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When maize is not the first choice: advances in paleodietary studies in the Archaeological Site Río Doncellas (Jujuy, Argentina)

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ABSTRACT: In this work we present new values of stable isotopes of carbon ($\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$) and nitrogen ($\delta^{15}N$) measured in a sample of 13 human individuals found in the Río Doncellas Archaeological Site (Late Period or Regional Developments, ca. 1000 AD–1450 AD) located in the Puna of Jujuy, Northwest of Argentina. The skeletal series belong to the collection of Museo E. Casanova, FFyL – UBA and the Instituto Nacional de Antropología y Pensamiento Latinoamericano, being the result of investigations carried out during the decades of 1940 and 1970, respectively. In addition, in this work we present isotopic compositions of food resources (vegetal and fauna) found in the archaeological record as well as gathered in modern farms located in the study area (Abra Pampa, Cochinoca, Jujuy). This information was used for paleodietary inference, allowing us to establish a hierarchy of the resources that were consumed. The results indicate that maize (*Zea mays*) is less important than other vegetal resources in the diet, which contradicts the expectations generated from the macrobotanical evidence of the site and the cultivated terraces that surround it. On the other hand, camelids seemed to be widely exploited, which is coherent with the current importance of meat production within the region. These results allow us to assert that the growth of cereals did not have a progressive relevance over other resources.

KEY WORDS: $\delta^{13}C$, $\delta^{15}N$, *Solanum tuberosum*, *Zea mays*, Camelidae, aridity

Introduction

The Río Doncellas Archaeological Site (RDAS from now on) is one of the best known sites of the Late period (ca. 1000 AD–1450 AD) within the Argentinean Puna, due to the wide variety of funerary structures and the large amount of archaeological materials found there (Alfaro de Lanzone 1988, Pérez de Micou 1996, Pérez and Killian Galván 2011). From the investigations developed in the site between the decades of 1940 and 1970, it has been proposed that the population which occupied the area had camelid herding as the main economic activity, but also practiced extensive crop agriculture. On one hand, the area is fit for the exploitation of camelids not only for direct consumption but also for secondary exploitation (wool and transportation) (Albeck and Zaburlin 1996, Pérez

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de Micou 1996, Yacobaccio and Madero 2001, Pérez and Killian Galván 2011). On the other hand, indicators such as crop terraces, crop fields and hydraulic systems can be found, which could have allowed an agricultural economy of abundance (Ottonello de García Reinoso 1973, Alfaro de Lanzone 1988). The importance of understanding the place of each component inside an economic system lays in establishing if the surplus production of maize crops (*Zea mays*) guaranteed the high demography postulated for the period as well as the social hierarchy which has been inferred by some researchers (Tarragó 2000). Even though the environmental conditions of high aridity and altitude are more benevolent for micro thermal vegetables (Nielsen 2006a), maize has been proposed as a fundamental part of the prehispanic economy of the area, given the ubiquity of macrobothanical evidence for this species (Alfaro de Lanzone 1988). Recently, a sample of maize recovered during the last excavations carried out on the site has been analyzed and eight races have been identified (Killian Galván et al. 2014), showing a high biovariability within the assemblage which would strengthen this last postulate.

Based on the above, the objective of this work is to summarize the paleodietary analysis of the skeletal series found in RDAS, adding new data to what has already been published (Pérez and Killian Galván 2011, Killian Galván et al. 2012), with the objective of establishing which group of resources was most important in human diet, if those derived from the exploitation of fauna resources or those produced by high altitude agriculture. The analysis of stable isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) is adequate to address this type of problems because carbon isotopic composition is a powerful tool to ascertain the dominant photosynthetic pattern of the diet, considering that $\delta^{13}C$ values do not change much along the trophic chain, which allows the identification of maize (and/or amaranth) consumption. On the other hand, nitrogen isotopic composition allows us to know the position of the specimen within the trophic chain (Fry 2006). In this work, we will also take into consideration the influence of scarce precipitations on $\delta^{15}N$ values of plants and animals (Hartman 2011) and the use of soil fertilizers (Bogaard et al. 2007) as a source of isotopic variation. The proposed isotopic analysis has been done on carbon and nitrogen from bone and dental collagen, as well as the analysis of carbon in the inorganic fraction (hydroxyapatite), given that bone and dental collagen is the product of protein consumption within the diet (Krueger and Sullivan 1984). Therefore, we will refer to "protein diet" as the paleodietary inference assessed from the organic fraction (collagen) and "total diet" to that assessed from the mineral fraction (hydroxyapatite). This differentiation is pertinent since the isotopic signal of a resource as relevant as maize could be overrepresented, given the low protein content of this cereal in particular.

