Analyses of ^{13}C and ^{15}N and the New Perspectives on Ancient Diet

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Introduction

Archaeology is the study of human past, how we lived and how we organized ourselves. To survive, we need to eat everyday to sustain our bodies. Consequently, food is one of the critical resources of human societies. At the same time, food is closely related to the concurrent technology of the human group, the natural environment and the cultural custom. The study of ancient diet, therefore, is an indispensable component of modern archaeology.

There are several approaches to study the past human diet. Traditionally, they are based on the material remains recovered from archaeological sites. For examples, staple food is inferred from the floral and faunal remains recovered from settlement sites and burials; ancient diet is inferred from the residues recovered from food vessels; and the tools may contain useful clues about the farming style and the crops cultivated. In recent years, these various methods of study have been greatly supplemented by cutting-edge technology that extracts direct information from the bodies of past people. This paper discusses the extraction of ^{13}C and ^{15}N from human bones and their implications in the study of past human diet.

Principle and Method

1. Analysis of ^{13}C

It is known that there are consistent $\delta^{13}C$ value for every kind of plants in nature, such as -23‰--30‰ for rice and wheat of the C_3 family, -8‰--14‰ for millet, sorghum and maize of the C_4 family, and -12‰--30‰ for pineapple and sugar beet for the CAM family, and that there are fractionations approximately in apiece human tissues. So, the body would develop detectable characteristics when a specific plant food is ingested regularly. As a result, analysis of stable isotopes from the human bone can tell the diet of the past.

2. Analysis of ^{15}N

Distribution of ^{15}N in the biology of nature is also predictable. Generally, it is low for plants at about 3‰, about 6‰ for terrestrial herbivore; about 15‰ for marine animals. The higher the food chain, the higher the $\delta^{15}N$ value of biology and the higher nutrition level. Fractionation of human collagen is about 3‰ relative to the food. Therefore, analysis of $\delta^{15}N$ of human bones can tell the nutritional statuses of the subjects.

Details of the method of analysis can be seen in the references.

In China, $\delta^{13}C$ analysis was introduced by the radiocarbon dating laboratory in the Institute of Archaeology in 1980s. And the method of $\delta^{15}N$ analysis by element analyzer was first established in the same laboratory in 2001. Thus, a full range of $\delta^{13}C$ analysis and $\delta^{15}N$ analysis are available to Chinese archaeologists. Because of their popularity, several research institutes, such as Beijing University, Chinese University of Science and Technology and Jilin University, have done this work.

Examples of Application

1. $\delta^{13}C$ study

The study of $\delta^{13}C$ has many successful examples. Here we use a few for demonstration.

Yinxu site and Liulihe site

Bone specimens from 39 individuals from the Yinxu 殷墟 site were subjected to $\delta^{13}C$ analysis. The results suggest that only one specimen was a regular C_3 plant eater, at a rate of 100%. The remaining 38 specimens had C_4 plants in their diet at an average of 93%. The archaeology context indicates that it is likely that millet

was the main source of C_4 plant in the diet.

Bone specimens from 19 individuals from the Liulihe 琉璃河 site of the Western Zhou in Fangshan 房山, Beijing 北京 were subjected to $\delta^{13}C$ study. The results indicate that C_4 plants comprised about 91% and C_3 plants comprised the remaining 9% in the diet of the specimens as a group. Again, millet is the likely source of C_4.

These two sites were selected for the study of a general survey program of the staple food structure of the ancient populations distributed along the Yellow River valley.

Shangsunjia site and Yanbulake site

Shangsunjia 上孙家 site of the bronze-using Kayue 卡约 culture in Datong 大通 County, Qinghai 青海dated back to about 3000 BP. Remains of millet, as well as that of wheat, had been recovered from the site. Bone remains from 18 individuals were sampled for study. In average, the diet of the tested sample contains 30% C_4 plants and 70% C_3 plants. Millet and wheat are the possible grain sources of C_4 and C_3 respectively.

