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Case report

Diet and subsistence mode of Neolithic Yuan-Shan people in Taiwan: Perspective from carbon and nitrogen isotope analyses of bone collagen

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ABSTRACT

Carbon and nitrogen stable isotope analyses were conducted on Neolithic Yuan-Shan faunal bone collagen to reconstruct a site-specific dietary isotope baseline, and to evaluate the contribution of potential food resources to the diet of Yuan-Shan people. The mean $\delta^{13}C$ and $\delta^{15}N$ values of terrestrial mammals were −17.7 ± 3.6‰ and 5.4 ± 1.3‰, respectively. The mean $\delta^{13}C$ and $\delta^{15}N$ values of freshwater fish were −20.8 ± 2.2‰ and 7.7 ± 2.0‰; while the marine fish had the highest mean $\delta^{13}C$ (−11.8 ± 1.2‰) and $\delta^{15}N$ values (12.1 ± 1.7‰). Combined with archeological evidence and previous isotopic data derived from Yuan-Shan human bone collagen, we suggest that the subsistence strategies of Yuan-Shan people were broad. They relied on rice cultivation, hunting, fishing and gathering food resources from the wild; in addition, they probably raise pigs, as early as 4200 yr BP. Although the Yuan-Shan people relied on broad-spectrum food resources, the foods they mainly consumed were terrestrial herbivores and freshwater fish based on the result of multi-source mixing model. Besides, marine fish, shellfish, and C_3 plants also contributed substantially to their diet. By comparison, the contribution of C_4 plants was minor.

1. Introduction

Research on subsistence strategies of prehistoric human groups has attracted great attention in anthropological and archeological communities. Discovering where, how, when and why prehistoric human groups changed their subsistence practices and adopted new strategies plays a significant role in understanding the nature and evolutional processes of human societies, and material flow and food transportation across human groups (cf. Johnson and Earle, 2000). It is generally believed that the human groups in East Asia practiced hunting, fishing, and collection of wild food resources as their subsistence modes during the late Pleistocene epoch between ca. 35,000 and 10,000 calibrated years before present (yr BP) (e.g. Chen, 2006; Gao and Pei, 2006; Norton and Gao, 2008). Their subsistence strategies gradually changed to cultivating plants in the warm Holocene epoch (since 10,000 yr BP) – for example, millet in northern China and rice along the Yangtze River (Nakamura, 2010; Zhao, 2011) – and to raising animals (Yuan and Flad, 2002; Liu et al., 2004; Huang, 2010; Larson et al., 2010; Yuan, 2010) in order to increase and stabilize food resources. The development of agriculture and animal husbandry supported population growth (Fuller and Qin, 2009) and triggered population migration to new areas, one of which was Taiwan (e.g. Bellwood, 2011; Bellwood and Dizon, 2005; Fuller, 2011). Some of these immigrants moved to northern and southern Taiwan and probably started plant cultivation in southern Taiwan at ca. 5000 yr BP, evidenced by cultivating tools and certain numbers of rice and millet remains (Tsang et al., 2006). This was called as "the incipient agriculture in Taiwan" by some scholars (Tsang et al., 2004, 2006). Those immigrants continued to spread throughout Taiwan, forming the Dabenkeng culture during the early-Neolithic period (6000–4200 yr BP, Hung and Carson, 2014), and they were considered as the ancestors of following cultures in Taiwan and of Austronesian-speaking populations (Bellwood and Dizon, 2005). According to extant archeological evidence, however, it seems that agricultural economics did not dominate most regions in Neolithic Taiwan until the later periods. Most Neolithic human groups still relied on a variety of subsistence strategies, and the method and the degree of plant cultivation and animal raising also varied through time and space. In order to give insight into the potential causes for discrepancy and shift in inter-group diet as well as the development of subsistence strategies and spread of agriculture in Taiwan, it is useful to reconstruct and

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compare the subsistence strategies of each human group who lived in Taiwan during the Neolithic period. However, such studies are still quite sparse in Taiwan, therefore this project was conducted to discover the subsistence strategies of some ancient societies in Taiwan.