For paleodietary interpretation, we will consider the studies on isotopic ecology of the region, which allow us to establish altitude as a variability axis to understand the isotopic variation. Studies of camelids (*Lama glama* and *Vicugna vicugna)* have identified a negative correlation between altitude and $\delta^{13}C$ values in collagen (Fernández and Panarello 1999–2001, Yacobaccio et al. 2009, Yacobaccio et al. 2010, Samec 2011). Also, a negative correlation has been found

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between $\delta^{15}N$ values and altitude, as water is more available in higher altitudes (Samec 2014, Samec et al. 2014). As for vegetal resources for human consumption, a study on current crops has been started in the Southern Puna (Killian Galván and Salminci 2014) and on an archaeological sample of *Zea mays* in RDAS (Killian Galván et al. 2014).

Materials and analytical methods

Research Area. The Archaeological Site Río Doncellas (Cochinoca Department, Province of Jujuy) is located in the "Guayatayoc-Miraflores" basin between 22°49'12,28" S and 66°03'54,89" O, shaping an imaginary rectangle of 35 by 25 km (Fig. 1). It is located in a typical Puna environment (Alfaro de Lanzone 1988), with annual precipitations which do not surpass the 350 mm and usually occur in a torrential way (Tchilinguirian 2008). The altitude and topographic characteristics also have an influence in average temperatures (which can be lower than 10°C), which vary specially during winter (Ottonello de Reinoso and Ruthsatz 1982, Bianchi et al. 2005). Nevertheless, there have been different climate scenarios throughout the Late Holocene period. Schavitz et al. (2001) have inferred a higher humidity period between the 3700 BP until the 1500 BP leading later to more arid conditions, a fact which has to be taken into consideration when interpreting the results of the isotopic analysis.

The Archaeological Site. It comprises different sectors: the pit-houses in its entrance, the main village, and the outcrop sector on both sides of the village (North and South). These last two have funerary structures (Ottonello de García Reinoso and Krapovickas 1973) where the individuals analyzed in this work were exhumed (Fig. 2). Also, the village is surrounded by field terraces, caves and rockshelters, at distances which do not surpass 5 km. Radiocarbon dating offered a chronology which locates the occupations between *ca.* 740 and 310 years BP (Alfaro de Lan-

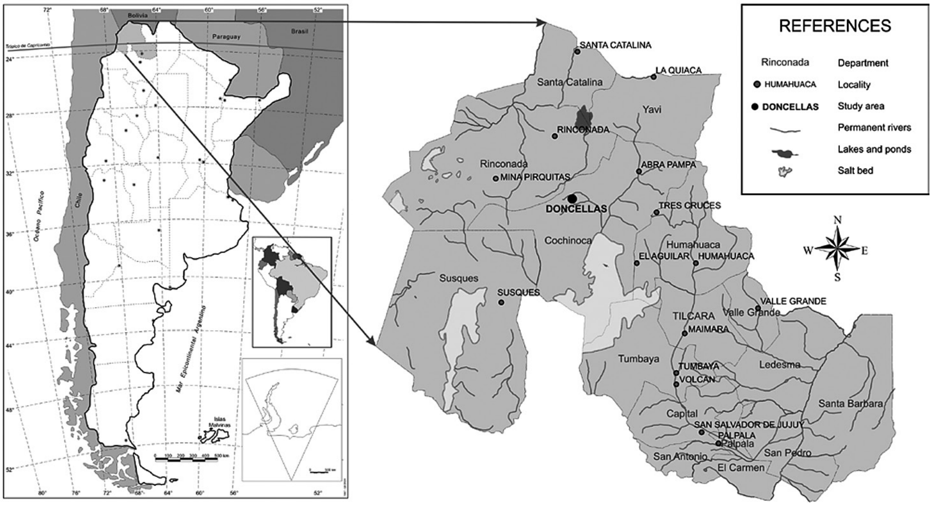

Fig. 1. Río Doncellas archaeological site location in the Jujuy Province, Argentina.

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Fig. 2. Funerary structures over the outcrop sector in Río Doncellas archaeological site.

zone 1988, Pérez de Micou 1996, Fuchs and Varela 2013). Also, the presence of a Spanish coin dated to the year 1677 found in the site during Vignati's investigations (1938), among other signs, informs us that the village was occupied until Hispanic times. It is important to emphasize that at the moment is not possible to establish differences between the periods of occupation of the village in relation to the rest of the sectors.

