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Mummies, maize, and manure: multi-tissue stable isotope analysis of late prehistoric human remains from the Ayacucho Valley, Perú

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Abstract

This paper reports the $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen, muscle and skin from several late prehistoric–early colonial (AD 1490–1640) mummies from Perú's Ayacucho Valley. The mean of the $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen are -11.5 ± 1.4 and $11.1 \pm 0.7‰$, respectively. The mean of the $\delta^{13}C$ values for Vinchos skin is $-11.8 \pm 1.2‰$ and the mean of $\delta^{15}N$ values is $13.2 \pm 0.5‰$. The samples of muscle tissue have a $\delta^{13}C$ mean of $-11.9 \pm 0.9‰$ and a $\delta^{15}N$ mean of $12.7 \pm 0.3‰$. The data from bone collagen indicate maize was the basis of the region's subsistence economy. A significant correlation between $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen ($R^2 = 0.75$) is consistent with the preferential fertilization of maize with composted manure. Both skin and muscle samples are consistently enriched in $\delta^{15}N$ relative to paired samples of bone (2.1 ± 0.5 and $1.6 \pm 0.7‰$, respectively), possibly as a result of short term physiological stress or differential decomposition.

Keywords: Mummies; Maize; Ayacucho; Inka; Manuring; Stable isotopes; Carbon; Nitrogen

1. Introduction

1.1. Stable isotope analysis in the Andes

Although the study of paleodiet through the analysis of the stable isotope composition of archaeological human remains has been undertaken for 30 years (Vogel and van der Merwe, 1977; Van der Merwe and Vogel, 1978; see Schwarcz and Schoeninger, 1991; Katzenberg, 2000; Ambrose and Kringbaum, 2003 for reviews), isotopic techniques have been underutilized in the Central Andes relative to the extent of the region's archaeological remains and the number of excavations undertaken in the area (but see Ericson et al., 1989; Hastorf, 1990; Burger and van der Merwe, 1990; Ubelaker et al., 1995; Tykot and Staller, 2002; Burger et al., 2003; Tomczak, 2003; Tykot et al., 2006; Gil et al., 2006; Finucane et al., 2006). As a result of the dearth of isotopic data, it has heretofore been difficult to assess synchronic and diachronic variations in the subsistence economies of Andean societies and hence the relationship between economic development and sociopolitical change in the region during prehistory.

Though patchy, the available isotopic evidence from the Central Andes indicates that maize (*Zea mays*) agriculture was the economic mainstay of the region's urban, state societies. Maize was the foundation of the subsistence economy of the Wari polity (ca. AD 700–1050) (Finucane et al., 2006) and the later Inka Empire, both within the Inka's imperial heartland of Cuzco (Burger et al., 2003) and in the Wanka province of the Mantaro Valley (Hastorf, 1990). Quantitative evidence has been lacking for the role of maize in other regions of the Central Andean highlands during the period of Inka hegemony known as the Late Horizon (AD 1450–1532).

Moreover, the isotopic study of paleodiet in the Central Andes has generally been limited to analysis of bone collagen and apatite; long lived tissues which provide decadal records of diet (but see Aufderheide et al., 1994; Fernandez et al., 1999). Where preserved by either cold or extreme aridity, faster growing tissues such as hair, nail, skin and muscle provide short term records of ancient human diet and physiological status which complement the data available from bone (White, 1993; O'Connell and Hedges, 1999; O'Connell et al., 2001; Schwarcz and White, 2004).

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This present study presents the results of isotopic analysis of mummified human remains from Perú's Ayacucho Valley which shed light on human subsistence in the region during the late prehispanic–early colonial period. As one of three regions of autochthonous state formation in the Central Andes (Stanish, 2001), the Ayacucho Valley provides an important case study of the economic correlates of sociopolitical evolution and devolution.

1.2. Ayacucho valley during the Late Horizon

Archaeological evidence from the Ayacucho Valley strongly suggests the Inka Empire stressed maize production in the region, subsequent to its conquest ca. AD 1460 (Stern, 1982). The only Inka installation in the valley is Tinyaq (12°58′43″ S, 74°12′00″ W, 3284 m) a storage facility located on a hillside above the village of Macachacra, southeast of the town of Huanta (Fig. 1). The facility consists of 32 rectangular storerooms (*colcas*) with internal dimensions of 7–8 m in length to 4–5 m in width, spaced at 5 m intervals (Gonzalez Carré and Vivanco, 1998; Valdez, 2003). As the facility is situated within the maize growing *kichwa* ecozone, the primary function of Tinyaq is thought to have been maize storage. Although ethnohistoric and archaeological sources document the importance of maize for the staple finance of the Inka Empire's political economy (see Watchel, 1982; D'Altroy and Earle, 1985), less is known about the role of maize in the domestic economy of the empire's population. Indeed some scholars (Murra, 1960, 1984) have argued that the importance of maize lay entirely within the realms of the political economy and ceremony and posit that the empire's populace was sustained by tubers, such as the common potato (*Solanum tuberosum*), *oca* (*Oxalis tuberose*), *ulluco* (*Ullucus tuberosus*), and *mashwa* (*Tropaeolum tuberosum*).

