Contribution of Bone Chemistry and Ceramic Residues to Dietary Adaptations During the Longshan Period, Shandong, China

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Introduction

In northern China, by the late Neolithic period diets were based on millet, rice, and domesticated animals, but the degree of dietary variation is not known. At the site of Liangchengzhen in Shandong province, archaeobotanical remains attest to the importance of rice and millet. Stable carbon and nitrogen isotope analysis of human skeletal remains is a well-established technique for determining the dietary contributions of terrestrial and marine foods, as well as C4 plants in otherwise C3 systems. Our continuing isotopic analyses provide complementary, quantitative data for the relative importance of these isotopically diverse food groups, in addition to preliminary data that identify residues from ceramics sherds.

Liangchengzhen and other sites in China with stable isotope data.

Diet in Ancient China

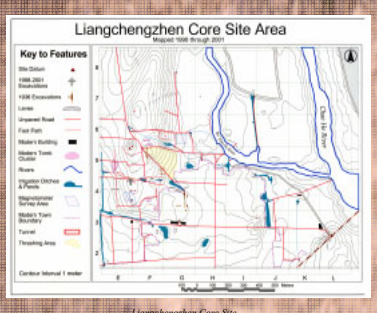
During the last decade, more information about regional variability in dietary and agricultural practices during the Neolithic period of China has become available (Cohen 1998; Crawford et al. in press; Lu, 1999; Pechenkina et al. 2002; Underhill 1997). In particular, the increased use of flotation to systematically collect macrobotanical remains is showing that these practices were more diverse than previously realized, with a considerable range in northern China alone. In Shandong, both millet and rice have been found at a number of sites from the late Neolithic period, including Longshan period sites, ca. 2600-1900 BC (Crawford et al. 2005). Domesticated animals in Shandong province and other parts of northern China likely included pig, dog, and cattle.

Burial M35 with pots at Liangchengzhen

Liangchengzhen

Liangchengzhen is a Longshan period site within the Rizhao district of southeastern Shandong. A systematic, regional survey has established that Liangchengzhen was a large regional center with smaller, neighboring settlements clustered around it (Underhill et al. 1998; 2002). A collaborative Sino-American excavation involving Shandong University and The Field Museum took place from October-December, 1999-2001.

The preservation of all bone (animal and human) was very poor, probably due to water retention in the clayey soil. Good samples of macrobotanical remains, including both rice and millet, were recovered. Based on discoveries at other Longshan period sites in Shandong, the geographic location of Liangchengzhen, and the diet of its modern residents, we expect that the residents of the Longshan period town also would have consumed domesticated animals such as pig, and both riverine and marine resources.



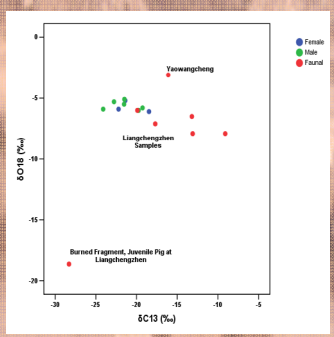
Liangchengzhen Core Site

Stable Isotope Analysis

Stable isotope analysis can differentiate between C3 and C4 terrestrial diets in humans and animals. C3 plants have a δ13C value averaging about –26‰, whereas C4 plants have δ13C values averaging -12‰. Nitrogen isotope ratios (δ15N), which are generally similar among plants, do increase with trophic level, and are also generally higher in aquatic than in terrestrial systems. These natural differences in carbon and nitrogen isotope ratios of plants and animals are passed on to their human consumers, and thus archaeological samples of bones and teeth may be analyzed to measure the relative importance of isotopically diverse food groups.

Ding tripod vessel. Results for guan jar residues are reported here; analyses of ding tripods in progress..

Carbon isotope ratios may be measured in two different bone tissues - collagen (a protein) and apatite (the bone and tooth mineral) - while nitrogen is only present in collagen. Controlled dietary studies have demonstrated that the δ13C values of collagen mainly reflect the contribution of dietary protein, while bone apatite and tooth enamel reflect the whole diet (e.g. Ambrose & Norr 1993). In addition, bone collagen and apatite are constantly resorbed and regenerated, and thus reflect diet over at least the last several years of an individual's life, while tooth enamel apatite reflects diet only during the age of crown formation. Metabolic processes in the formation of these tissues result in isotopic fractionation, so that collagen is enriched about 5‰ in δ13C and 2-3‰ in δ15N, while bone and tooth enamel apatite are enriched about +12‰ in δ13C.



δ13C and δ18O values may indicate a different geographic origin for the juvenile pig at Liangchengzhen. Yaowangcheng is a Longshan site 29 kilometers northwest of Liangchengzhen

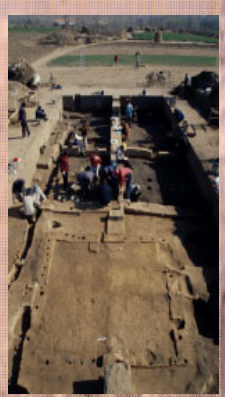
Analytical Methods

Our continuing research on subsistence at Liangchengzhen during the Longshan period is an attempt to document the relative importance of millet and rice as well as terrestrial domesticates and aquatic resources. Unfortunately, no collagen was extracted from the bone.

The present analysis of human remains focused on the enamel from fourteen individual teeth plus one bone apatite sample, as well as six porcine faunal apatite samples for which established laboratory protocols were followed to remove any nonbiogenic carbon contaminants (Koch et al. 1997).