Protocols and equipment employed. The $\delta^{13}C$ and $\delta^{15}N$ measurements were carried out in the Biogeochemistry Laboratory of INGEIS (CONICET-UBA) on 13 human individuals, three llamas, six vicuñas, two specimens of *Cervidae* sp. and one of *Lagidium* sp. Also, modern grown vegetable specimens were analyzed, such as *Solanum tuberosum* (n = 24,) *Opuntia ficus-indica* (n = 1) and *Zea mays* (n = 1), which were collected from organic gardens belonging to local families and in the Central Market of the city of Abra Pampa (Cochinoca Department). The procedure to extract bone collagen (Tykot 2004) consists of two phases, demineralization and elimination of posdepositional particles. The first step requires a chloridric acid attack (HCl 2%) for 72 hours, changing the reactive each day. Before and after this step, the material is submerged for 24 hours in sodium hydroxide, to eliminate humic acids. Then the sample is rinsed and dried in a stove at <60°C. In the pretreatment of the inorganic fraction we used the protocols proposed by Tykot (2004) and Garvie-Lok and coauthors (2004). Plants were washed with ultrasonic baths for 45 min and then oven dried at 60°C for 24 h. Afterwards, the samples were hand ground using an agate mortar and pestle and homogenized to obtain the average isotopic composition for each plant specimen (Cadwallader et al. 2012). Measurements of each sample $\delta^{13}C$ and $\delta^{15}N$ values were made on a Carlo Erba Elemental Analyzer (CHONS) coupled to a Finnigan MAT Delta V continuous-flow isotope ratio mass spectrometer (CF-IRMS) through a ThermoConFlo IV interface using internal standards. These standards (caffeine: $\delta^{13}C = -39.33‰$, $\delta^{15}N = 7.02‰$; sugar: $\delta^{13}C = -11.41‰$; and collagen: $\delta^{13}C = -18.18‰$, $\delta^{15}N = 6.12‰$) were calibrated against VPDB and AIR reference standards for carbon (L-SVEC, NBS– 19 and NBS-22) and nitrogen (IAEA N1 and IAEA N2) (Coplen et al. 1992, 2006, Craig 1957). Replicates of internal standards showed analytical errors (SD) to be on the order of ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$ values. The analysis of isotopic composition of carbon in carbonates was done using the Phosphoric Acid method developed by McCrea (1950) and later modifications (Panarello et al. 1980). The spectrometer used for hydroxyapatite samples is a Delta S Finnigan Mat triple colector. In this case, the analytical errors (SD) were on the order of ±0.2‰.

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Results

Vegetables

We obtained 24 isotopic measurements of *Solanum tuberosum* for both carbon and nitrogen stable isotopes compositions (Table 1). For δ^{13}C values an average of –26.0‰ ± 0.8 was obtained, and for δ^{15}N values the average was 6.2‰ ± 3.4. The higher dispersion for nitrogen is provided by three specimens that showed surprisingly high values, even when harvested in fields with equal water restrictions, soil quality and natural fertilizers. (δ^{15}N values of +13.5‰, +13.7‰ and +15.2‰). The δ^{13}C and δ^{15}N values in maize were –11.4‰ and +6.6‰ and in *Opuntia ficus indica* they were –12.3‰ and +8.3‰. The details of chemical characteristics of the soil and collecting methodology have been summarized in Killian Galván et al. (2016).

Fauna

All the bone specimens analyzed here presented acceptable C/N relations, that is within the range from 2.9 to 3.6 (De Niro 1985) (Table 2). If we take into consideration the δ^{13}C values of Camel-

Table 1. Summarized statistics of the total δ^{13}C and δ^{15}N values measured on vegetables from Abra Pampa, Cochinoca, Jujuy, Argentina.

Gender and species	Common name	Anatomical fration	n	δ^{13}C‰ (V-PDB)				δ^{15}N‰ (AIR)			
				Mean	SD	Min	Max	Mean	SD	Min	Max
Solanum tuberosum	papa	tubérculo	24	–26	0.8	–27.7	–24.4	6.2	3.5	2.5	15.2
Opuntia ficus indica	tuna	fruto	1	–12.3				8.3			
Zea mays	maíz	grano	1	–11.4				6.6			

Table 2. Summarized statistics of the total δ^{13}C and δ^{15}N values measured on bone collagen extracted from fauna of the Jujuy Puna. It details the percentage of C$_3$ and C$_4$ pastures contribution in diets. Modern samples δ^{13}C values (*) were corrected for the fossil fuel effect, using a correction of +1.5 ‰.