In this study, we selected Yuan-Shan (here after labeled YS) archeological site as our pioneer study area since it is located near the Dabenkeng site in northern Taiwan. In addition, multiple cultural strata have been identified in YS site, including Dabenkeng culture, YS culture and others (Shih, 1954; Song, 1954; Huang, 1989, 1991, 1992; Huang and Liu, 1999). Most important, large number of artifacts and ecofact remains, and a few human burials have been found from the stratum of the YS culture, which make it a good choice to reconstruct the subsistence strategies of YS people (Shih, 1954; Song, 1954).

In order to reconstruct subsistence strategies, archeologists usually rely on a diverse array of ecofact and cultural material remains to reveal the food types consumed by prehistoric people. However, the preservation of these materials is strongly affected by the depositional environment (Fraser et al., 2013). This hinders archeologists from a comprehensive understanding of the prehistoric diet. Although new recovery techniques, such as flotation and phytolithic analysis, make it possible to rebuild a more detailed subsistence history (Zhao, 2011), they were not used widely in earlier archeological research. Besides, these evidences show the diet and subsistence strategies of a whole group rather than of a single individual, and provide more descriptive than quantitative information. Therefore, variation in inter- or intra-group diet couldn't be explicitly presented, solely by ecofact and cultural material remains. By contrast, human bone isotope compositions can show long-term (10–15 years) individual dietary characteristics (Hedges et al., 2007), and therefore, provide dietary information of individuals and groups. In addition, the dietary information gives insight into prehistoric economic modes and social structures when combined with archeological evidence or historical archives. In an archeological context, carbon and nitrogen isotopes of bone collagen have been routinely used to infer paleodietary components. Over the past few decades, this technique has been applied to studies on a variety of research topics, such as agricultural origin and spread, crop cultivation practice, the potential immigrants within a group, gender and social status, and dietary components of early *Homo* (e.g. Hu et al., 2006, 2008; Kanstrup et al., 2014; Pechenkina et al., 2005; Pollard et al., 2011; Richards et al., 2001; Sealy et al., 1995).

This technique, however, requires a site-specific dietary isotope baseline being reconstructed from local and coeval faunal and botanical remains, to better discover the potential food resources consumed by prehistoric human groups. In our previous study, we have analyzed the bone collagen carbon and nitrogen isotopes of seven human and three faunal remains collected from one archeological site, the YS site in Taiwan (Lee et al., in review). The analysis of carbon and nitrogen isotope compositions of YS human bone collagen yielded mean δ^{13}C value of -15.0 ± 0.7‰ and mean δ^{15}N of 9.3 ± 0.6‰. Due to sparse faunal isotope data, the YS human isotope data were compared with Japanese isotope dietary baseline, and we put an interpretation that the YS people could mainly consume C_3-based and marine foods, with minor input from C_4 plants. Without the site-specific isotopic dietary baseline, however, this preliminary dietary picture was not so robust and the contribution of each food resources could not be estimated adequately. Therefore, in this study, another 68 faunal bone collagen carbon and nitrogen isotope data are added, including seven animal species. We compare the YS human isotope data published before with these faunal isotope data to reveal the paleodiet of YS people in more detail.

2. Yuan-Shan culture and food availability at the YS site

The YS culture (4200–2200 yr BP) consists of over 50 archeological sites distributed in the Taipei Basin and along the northern to northwestern coastal area of Taiwan (Huang, 1991; Kuo, 2002; Li, 2003). The YS site is situated in the southwestern riverbank of Kee Lung River in the Taipei Basin (Fig. 1) and is close to the estuary of Tan-Shui River (ca. 25 km). Therefore, the YS site is surrounded by rivers, terrestrial basin, small hills, volcanic mountains, and coastal marsh and intertidal zones. The environment around YS site is complex, implying that the people who lived here in the past could get a variety of food resources.