The Yanbulake 焉不拉克 site in Hami 哈密, Xinjiang 新疆 can be partitioned into three cultural phases. Two specimens of human bones from tombs of the later phase at the Zhou times were sampled. The biological study of the skeletons indicates that these individuals show strong Caucasian characteristics. The ^{13}C study suggests that their diet comprises an average of 41% C_4 plants and 59% C_3 plants. It is very likely that millet and wheat were the dietary source of the staple isotope.

The purpose of the stable isotope study of these two sites is to understand the staple food structure of human groups living in different environments.

Hemudu site and Qingpu site of Songze culture

In the Hemudu 河姆渡 site, a great amount of rice remains and farming tools for rice cultivation were discovered. The site comprises of four cultural layers. The third and the fourth layers are dated to about 6000–6800 BP and 6900 BP, respectively. Four specimens of human bones were selected from the third layer. The results show that their diet, in average, is composed of 14% C_4 plants and 86% C_3 plants. Rice is the most likely source of C_3.

Qingpu 青浦 site of the Songze 崧泽 culture, a typical rice-consuming culture, is expected to yield human bones that show a large ratio of C_3. Two specimens of human bones were sampled from the site for stable isotope study. The results suggest that their diet comprises of 99% C_3 plants and only 1% of C_4 plants. It is obvious that the ancient people at Qingpu took C_3 plant as their staple, and rice was the most likely grain food.

These two studies shed light on the staple food of the past people living in the Yangtze River valley.

2. Analysis of ^{15}N

To demonstrate the capacity of ^{15}N study, we take several examples in the following:

Xinglongwa site of the Xinglongwa culture

The Xinglongwa 兴隆洼 site is dated to older than 7000 BP. It yielded a fair number of farming tools, such as hoe-shaped and spade-shaped stone artifacts, milling stones and milling cylinders used for grain processing. In addition, a large amount of animal bones of the deer, roe deer and pig, shells from nuts were also recovered from the site.

Human bones from five individuals of the site were analyzed. In average, they contain 9.56‰ of $\delta^{15}N$; thus indicating that the diet of the Xinglongwa people contained meat in a regular basis. This is consistent with the archaeological finding.

The Neolithic collective burial in Beizhuang 北庄, Changdao 长岛 Island

Archaeologists discovered millet husk in the wall plaster of a house and hunting and fishing tools in the site. It is the desire of the archaeologists to find out the status of the individuals interred in a collective burial. The specific question is whether the deceased were native residents or aliens.

Analysis of $\delta^{13}C$ of the bones shows that the diet of the individuals under investigation contains 93% of C_4 plants. The results of $\delta^{15}N$ analysis show a value at 13.174‰, which is a high nutritional level. It is inferred that fish was an important component in their diet, and it is more likely that these individuals were native residents.

3. The synthetic analysis of ^{13}C and ^{15}N

The analysis of ^{13}C can tell us about the composition of staple food; the ^{15}N analysis can reveal the amount of animal protein in the diet. When these two methods of study are used simultaneously, we gain comprehensive pattern of the diet of ancient population.

Jiaochangpu site

The Jiaochangpu 教场铺 site, located in Liaocheng 聊城, the southern part of Shandong 山东, yielded material remains typical of the Longshan culture. What resources were available to these people at that time, and what was their staple food? These are unresolved questions in archaeology. Remains of millet and rice had been recovered from the site. It seems that the ques-

tions have been answered. Nevertheless, what was their dietary structure, and what was their rate of animal protein intake?

Bone samples from 10 individuals were extracted from the site and analyzed with the $\delta^{13}C$ method. The results show an average of -7.2‰, and C_4 plants comprise about 96% of the diet. It seems that these people had more millet than rice in their daily staple intake. The site yielded considerable number of bones of terrestrial animals and fish. Six specimens of human bones were subjected to $\delta^{15}N$ analysis, and the results show an average of 10.34‰, indicating the tested individuals had considerable meat in their diet. Moreover, an individual shows unusual high rate of $\delta^{15}N$. The human remains recovered from house feature 40 in grid T3431 contain 13.064‰ of $\delta^{15}N$. This individual might regularly have fish in his diet.