Provenance	Species	Common name	Anatomical fraction	AIE	δ^{13}C‰ (V-PDB)	δ^{15}N‰ (AIR)	C/N	%C$_3$	%C$_4$
Río Doncellas	*L. glama*	llama	metacarpus	2 2004	–17.0	8.1	3.6	75.9	24.1
	L. glama	llama	phalanx	2 2006	–17.0	6.7	3.4	75.9	24.1
	L. glama	llama	phalanx	2 2007	–16.3	8.8	3.2	71.0	29.0
	Lama sp.	s/d	phalanx	2 2008	–15.9	6.2	3.3	68.3	31.7
	V. vicugna	vicuña	metacarpus	2 2003	–16.2	8.5	3.4	70.3	29.7
	V. vicugna	vicuña	phalanx	2 2009	–15.7	8.1	3.2	66.9	33.1
	Cervidae sp.	s/d	scapula	2 2005	– 19.9	6.1	3.3	95.9	4.1
	Cervidae sp.	s/d	metatarsus	2 2011	–18.9	6.1	3.3	89.0	11.0
	Lagidium sp.	vizcacha	skull	2 2010	–14.0	8.7	3.3	55.2	44.8
Abra Pampa	*V. vicugna**	vicuña	tibia	22639	–14.6	9.5	3.2	49.0	51.0
	*V. vicugna**	vicuña	rib	22640	–17.9	11.3	3.3	71.7	28.3
	*V. vicugna**	vicuña	humerus	22641	–15.3	10.5	3.3	53.8	46.2

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idae assemblages recovered at RDAS, the average is –16.4‰ ±0.5. Regarding the δ^{15}N values, the average is +7.7‰ ±1. The deer specimens of this site present lower δ^{13}C values than the camelid specimens, although there is no difference for the δ^{15}N values. Differences cannot be found for any of the isotopic relationships for the values of *Lagidium* sp. For modern values of *Vicugna vicugna* of Jujuy's Puna, the average δ^{13}C value is –15.8‰ ±1.4, while regarding δ^{15}N values the average is +9.6‰ ±1.9.

In respect to dietary[1] estimation, we have observed that the deer specimens have a C_3 plant dominated diet. For *Lagidium sp*. there is a more even integration of C_3 and C_4 plant species in the diet. At the same time, modern vicuña specimens consume a more substantial percentage of C_4 species. Even though it is a small faunistic sample, it evidences that, in this region, human diets could be framed indirectly under a C_4 photosynthetic pathway, not necessarily by the direct consumption of C_4 plants, but instead by the consumption of animals that were fed C_4 pastures.

Human bone and dental record

All the analyzed samples fulfill the criteria of accepted carbon-nitrogen atomic ratio (C/N) (Table 3). We decided to exclude a subadult individual from the descriptive statistics, which presented the following values: $\delta^{13}C_{co}$ = –17.3‰, δ^{15}N = +17.5‰ and $\delta^{13}C_{ap}$ = –12.4‰. This individual probably shows the effect of breast feeding given the elevated nitrogen isotopic value. But this is striking, because this individual was 3 or 4 years old at the time of dead. The average and SD values of the isotopic relationship of the rest of the values are $\delta^{13}C_{co}$ = –15.9‰ ± 1, δ^{15}N = +12.5‰ ± 0,8 and $\delta^{13}C_{ap}$ = –11.6‰ ± 1,8. We have to take into account that two individuals were sampled from dental records (M1 and M2)[2], but they do not present differences regarding the rest, hence, the differences that we found cannot be connected, at present, with the age segments the individuals belong to. For $\delta^{13}C_{co}$ values we observed that the more negative ones belong to an individual ($\delta^{13}C_{co}$ = –17.2‰) which was probably buried in the North Outcrop without any funerary objects -with the exception of a woolen *poncho*-and to another individual ($\delta^{13}C_{co}$ = –18.5‰) which presented an oval perforation, being identified as a "trophy skull" and of which no postcraneal remains could be found. The two individuals with more positive values ($\delta^{13}C_{co}$ = –14.6‰ and –14.8‰) were buried in the South Outcrop and possessed grave goods. This does not mean an existing relation between isotopic values and their

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[1] Percentages for consumption of C_3 and C_4 pastures were estimated from average plants' values published in Fernández and Panarello (1999- 2001) and using an offset of +5‰ for $\delta^{13}C_{diet\text{-}collagen}$. The 100% C_3 diets would be δ^{13}C –22‰ and –7,5‰ for C_4. This reference values were modified considering the *Suess Effect* over vegetables. The proportion of a source is calculated by the formula: $f_A = \delta_M – \delta_B / \delta_A – \delta_B$, where δ_M, δ_B, δ_A represent the average isotopic signals of the *Mixture* and the sources *A* and *B* and f_A and f_B are the proportions of *A* and *B* in *M* (mixture) (Balesdent and Mariotti 1996 in Phillips and Gregg 2001).

[2] The first molar (M1) forms between birth (±2 months) and eight years (± 24 months); the second molar (M2) forms between three years (±12 months) and 15 years (±36 months) (Ubelaker 1999).