The first formal excavation of the site was conducted in 1953 to 1954 by the Department of Anthropology, National Taiwan University (NTU) and the Taipei City Archives (Shih, 1954; Song, 1954). Several important investigations and excavations were conducted in 1986 to 1987 and in 1991, 1992, 1997, and 1999. Multiple cultural strata, such as preceramic, Dabenkeng (early-Neolithic), Xuntangpu (mid-Neolithic), YS (mid- to late-Neolithic), Zhiwuyuan (late-Neolithic), and Shisanhang (Iron Age) cultures, have been identified from these excavations (Huang, 1989, 1991, 1992; Huang and Liu, 1999). Five human skeletons have been unearthed from the stratum of the YS culture as well (Shih, 1954; Song, 1954).

Evidence of artifacts and ecofact remains discovered from the same stratum showed that the food resource consumed by the YS people was diverse (Huang, 1989, 1991, 1992; Huang and Liu, 1999; Li, 2003; Lien, 1988; Shih, 1954; Song, 1954; Tan, 1934). Based on the large quantities of shell remains, archeologists indicated that shellfish was probably one of the major food resources of YS people. The common species of shellfish included *Cyrenobatissa subsulcada* (i.e. *Corbicula maxima* Prime), *Cytherea meretrix*, *Viviparus* sp., *Melanoides* sp., *Ostrea* sp., *Trochus* sp., and *Nassarius* sp. (Li, 2003; Lien, 1988).

In addition to shell remains, myriads of fish bones and the artifacts such as arrows with hooks, spears, net sinkers, and potsherds decorated with a net pattern and fish bone design were found at the YS site and these evidences demonstrated that the YS people fished in rivers, lakes, or coastal areas to acquire aquatic foods (Huang, 1991, 1992; Song, 1954). Some of the fish vertebrae exhibited a diameter of approximately 5 cm, suggesting that the larger fish were probably marine origin. Recovery of other faunal remains showed that the potential terrestrial food resources the YS people consumed included pigs (*Sus* sp.), deer (*Cervus* sp.), muntjac (*Muntiacus reevesi*), dogs (*Canis* sp.), rats, snakes, rabbits, turtles, and birds (Huang, 1991, 1992; Li, 2003; Song, 1954), however, the dominant faunal remains were pigs and deer.

Furthermore, finding of sickles, which were regarded as crop harvesting tools, suggested that the YS people probably cultivated crops for food (Song, 1954). Some carbonized rice grains were found in the excavation of 1997, indicating rice as one possible crop (Huang and Liu, 1999). Other wild plant remains contained the seeds of *Mallotus* sp., *Melia* sp., *Diospyros* sp., *Broussonetia* sp., and *Cucumis melo*; while in small amounts (Huang and Liu, 1999). In summary, the presence of these ecofact and artifact suggested that the subsistence strategies of YS people consisted of gathering shellfish and wild plants, fishing, hunting, and rice cultivation.

3. Principles of diet reconstruction using stable isotopes

Carbon and nitrogen isotope analyses are commonly used in archeology to reconstruct paleodiet and subsistence strategies (Lee-Thorp, 2008). The approach rests on the premise that the isotope compositions of consumer's tissues directly reflect the diet. The tissue most commonly employed in paleodietary studies is bone collagen, which is thought to take carbon and nitrogen mainly from the protein in the foods of the consumer (Ambrose and Norr, 1993).

Plants with different photosynthetic pathways have large differences in δ^{13}C values, typically with a mean δ^{13}C value of -26‰ in C_3 plants and -12‰ in C_4 plants (van der Merwe et al., 1981; van der Merwe, 1982). Thus, analyzing the carbon isotopes on bone collagen can differentiate the various plants with different photosynthetic pathways that were consumed. In addition, marine foods can be distinguished from terrestrial foods by ca. a 7‰ difference between the δ^{13}C of seawater bicarbonate and atmospheric CO_2 (Dufour et al., 1999; Schoeninger et al., 1983). Marine mammals and fishes have δ^{13}C values that are higher than terrestrial animals feeding on C_3 foods (Richards