In order to assess the relative importance of maize in subsistence economy of the Ayacucho Valley during the Late Horizon, isotopic analysis of tissues from six late prehistoric mummies was undertaken (Fig. 2). The mummies were recovered by the archaeologist Jose Ochatoma of the Universidad Nacional de San Cristobal de Huamanga during salvage operations in a looted cave near the town of Vinchos (13°14′ S, 74°20′ W, 3000 m), 15 km to the southwest of the city of Ayacucho (Fig. 1). The site lies within the ecological region known as *kichwa*, a vegetational zone of thorn scrub forest. As the label implies, the wild flora of this zone comprises mainly shrubs and cacti (CAM plants), such as *Opuntia* sp., *Agave americana*, *Agracia macaranta*, *Cesalpina spinosa*, and *Fourcroya anima*.

In contrast to the better known mummies of Egypt, the preservation of the Vinchos mummies resulted not from special treatment afforded to the remains of societal elite, but from natural processes. Rather than evisceration and embalming, natural desiccation preserved these remains. This desiccation resulted in the preservation of muscle and skin, though not the organs of the abdominal or thoracic cavities. The hair of all six mummies was lost post mortem. The mummies are currently stored in the Archaeology Laboratory of the University Nacional de San Cristobal de Huamanga in Ayacucho, Perú where they were examined and sampled by the author in April 2005.

1.3. Tissue turnover

Due to the preservation of these individuals it was possible to analyze skin and muscle in addition to bone collagen. Collagen constitutes ∼20% of bone by weight and like the mineral component of bone undergoes constant remodeling during the life of an organism. This remodeling is mediated by osteoblasts, which produce collagen-rich osteoid which latter calcifies with the deposition of crystals of hydroxyapatite, and osteoclasts which are responsible for bone resorption (White and Folkens, 2000). The annual rate of bone turnover is between 2 and 10%, depending on the age, sex and physiological status of an individual (Stenhouse and Baxter, 1977; Manolagas and Jilka, 1995; Shin et al., 2004). Bone collagen thus provides a record of paleodiet at a decadal level of resolution.

Like bone collagen, skeletal muscle protein is continually synthesized and catabolized during the lifetime of an individual. The relative rates of these processes are variable, with the former being exercise dependent. Rates of protein turnover in skeletal muscle are on the order of ∼40–60 days (Moore et al., 2005). Dermal collagen has a turnover rate on the order of 2–4 months (El Harake et al., 1998; Babraj et al., 2005).

1.4. Stable isotope analysis

The study of paleodiet through stable isotope analysis proceeds from the experimental observation that the isotopic composition of animal tissues generally reflects that of the diet they consume (for a review see Schwarz and Schoeninger, 1991; Katzenberg, 2000; Ambrose and Kringbaum, 2003). Such analyses utilize the variation in the ratios of the stable isotopes of carbon and nitrogen within ecosystems to measure the relative contribution of different resources to animals' diets (DeNiro and Epstein, 1978, 1981). As some foods, such as maize, have distinctive isotopic signatures, it is often possible to identify the consumers of these resources.

The stable isotopes of carbon (^{13}C and ^{12}C) and those of nitrogen (^{15}N and ^{14}N) are expressed in per mil (‰) as δ values:

$$\delta = \left[\left(R_{\text{sample}}/R_{\text{standard}}\right) - 1\right]1000$$

where $R = {}^{13}C/{}^{12}C$ for the measurement of carbon and $^{15}N/^{14}N$ for the measurement of nitrogen. The standards to which samples are compared are the limestone Vienna PeeDee Belemnite (VPDB) and atmospheric nitrogen (AIR) for carbon and nitrogen, respectively. As most materials, including plant and animal tissues have less ^{13}C than VPDB, $\delta^{13}C$ values are typically negative.

The overwhelming majority of plants, including Andean tubers and the grain quinoa (*Chenopodium quinoa*) utilize the Calvin Cycle (C_3) and have tissues with an average $\delta^{13}C$ value of −26.5‰ (O'Leary, 1988). The $\delta^{13}C$ values of plants relying upon the Hatch–Slack pathway (C_4), mainly tropical grasses