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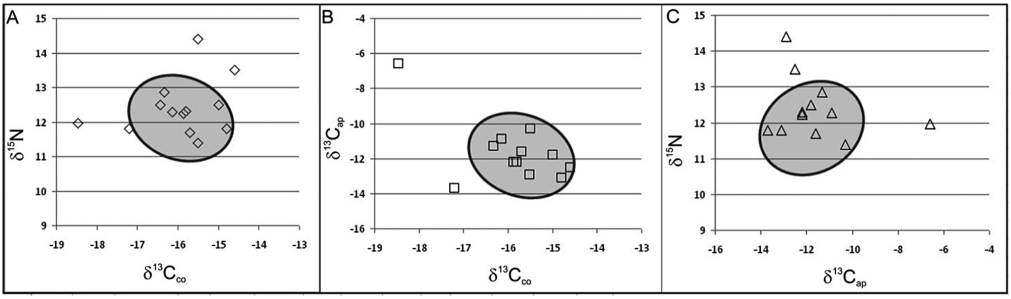

Fig. 3. Bivariate plot showing $\delta^{13}C$ (collagen) and $\delta^{15}N$ value (A), $\delta^{13}C$ (collagen and apatite) values (B) and $\delta^{13}C$ (apatite) and $\delta^{15}N$ value (C) of human individuals from Río Doncellas Archaeological Site.

social status within the social group, since probably the rest of the individuals found in the graves of Outcrops also had funerary objects at the time of their burial (Egaña 1999). The more positive $\delta^{15}N$ values were again found between one of the individuals who had funerary objects ($\delta^{15}N$ = +13.5‰) and an individual of whose exact location cannot be specified, but who probably was buried inside the Village ($\delta^{15}N$ = +14.4‰), given the documentation available of the excavations on the site. For the $\delta^{13}C$ values measured on hydroxyapatite, the variation within the sample is remarkable given the presence of an individual which presents an exceptionally high value ($\delta^{13}C_{ap}$ = –6.6‰). By coincidence, it is the individual identified as a "trophy skull", which presents the most negative

Table 3. Summarized isotope values measured on human remains. Sex is indicated as F, Female; M, Male; and U, Unknown. Collagen quality indicators are also included. (*) Environmental Isotope Laboratory, Department of Earth & Environmental Sciences, University of Waterloo.

n		Sample	Sex	Age	Collagen				Hydroxyapatite	
					AIE	$\delta^{13}C$‰ (± 0,2)	$\delta^{15}N$‰ (±0,2)	C/N	AIE	$\delta^{13}C$‰ (±0,1)
1	Doncellas (FFyL)	M1	M	adult	27640	–16.3	12.9	3.2	30514	–11.3
2		rib	M	adult	27722	–16.4	12.5	3.2		~
3		skull	M	adult	27515	–18.5	12	3.3	30518	–6.6
4		skull	U	adult	27521	–15.9	12.2	3.3	30515	–12.2
5		M2	F	adult	27506	–16.1	12.3	3.2	30516	–10.9
6	Doncellas (INAPL)	rib	F	Adult +30	19234	–15.0	12.5	3.2	522	–11.8
7		rib	U	Youth 14–20	19235	–15.7	11.7	3.2	515	–11.6
8		rib	U	adult	19236	–17.2	11.8	3.2	514	–13.7
9		skull	U	adult	19237	–15.8	12.3	3.2	5 19	–12.2
10		rib	M	adult	19238	–14.6	13.5	3.2	521	–12.5
11		rib	F	Adult +30	19239	–14.8	11.8	3.2	513	–13.1
12		vertebrae	U	Infant 3–4	19242	–17.3	17.5	3.2	517	–12.4
13		rib	U	adult	93931*	–15.5	14.4	3.1	518	–12.9

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value in relation to $\delta^{13}C$ values measured in collagen.

When we compare the different isotopic data, we find that it is difficult to separate the whole sample set into groups. For example, one of the individuals, which was identified as a "trophy skull", presents the same isotopic values as one of the individuals buried in the Village sector of RDAS. Both measurements, performed on skulls, were obtained from different archaeological campaigns in different decades (Casanova and Lanzone were in charge respectively). The individuals which can be separated from the rest of the assemblage are: one of the denominated "trophy skulls", the only individual buried in the South Outcrop, because of the lower $\delta^{13}C$ values in collagen and enriched $\delta^{13}C$ values in hydroxyapatite (Figures 3a, b and c), and another, one probably buried in the Village Sector found by Lanzone, with more positive $\delta^{15}N$ values (Figures 3 a and c). Therefore, we did not obtain a segregation pattern from the available contextual patterns.