Lajia site

The Lajia 喇家 site at Qinghai 青海, a mid-Qijia 齐家 culture ruins, yielded typical evidence of natural disaster. Excavation of the site started in 1999. To date, more than 3000 square meters have been excavated, which include 30 house structures and more than 20 burials, and the skeletal remains of more than 40 individuals. Bones of the pig and the sheep have also been found. Although remains of millet have been recovered from the site, we are hesitant to conclude the dietary structure of this people because the environment at Qinghai is very different from that of the Central Plains. Because of that, we gathered a sample of human bone for analyses.

The results from the bone specimens of 12 individuals indicate that in average, the $\delta^{13}C$ value is -6.89‰ comprise of 100% of C_4 plants. The results are consistent with the archaeological recovery of millet remains in the site. Moreover, the $\delta^{15}N$ value has an average of 10.3‰, indicating that meat was a regular component in the diet of the people. The amount of meat that this people had in their diet is similar to that of the Jiaochangpu people.

Huoshaogou site in Yumen, Gansu

The Huoshaogou 火烧沟 site in Yumen 玉门, Gansu 甘肃is a Bronze Age site, dated to 3700–3900 BP, was excavated in 1970s. Over three hundred tombs have been unearthed. The grave offerings recovered from the site suggest that these people might be a branch of the ancient tribe of the Qiang 羌. Their economy was based on animal husbandry. However, some scholars argue that they were settled farmers.

Fourteen specimens of human bones were studied with the ^{13}C and ^{15}N methods. The value of ^{13}C analysis, in average, is -12.48‰, which shows the people of Huoshaogou neither took C_4 plants as their main staple food, like that of the people of Yinxu, nor took C_3 plants as their main staple food, like that of the people of Hemudu or Songze. Instead, they took both in their diet, 58% C_4 plants and 42% C_3 plants. This dietary structure is similar to that of the Shangsunjia people in Qinghai; albeit the later had more C_3 plants in their diet.

The most intriguing results come from the ^{15}N analysis. The average of $\delta^{15}N$ from fifteen individuals is 12.75‰. The value is comparatively high among our various studies. The fact that all the specimens we tested are consistently high in ^{15}N is very interesting.

In 2004, we presented our study on Huoshaogou in the "Seventh Conference of Archaeometry of China." At that time, we had just finished the ^{13}C analysis. Based only on the ^{13}C results, we proposed two scenarios. First, the ^{13}C results are attributable to the direct intake of C_4 and C_3 plants, such as millet and wheat respectively; and second, the results are the function of both direct and indirect intake. Indirect intake means that livestock's dietary structure would affect the composition of stable isotope of the people who consume the livestock. The possibility of the second scenario is, to a great extent, dependent on the analytical results of ^{15}N analysis. At the same time, this question also involves the discussion about the subsistence economy of the people, that is, a question of farming or animal husbandry. All eyes are focusing on the results of the ^{15}N analysis. The fact that the Huoshaogou population has a higher than usual value of $\delta^{15}N$ offers evidences resolving the question. It is possible that the composition of C_3 and C_4 at Huoshaogou was a mixture of direct and indirect intake. At the same time, the analytical results also indicate that the animal domestication at Huoshaogou had developed into an important department in the subsistence economy.

Before we conclude this paper, let us put the data of $\delta^{13}C$ and $\delta^{15}N$ studies on a bi-variable graph. Each of the sites we investigated occupies a space in the graph. The spatial relationship between the sites is a function of the similarities and dissimilarities of the environment and the various interacting aspects.

Conclusion

The results of ^{13}C analysis of human bones agree with the archaeological study. In the early stage of Chinese

agriculture, people in the Yellow River valley took millet as their staple food and people in the Yangtze River valley took rice as their staple food. The ^{13}C and ^{15}N approaches coupled with contextual information can raise the study of paleo-diet to a new level.

The analyses of ^{13}C and ^{15}N extract direct information from the bodies of the people we studied. They provide the basic data for the archaeological study of past human diet. In fact, they are analytical models based on laboratory experiments. We must put them in the archaeological context to obtain specific results; only in doing so we can expand the horizon of the scientific methods.

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