Journal of Archaeological Science 66 (2016) 7–20

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Variation in camelid $\delta^{13}C$ and $\delta^{15}N$ values in relation to geography and climate: Holocene patterns and archaeological implications in central western Argentina

Adolfo F. Gil [a,*], Andrew Ugan [b,c,d], Clara Otaola [e], Gustavo Neme [a], Miguel Giardina [a], Lumila Menéndez [f]

[a] CONICET-IANIGLA Grupo Vinculado San Rafael/Museo de Historia Natural de San Rafal, UTN Facultad Regional San Rafael, Centro Tecnológico de Desarrollo Regional Los Reyunos, Parque Mariano Moreno, San Rafael, Mendoza, Argentina
[b] Far Western ARG, Davis, CA, USA
[c] University of Utah, Salt Lake, Utah, USA
[d] Museo de Historia Natural de San Rafael, San Rafael, Mendoza, Argentina
[e] CONICET-IMHICIHU, Saavedra 15, Buenos Aires, Argentina
[f] CONICET-Departamento Científico de Arqueología, Facultad de Ciencias Naturales y Museo/UNLP, Paseo del Bosque, La Plata, Argentina

ARTICLE INFO

Article history:
Received 29 May 2015
Received in revised form
9 December 2015
Accepted 12 December 2015
Available online xxx

Keywords:
Camelids
Stable isotopes
^{13}C
^{15}N
Central-western Argentina
Holocene ecology

ABSTRACT

Camelids are among the largest wild and domestic faunas in South America and represent one of the most important taxa to pre-hispanic South America human populations. Stable isotope data from these animals play an important role in improving our understanding of human paleodiet, past human-animal interactions, Holocene environmental change, and modern camelid management. This paper presents $\delta^{13}C$ and $\delta^{15}N$ values taken from 91 camelid specimens distributed across western Argentina between 30° and 37° S. These samples come from three desert environments (Andean, Patagonia, and Monte) and include both modern and prehistoric samples. Camelid $\delta^{13}C$ values range between −20.3‰ and −10.7‰, while $\delta^{15}N$ values vary between 2‰ and 10.2‰. Mean isotope values differ by environmental context, with significant difference in $\delta^{13}C$ and $\delta^{15}N$ between Patagonian and Monte or Andean deserts. Camelid isotope values also vary with latitude, altitude and longitude, though differences in $\delta^{15}N$ are weak, and these geographic differences are tied to climatic variables such as annual mean temperature, annual precipitation, and season of precipitation. When comparing camelid $\delta^{13}C$ values from Central-western Argentina with those from Northwest Argentina and Patagonia, we see a latitudinal trend of decreasing $\delta^{13}C$ values, with the most negative values occurring in southern Patagonia and the most positive values in Northwest Argentina. Variation in camelid stable isotope values and their association with particular environmental contexts shows their value as a geographic marker and possibly as a paleoecological proxy. These results highlight the need to consider the geographic origin of camelid isotope values when using them to reconstruct human diet.

1. Introduction

Human isotope ecology is not only an innovative way to explore human diet but also a method to help understand other aspects of ecosystem structure such as biogeographical range, human mobility, animal husbandry, and climatic change (Bocherens et al., 2015; Fry, 2006; Koch, 1998; Martínez del Río et al., 2009; Newton, 2010; Rubenstein and Hobson, 2004; Samec et al., 2014; Szpak et al., 2014; Ugan and Coltrain, 2012). Our ability to apply stable isotope methods to these problems depends on our understanding of isotopic fractionation, which often depends not only on the species involved, but also on particular features of the local environment. For most wild animals, such natural, intraspecific variability in their stable isotope composition is neither well documented nor well understood (Stevens et al., 2006). There are insufficient data on relevant, free-living animals from similar environments to provide a clear indication of how much variability may be expected, and therefore what would constitute an adequate

* Corresponding author.
E-mail address: agil@mendoza-conicet.gob.ar (A.F. Gil).

http://dx.doi.org/10.1016/j.jas.2015.12.002
0305-4403/

sample size to define the isotopic composition of a given species in a particular habitat. Most human palaeodietary reconstructions have been made on the basis of a sample size that is arguably insufficient to provide the statistical power needed to validate their conclusions, although the nature of palaeodeposits may give little choice in terms of the faunal assemblage used, the number of samples available, their contemporaneity, or the homogeneity of their original habitat. Without such a definition of the relevant baseline, palaeodietary reconstructions are hard to justify and may lead to circular arguments (Stevens et al., 2006).

In southern South America, the camelids are among the most significant resources in pre-hispanic diets (Politis et al., 2011; Otaola et al., 2012; Borrero, 1990; Miotti and Salemme, 1999; Mengoni Goñalons, 2009, 2010). They are also ubiquitous in the South America zooarchaeological record, and are some of the most important animals to explore in terms of their stable isotope signals. Not surprisingly, there has been an increasing use of stable isotopes from these animals in order to define their contribution to human diets. Researchers have also shown the potential of faunal isotopes to help define the geographic range of human exploitation, as well as their possible role of camelid isotopes as paleoenvironmental proxies (Thorton et al., 2011; Yacobaccio et al., 2009; Samec et al., 2014; Brookman and Ambrose, 2013). Given this, it is necessary to improve this line of research and the development of a relevant isotopic ecology (Barberena et al., 2009; Falabella et al., 2007; Giardina et al., 2014; Martínez et al., 2009; Laguens et al., 2009; Thornton et al., 2011; Zangrando et al., 2004; Izeta et al., 2009; Mengoni Goñalons, 2007; Szpak et al., 2014).