Paleodietary inference

In order to account for the predominant resources in human diets, we will use the isotopic fractionations proposed by Newsome and collaborators (2004) and Drucker and Bocherens (2003). From the first authors' proposal, not only the meat component of the diets ("proteic diet") was estimated, but it was aimed to include the vegetable consumption. To accomplish this, a diagram of isotopic ranges of the probably consumed resources was established, employing the flora and fauna data generated in this work, as well as those provided by other investigators (Fernández and Panarello 1999–2001, Samec 2011, Samec et al. 2014, Yacobaccio et al. 2010, Killian Galván and Salminci 2014). It was resolved to establish five groups: 1) meat resources at higher altitudes than 3900 masl, 2) meat resources below 3900 masl, 3) vegetables for human consumption under C_3 photosynthetic patterns, 4) maize and 5) CAM plants. Also, we included a sixth group, considering archaeological *Zea mays* cobs found in RDAS. This sample of twenty cobs showed surprisingly high nitrogen values, even compared to the values originated in coastal environments (Killian Galván et al. 2014). Initially, we considered that this exceptional range could be related to its archaeological origin and the alteration of the original signal due to diagenetic processes. Since the $\delta^{15}N$ values measured in *Solanum tuberosum* specimens reached +15.2‰, we reevaluated the pertinence of its use. So, we performed analyses on a subsample of cobs, considering the carbon percentages (% C) and nitrogen (% N) exhibited by each one. In this way, we took the composition of present Andean maize as a threshold to separate the acceptable results (see Szpak et al. 2013 who performed a detailed isotopic study of vegetables in Peru)[3]. This resulted in an assemblage of eight cobs with an average $\delta^{13}C$ value of –10.3‰ and ± 0.9 and an average $\delta^{15}N$ value of +9.3‰ and ±2.5. Nevertheless, these last specimens exhibit higher $\delta^{15}N$ values, being in some cases similar to the values found in potato specimens from Abra Pampa. Is important to highlight that for both the potatoes and the archaeological maize cobs a relationship could not be found

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[3] The percentage ranges presented by the author can be found between 39.3 and 41.8% and 0.8 and 1.6% for $\delta^{13}C$ and $\delta^{15}N$, respectively.

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between the nitrogen percentage of the specimen and the isotopic δ^{15}N value (Killian Galván et al. 2014).

On the other hand, even though the largest number of measurements were performed on camelids, different animal species have been placed into groups (including 12 δ^{13}C values of *Octodontomys gliroides*, *Felis* sp., *Dusicyon* sp., *Ctenomys* sp., *Puma concolor*). The spatial stratification for meat resources, mentioned above, answers to a theoretic expectation, which indicates a higher availability of humidity above the 3900 masl threshold (consequently with lower δ^{15}N values) and also a higher proportion of C_3 plants. Also, we included different resources with similar isotopic signals under the category of C_3 plants (*Solanum tuberosum*, *Chenopodium quinoa*, *Prosopis* sp. y *Geoffroea decorticans*), while under the C_4 category we included maize values (*Zea mays*) as well as an unpublished value from a specimen of amaranth (*Amaranthus caudatus*) from the Puna of Jujuy (δ^{13}C = –11.9‰ ± 0.04; δ^{15}N = +4.9‰ ± 0.1). As can be observed in Table 4, where the descriptive statistics of the assemblages are synthesized, the distinction between lower and higher altitude fauna assemblages is useful to understand the large range of the second assemblage, as it encompasses enriched values for both δ^{13}C and δ^{15}N.

The estimated human diets can be observed in Figures 4 and 5, where the δ^{13}C and δ^{15}N values measured in collagen (4) and hydroxyapatite (5) are represented along with the isotopic distribution of the resources that were probably consumed. In both figures we can infer an almost total coincidence between human diets and ranges of isotopic distribution presented by meat resources of the Argentine Northwest's Puna. Nevertheless, it is not possible to establish if there is a larger affinity with groups at a higher or lower altitude. This is an important aspect, given it would allow us to understand which were the pasture areas used within the herding exploitation strategies employed by these societies. At the same time, if we take into consideration minimum and especially maximum values of these resources we can explain the total estimated human diets. Considering the δ^{13}C$_{ap}$ values, even the one inferred for the individual which presents a high proportion of C_4 in its total diet (δ^{13}C$_{ap}$ = –6.6‰), we can explain them considering the camelids that pasture under the 3900 masl threshold. Therefore, when we compare diets with a predominance of protein component of animal origin (Fig-

Table 4. Summary statistics for δ^{13}C and δ^{15}N values corresponding to main diet groups.