Previous isotope analysis at Liangchengzhen included two human enamel samples, a single faunal molar sample, along with several solid residues from two *guan* jar pottery sherds excavated at the site. A baseline for interpreting human results was previously established by analysis of 27 modern fish from the Yellow Sea, freshwater fish, and rice from the Rizhao area.

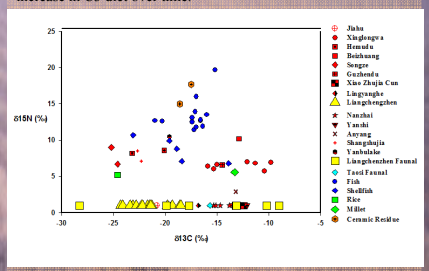
All samples were prepared at the Laboratory for Archaeological Science in the Department of Anthropology. Stable isotope analysis by mass spectrometry was performed at the Stable Isotope Laboratory, also at the University of South Florida.



Residential excavation at Liangchengzhen

Results and Discussion

The isotope results for the human apatite sample and 14 tooth enamel samples average -9.8‰ (–6‰ to -12‰) and suggest that diet was based on foods ranging from –18‰ to -24‰. Since rice and other C3 plants average about -26‰, these results indicate that while some individuals consumed a significant amount of C4 plants, or animals which ate C4 plants, or marine foods in childhood, others had a diet high in C3 foods. Results from one individual indicated a difference in diet from childhood (2nd molar –9.5‰) to adulthood (-7.8‰, bone apatite). The variation in isotopic values cannot be differentiated by social rank at this time. The δ13C values for Liangchengzhen males suggest a diet with more C3 foods than Liangchengzhen females, although additional human samples need to be analyzed to confirm the trend. The rice sample tested, along with a published value for millet, indicate that the values for C3 and C4 plants are about the same in China as elsewhere. The fish tested, however, average about -17‰, which is more negative than commonly found for marine fish in other world regions. The very positive δ13C value (-1‰ average) obtained for early Longshan pig molars indicates nearly complete dependence on C4 foods, and is similar to the result obtained on collagen from a pig sample at Taosi, another Longshan site (Cai & Qiu 1984). The pig molar δ13C values from middle Longshan (-6.4‰ average) and late Longshan (-10.9‰ average) indicate an increase in C3 diet over time.



Estimated Dietary Values from Bone and Tooth Enamel, Compared with Food Samples (human collagen values (red) have been corrected to represent diet (d13C + 5; d15N + 3). Liangchengzhen apatite values have also been corrected to represent diet (d13C + 12 for humans and d13C + 9 for the faunal bone sample to represent flesh), with d15N values arbitrarily-assigned a value of 1. Taosi faunal collagen value has been corrected to represent flesh (d13C + 2), and d15N was arbitrarily assigned a value of 1.

These results strongly suggest that by the Longshan period domesticated animals were mainly fed millet, with more C3 foods included by the late Longshan. (Yuan & Flad 2002). The δ13C and δ18O values of -19.3 and -15.6, respectively, for the burned juvenile pig fragment from Liangchengzhen suggests a different geographic origin and may have been offered as a gift from another region. The solid residues from the two pottery vessel samples produced δ13C values averaging -18‰ and δ15N values averaging +16‰, strongly suggesting that both vessels contained fish. Since the human isotopic results from Liangchengzhen, as well as the macrobotanical remains and ceramic residues, clearly indicate the incorporation of non-C3 plants/animals in the diet, but the fish are not very positive in d13C values, it would appear that a significant amount of millet and/or domesticated animals fed millet was consumed. Even if fish were not important, millet and millet-fed animals could not have comprised more than 25-30% of the diet. Unfortunately, without collagen samples to provide nitrogen isotope results for the Liangchengzhen individuals, we cannot estimate the relative contribution of aquatic foods.

Conclusions

The isotopic data available from other sites in China illustrate a great range of variation based on geography and chronology. In the earlier Neolithic, millet must have been the staple crop at Xinglongwa in northeast China, and Guzhendu in northeastern Shandong, with collagen δ13C values around -14‰ suggesting that it comprised not only the dominant part of the whole diet but also perhaps half of dietary protein (Zhang et al.2003). Millet is not noticeable, however, at Hemudu and Songze in the lower Yangzi river valley of southern China, where collagen δ13C values average about -23‰. The Liangchengzhen results suggest that by the Longshan period, the people in this area of Shandong no longer relied as heavily on millet, while it was probably the main source of fodder for domesticated animals such as pigs. This suggests that other agricultural crops, especially rice, had increased in importance for direct human consumption.

The recovery of macrobotanical remains from other sites, and analyses of pottery residues and faunal remains, will shed further light on subsistence adaptations in this region. This small study has shown the utility and advantages of the methods used by providing an independent analysis that complements the study of diet from macrobotanical and faunal remains.

Acknowledgments

Excavations at Liangchengzhen were made possible by the National Bureau of Cultural Relics in Beijing, the Shandong Province Institute of Archaeology, Shandong University, the Rizhao City Museum, and The Field Museum. Charcoal macrobotanical samples are analyzed by Gary Crawford and Gyoung-Ah Lee at the University of Toronto, and by Zhijun Zhao at the Institute of Archaeology, Beijing. The site map was prepared by Geoffrey Conrad (Yale U.) and Rob Quick (U. of Illinois-Chicago), while Ethan Goddard (U. South Florida) assisted with the mass spectrometric analysis of the samples. Yu Huang (U. of South Florida) provided translations of the Chinese journal articles. Background photo by Chris Needs. Burial photos by Anne P. Underhill.

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