Research along these lines has taken place in three primary areas. In the Pampas and Patagonian regions of southern Argentina, recent stable isotope studies have focused largely on guanaco (*Lama guanicoe*; Barberena et al., 2009). This research was based on $\delta^{13}C$ data from bone collagen, mostly generated as a byproduct of radiocarbon dating of samples found between 34° and 54° SL (Barberena et al., 2009: Fig. 1). Barberena et al. (2009) found no temporal trends in stable carbon values, nor did they identify correlations between latitude and $\delta^{13}C$. Although there is a gradual tendency towards enriched average values at lower latitudes, this tendency is neither strong nor linear. At this smaller scale it is not possible isolate the role of latitude, as a direct conditioning of global climate, on guanaco isotopic values. The study found no significant correlation with altitude but did find higher $\delta^{13}C$ values in the area of southern Mendoza (the southern part of Central-western Argentina), which was considered an outlier.

Additional research on camelid isotope signatures has taken place in the Central Andes and Northwestern Argentina, between 10° and 28° SL (Fernández et al., 1991; Fernández and Panarello, 1999-2001; Finucane et al., 2006; Mengoni Goñalons, 2007, 2009; Samec, 2012; Samec et al., 2014; Thornton et al., 2011; Yacobaccio et al., 1997). There researchers have explored stable isotope trends not only among guanacos, but also wild vicuñas and domesticated llamas and alpacas. These papers have focused on isotopic ä^{13}C and $\delta^{15}N$ variation among camelid species and its relationship with altitude, and on using stable isotope values to differentiate domestic and wild camelids. Fernández et al. (1991), for example, demonstrate that the stable carbon ratios of camelid tissues decline with altitude and suggest that these changes reflect concomitant declines in the availability of C_4 plants. Other researchers have noted similar trends in carbon values (Fernández and Panarello, 1999-2001; Samec, 2012; Yacobaccio et al., 2009, 2010). Working in the Puna region, Samec (2012) notes that the $\delta^{15}N$ signatures of vicuñas and llamas also covary with altitude. The pattern shows a negative correlation between altitude and camelid tissue $\delta^{15}N$ values, which is thought to reflect greater water availability at higher altitudes (Samec et al., 2014). Looking at interspecific variation among wild camelids, Samec et al. (2014) found no significant difference in $\delta^{13}C$ or $\delta^{15}N$ between wild guanacos and vicuñas. Finally, more recent research on taxonomic variation in camelid diet and stable isotope values in the region has proposed that higher $\delta^{13}C$ values in domestic llamas may result from maize consumption (Dantas et al., 2014; Izeta et al., 2009).

This paper focus on camelid isotope variability in Central-western Argentina, the third area in which work has been done. Central-western Argentina (Fig. 1) is an area of environmental, ecological and geographic transition between the two previous mentioned study cases (Northwest Argentina and Patagonia). Previous research in this area has focused on taxonomic differences in stable carbon isotope values and using those values to differentiate wild and domestic species. These early efforts were based on a small sample of camelid bones ($n = 12$) and focused on stable carbon isotope data almost exclusively (Barberena et al., 2009; Gil et al., 2006). More recent research in this area has highlighted the difficulties encountered when trying to explain variation in camelid $\delta^{13}C$ values in this manner (Falabella et al., 2007; Gil et al., 2010; Tykot et al., 2009).

This paper presents the results of a broader study of $\delta^{13}C$ and $\delta^{15}N$ values from camelid bone collagen distributed throughout Central-western Argentina between 30° and 37° S (Fig. 1). The analysis involves samples from three ecological contexts, the Andean, Patagonia, and Monte deserts (Cabrera, 1976), and includes modern and prehistoric samples. The study aims to improve our understanding of camelid dietary variation and discusses the mechanisms that might explain it. Key goals are to evaluate the degree to which climate and geography explain patterns in camelid stable isotope values and to assess how variation in those values is best considered in order to improve paleoecological and archeological research.

2. Camelids in central-western Argentina: ecological, archaeological and isotopic framework

2.1. Project area and environment

Central-western Argentina is an appropriate location to explore the ecology of prehistoric camelid habitats analysis due to altitudinal variation in climate, hydrology, and vegetation. The study area (Fig. 1) is located between ca. 30° and 37° S latitude, and includes a combination of mountains in the west, plains to the east, and a volcanic area in the southeast. It is a temperate, continental region with an arid to semiarid climate. Three ecological units are defined within it: the Andea, Patagonia, and Monte deserts (Roig, 1972).

These ecological units are situated within the South American Arid Diagonal, where precipitation alternates seasonally between the Atlantic and Pacific anticyclone (Bruniard, 1982). From a climate perspective, these regions are highly contrasting due to their relief, dominant masses of maritime air and the season in which precipitation takes place. During the summer, the Atlantic anticyclone brings moisture from the Atlantic to the lowland Monte desert, in the eastern part of the region. During the winter, moisture is derived from the Pacific and precipitation primarily falls in the Andean and Patagonia deserts of the western mountains and fringing piedmont. Because of the great distance traveled, the humid winds of the Atlantic provide little precipitation, while the strong rain-shadow cast by the Andes results in most of the Pacific moisture falling in the mountains as snow, arriving further east as warm, dry winds (Abraham and Rodríguez, 2000).

The Andean desert include the Altoandina and Puna phytogeography which comprises the Andean cordillera above 2500–3000 m asl, is characterized by cold, windy climatic conditions and winter dominant precipitation of 300–800 mm per year.