Diet	δ^{13}C					δ^{15}N				
	n	Mean	SM	Min	Max	n	Mean	SM	Min	Max
Fauna >3900 msnm	65	–21.8	1.6	–26	–17.9	8	7.4	1.3	6	10
Fauna <3900 msnm	50	– 19.5	2.3	–24.1	–13.4	12	8.2	1.7	6.1	11.3
C_3	32	–24.6	1.3	–28.7	–22.9	26	5.6	1.9	2.5	8.7
Solanum tuberosm Abra Pampa	3	–25.5	0.6	–26.1	–25	3	14.1	0.9	1.5	15.2
C_4	11	–9.7	0.7	–11	–8.2	9	6.2	3.2	0.7	9.4
CAM	1	–10.8	~	~	~	1	8.3	~	~	~
Zea mays Doncellas	8	–10.3	0.6	–12	–9.5	8	9.6	2.5	6.4	14.4

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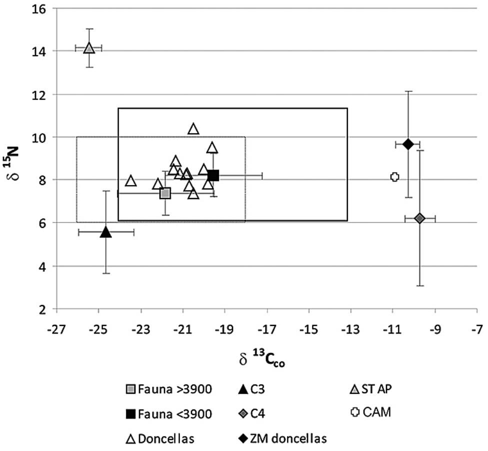

Fig. 4. Bivariate plot showing $\delta^{13}C$ and $\delta^{15}N$ as means and standard deviations for plant and faunal material, as compared with dietary $\delta^{13}C_{co}$ and $\delta^{15}N$ values for Río Doncellas individuals. Diet values were estimated using an offset of +5‰ for $\delta^{13}C_{diet\text{-}collagen}$ and +4‰ for $\delta^{15}N_{diet\text{-}collagen}$ in humans. The $\delta^{13}C$ values of resources are shown as means and standard deviations. All modern sample $\delta^{13}C$ values were corrected for the Suess effect, using a correction of +1.5‰. The values obtained from archaeological cobs were corrected considering the differences between vegetable tissues ($\Delta^{13}C_{grain\text{-}trunk}$).

ure 3) and those which include the energy contribution of vegetables (Fig. 4), we cannot find clear differences between them. With the exception of the "trophy skull", which exhibits an enriched value of $\delta^{13}C$ in hydroxyapatite but an impoverished value in collagen, the "total" diets show a larger importance of resources under the C_3 photosynthetic pattern, since $\delta^{15}N$ values of consumed vegetables are more impoverished than assimilated proteins of animal origin. Therefore, at least among the analyzed individuals, there was a more extended incorporation of vegetable resources such as tubers (not necessarily *Solanum tuberosum*), *quinoa* or gathering resources like *chañar* or carob, before maize. Therefore, vegetables were probably not as important as meat resources but, among them, those resources better adjusted to the aridity and altitude of the region were the most important ones. Additionally, although the Abra Pampa *Solanum tuberosum* samples, which show extreme values are far from the estimated human diets, this range of values must be considered to understand the enriched $\delta^{15}N$ values shown by humans.

It is remarkable that the individual with the lowest $\delta^{13}C$ values in collagen ($\delta^{13}C_{co} = -18.5‰$) is also the one which holds the highest contribution of C_4 photosynthetic pattern in the energy component of the diet ($\delta^{13}C_{ap} = -6.6‰$), therefore distancing itself from the rest of the samples. It would be pertinent in the future to compare this information with the DNA investigations being performed at the present (personal communication: V. Seldes) to establish if this different paleodietary pattern is due to the consumption of resources which cannot be

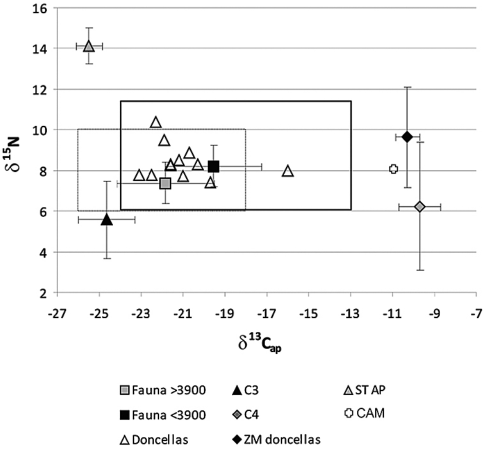

Fig. 5. Bivariate plot showing $\delta^{13}C$ and $\delta^{15}N$ as means and standard deviations for plant and faunal material, as compared with dietary $\delta^{13}C_{ap}$ and $\delta^{15}N$ values for Río Doncellas individuals. Diet values were estimated using an offset of +9,4‰ for $\Delta^{13}C_{diet\text{-}collagen}$ and +4‰ for $\Delta^{15}N_{diet\text{-}collagen}$ in humans.

