e.g. Zhao, 2005; Cao, 2008; Zhao, 2009a, 2009b; Betts et al., 2014; Jin, 2007; An et al., 2013; Boivin et al., 2012; Dodson et al., 2013; Barton and An, 2014).

The earliest suggested evidence for wheat in ancient China was recovered from Miaodigou, dated to about 5000 BC, in the form of wheat seed impressions on burnt earth (Li, 1993). However, Jin (2007) has argued that this can only be considered tentative evidence because of the obscurity of the impressions, which could be interpreted as either wheat or barley. From a detailed analysis of reliable archeological flotation results, Jin (2007) argues that the earliest appearance of wheat in ancient China was in the Longshan Period, the terminal stage of Neolithic culture in China dating to 3000–2000 BC. Recent radiocarbon dates on wheat remains support this viewpoint (Dodson et al., 2013). Wheat remains have been widely discovered in fully domesticated form at sites from the western end of northern China to its eastern peninsula in this period, suggesting a sudden and widespread expansion (Jin, 2007). Wheat is also repeatedly reported at sites spanning the transition from the terminal Neolithic to the early Bronze Age (Zhao, 2007; Liu and Fang, 2010).

In the Bronze Age, the Chinese character for wheat has been identified among the oracle bone inscriptions (Song, 2002; Fan, 2002), the earliest systematic Chinese characters carved on bones and tortoise shells 3500 years ago. These inscriptions also record official sacrifices and ceremonies for the planting and harvesting of wheat and barley (Fan, 2002), revealing the significance of wheat in the Bronze Age Shang dynasty. From then on, the gradual development of wheat cultivation is evidenced by records in later documents. Some experts even regard the expanded cultivation of wheat as one of the important factors that promoted the first union of China by Qin in the third century BC (Zhao, 2005; Zhao and Bei, 2011).

After its first union, China stepped into a prosperous dynasty, the Han (202 BC to 220 AD). According to historical records the most important crops of this period were millet, wheat and barley, and the government once sent agricultural experts to promote the cultivation of wheat in some areas around the capital city (Hsu, 2005, pp. 79–81). Knowledge about wheat cultivation was recorded in agricultural books and wheat was even mentioned in the nursery songs of the second century AD, reflecting its wide acceptance by people of that time (Hsu, 2005, p. 81).

Although scholars from various disciplines argue for an early predominance of wheat in ancient agriculture in northern China as well as in human diets (e.g. Li, 1993; Jin, 2007; Zhao, 2005; Hsu, 2005, p. 81; Dodson et al., 2013), there are also voices of disagreement. In their correspondence to Dodson et al. (2013), An and colleagues (An et al., 2013) point out that wheat was much less important than millet in archaeobotanical assemblages for thousands of years, arguing that its inferior status lasted to the mid-Tang Dynasty (618 to 907 AD), when the historical documents still referred to it as one of the "miscellaneous grains". Wang (2000, p. 70) is also cautious about the importance of wheat in early agriculture and argues that it is better not to overstate the prevalence of wheat in northern China during the Qin and Han dynasties (221 BC to 220 AD), although the documents do imply an increase in its cultivation. Other records suggest that wheat cultivation was only fully developed after the North and South Dynasties (420 to 589 AD), and that it did not gain an equal status to millet until the mid-Tang Dynasty (618 to 907 AD) (Wang, 2000, pp. 71–72). Zeng (2005) has further suggested that the predominance of wheat in northern China was not established until the Tang and Song Dynasties (7th to 13th centuries AD).

While our paper focuses on wheat use, it must be recalled that wheat was not the only outside cultivar introduced to ancient China. Notably, the remains of barley have occasionally been discovered together with wheat in northern China starting in Neolithic times. Barley remains are less common than wheat, and this co-occurrence is seen at a very low frequency (Jin, 2007). Barley use from an early era is also confirmed by likely references to it in oracle bone inscriptions of the Shang Dynasty (Fan, 2002; Song, 2002). However, the very low frequency of archeological and literary records of barley in comparison to wheat indicates that it was very likely a minor crop, of much less importance than wheat.

The significance of wheat in ancient northern Chinese agriculture is unarguable, but when this introduced crop began to challenge the importance of millet in agriculture and human diets and finally gained predominance is still open for debate. It seems that flotation evidence from early sites and clues from historical documents, the basis for arguments so far, are not enough to answer this intriguing question.

3. Agricultural crops and human diets

The influence of a new crop on an existing agricultural society may appear in different ways. Imported crops may exert great influence on a local society and eventually change its dietary habits. The story of the potato serves as a good example. This imported crop from South America, initially regarded with suspicion by Europeans, became a staple crop by the mid-nineteenth century with estimated per capita daily consumption rising well above 500 g in nations such as Holland and Belgium (Messer, 1997; Ó Gráda, 2006). The additional food energy provided has been proposed as a contributing factor to the Industrial Revolution (Komlos, 1998). Its crucial importance reached a peak in Ireland, with estimated per capita consumption in some areas rising above 2 kg (Ó Gráda, 2006). The Great Irish Famine (1846–1852), catalyzed by failure of the potato harvest due to potato blight, resulted in over a million deaths in a population of roughly eight million — an indication of the extent to which diets had come to depend on this crop less than 300 years after its introduction to the area (Japikse, 1994; Ó Gráda, 2006; Ó Gráda and Mokyr, 2006).

The adoption of a crop outside its place of origin, where it is treated as a staple food for people, may not always be due to its importance in human diets. The New World cultivar maize is now one of the most important crops throughout the world, but its importance in agriculture is not always reflected in direct consumption by humans. For example, statistics from the 1990s (CIMMYT, 1994, p. 52) showed 64% of the world's maize production to be used for animal feed, with only 21% destined for direct human consumption. The situation varied among different socioeconomic environments, with as much as 40% of the total maize production directly consumed by humans in some nations and as little as 4% in others with little tradition of culinary maize use.

The story of the potato in Europe illustrates that an imported crop can eventually transform an existing agricultural diet. At the same time we should not forget that for biological and cultural reasons it took almost 300 years for potatoes to be accepted by people throughout Europe (Messer, 1997). As well, the adoption and development of a new crop outside its original range may not necessarily be for human consumption, as evidenced by the situation of maize.

Inspired by the story of potatoes and maize, we should question whether the prevalence of wheat in ancient China evidenced by flotation results and documentary evidence was consistent with its actual