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found in the Argentinean Northwest or if this individual belongs to a segment of the population which never had exclusive access to corn and/or amaranth. Also, it would be the only consumer of herbivores pasturing over the 3900 masl threshold. It should be highlighted that if we had not complemented the study of this individual with isotopic analysis on hydroxyapatite, it would have been impossible to infer the presence of maize or other resources of low C_4 photosynthetic pattern in its food repertoire. Finally, the complementarily of lines of isotopic evidence also shows which positive $\delta^{13}C$ values in bone and dental collagen could be due to the relevance of C_4 pastures in the dietary composition of the domestic and wild fauna.

Discussion and final comments: consumption beyond diet

Our results show a limited predominance of cereal components in the diet of the individuals found in RDAS. Even though the number of individuals is still limited, these results concur with the expectations of authors such as Johnson et al. (2009) who established a threshold for maize production in relation to annual Effective Temperature, which should be higher than 12.75ºC, that is higher than the average for this sector of the Puna of Jujuy. This subestimation of maize consumption is also consistent with studies performed in dental records of the skeletal series analyzed in this paper, where a low prevalence of caries was found, allowing us to infer a scarce incidence of carbohydrates in the diet. Also, there were not found indicators associated with an inadequate ingest of food (Miranda 2010). Additionally, this scenario could be related to a comprehensive exploitation of camelids, such as the consumption of bone marrow and fat. Considering the analyzed individuals, the $\delta^{13}C_{ap}$ values are more impoverished than the collagen values, which could be expected in a strategy of energy intake through the consumption of animal lipids.

However, we understand that consumption patterns are not defined only by climate and environmental limitations since other causes can define food production and consumption modalities. The maize present in the archaeological record of the Puna, either as grave goods or gathered in caves, could have a dietary role but not strictly as a staple food, since it could have been important as fermented beverage (*chicha*). As it has been registered in Andean ethnohistory documents, these beverages are made from different races of maize, and its provenance from long distances was important (Hastorf 2003). Following Warinner and Tuross (2009), even though the isotopic signal of maize does not change as a consequence of cooking practices, the different processes of cooking could have different consequences in the assimilation by human beings, at least in bone collagen. In this sense, if a fermented beverage was consumed, possibly it was not processed enough to be better assimilated by the organism.

As already mentioned, the RDAS has an extensive chronology of occupation, although most radiocarbon dates are associated with the Late Period (also called Regional Developments). This period implied both political integration mechanisms and intensification of social interaction (Tarragó 2000). For example, when considering public celebration as a representation of political order, Niels-

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en (2001) mentions the cult of the dead as a moment when the collective consumption of food was particularly practiced. Previously, the presence of maize in the archaeological record of the site was interpreted as a result of "visits to the ancestors" and not as discarded food by those which occupied these archaeological sites (Killian Galván et al. 2012). Because of this, we consider food consumption as a key element in the reproduction of social, economic and political relationships.

In light of these results, we consider that the dismissal of the importance of maize in the diet of the individuals under analysis compared to its ubiquity in the rest of the archaeological record contributes to set us aside from a preconceived vision of the cultural and social significance of consumed food items. This highlights not an intrinsic but a contextual notion of the value of the objects, therefore defined by the society's representations and the relationships that take place within this society (*sensu* Nielsen 2006b). If we consider diet as an action that exceeds the mere fact of satisfying the vital need of subsistence or subjected to ecological boundaries, we could explain maize as an element used in celebratory situations, shared by the community in specific moments. Then, its production and exchange emphasis could have not been a matter of daily consumption, since it was maybe conceived as a luxurious food item (*sensu* Hastorf 2003) shared by the community at specific times. Under this suggestion, the existence of morphotypical variability of maize specimens could be related to the need of diversifying production to guarantee the success of the crop and not be the reflection of a production oriented to this resource.

In sum, this paper allows us to separate ourselves from the idea of the predominance of the agricultural intensification of maize, understanding that in unfavorable environments for cereal crops other resources could have been part of an intensification strategy.

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Authors' contributions

VAKG designed and conducted research; VAKG and CTS analyzed data; CTS provided essential materials, VAKG, CTS, and HOP wrote the paper; VAKG had primary responsibility for final content. All authors read and approved the final manuscript.

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