A Comparative Study of Camelid Diets between Sites during the Formative Period in the Northern Highlands, Peru

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1. Introduction

In the Andes, camelids are large domestic animals used for numerous purposes, including as a source of protein, fleece, fertilizer, fuel, building materials, pack animals, and ritual sacrifices. The camelid is an essential element in the development of the Andean civilization as it led to the spread of the culture through trade, the expansion of societies to acquire food resources, and the increase of societal complexity through resource control. This article reports on an isotopic study of camelid husbandry in early Andean societies during the Formative Period in the northern highland of Peru.

1.1 Domestication of Camelids and Their Spread

Llamas (*Lama glama*) and alpacas (*Vicugna pacos*) have been domesticated from the guanaco (*Lama guanicoe*) and vicuña (*Vicugna vicugna*), which inhabit the high plateaus (*Puna*) of South America at altitudes above 4,000 m (Kadwell et al. 2001). Their domestication is believed to have occurred in numerous areas, including the Central Andes in Peru, the Bolivian highlands, and the Southern Andes in Chile and Argentina (Wheeler 2012). Morphological changes in the body and teeth, the proportion of camelids in animal bone assemblages, the age distribution of the camelid, and structural remains, such as stone enclosures, have led to inferences about their husbandry. The general perspective is that the domestication of the alpacas and the llamas occurred independently. The first camelid domestication, probably of the alpacas, has been reported to have occurred around 6000 to 5500 years ago in the Telarmachay Rockshelter, the Junín highlands, in the Central Andes (Mengoni Goñalons 2008; Wheeler 1984, 2012). The llama domestication began later because the guanaco is larger and more difficult to control than the vicuña. It occurred in several areas above 3,000 m and is estimated to have occurred approximately 3500 years ago in Bolivia (Mengoni Goñalons and Yacobaccio 2006) and 4000 years ago in the Central Andes (Wheeler 2012). There is a report of domestication, not explicitly of a llama but of a large-size group, 3100–2400 years ago in northwestern Argentina and northern Chile (López et al. 2017).

In the coastal area of Peru, fleece from llamas or guinea pigs, dating from 2900 to 1970 BCE, was reported at the Huaca de Los Ídolos site, Aspero (Quilter 2014: 89), and

camelid bones were excavated from the Middle Formative Period at Huaca Partida in the lower Nepeña Valley (Shibata 2014). However, the unearthing of camelid remains in these coastal areas does not confirm local camelid husbandry. It cannot be ruled out that camelids may have been hunted in the wild, that camelids bred in high altitudes may have visited as a caravan, or that body parts of dead camelids may have been brought in as food, fleece, or bone material resources. Shimada and Shimada (1985) noted that camelid husbandry on the north coast may have been as delayed as just before the Middle Horizon. However, more recently, based on carbon, nitrogen, oxygen, and strontium isotope analysis, it has been established that camelid herding in coastal areas began in the Early Intermediate Period (Dufour et al. 2014; Mader et al. 2018; Szpak et al. 2014, 2020). Furthermore, in a few coastal sites, small groups of camelids may have been reared during the Late Formative Period (Szpak et al. 2016).

The husbandry and utilization of camelids can be divided into three stages: (1) Use and gradual herding initiated at the highland plateau, (2) use of camelids spread through caravans of highland groups, and (3) the husbandry strategies spread to the lowlands and initiated the direct management and use of the camelids. Isotope analysis can establish this gradual expansion of camelid utilization and management.

1.2 Estimation of the Diet Using Carbon and Nitrogen Isotope Ratios

Plants are divided into three major carbon isotopic groups based on differences in the photosynthetic systems (O'Leary 1981, 1988). The C_3 plants, with a C_3 pathway, also called the Calvin-Benson cycle, have a low carbon isotope ratio. In contrast, the C_4 plants, with a C_4 pathway that combines the Calvin-Benson and Hatch-Slack cycles, have a high carbon isotope ratio. Succulent plants, adapted to low precipitation areas, use crassulacean acid metabolism (CAM), are observed in both the C_3 and C_4 pathways, and have intermediate carbon isotope ratios. As CAM plants do not notably contribute to the camelid diet, a discussion of their intake is not included in this study.

Nitrogen isotope ratios do not vary significantly between plants in the same region, except for plants with nitrogen-fixing bacteria. However, there are variations in the isotope ratios between regions due to differences in temperature and humidity. Nitrogen isotope ratios are high in the dry coastal areas of Peru (Cadwallader et al. 2012; Szpak et al. 2013).

In addition, vegetation varies with altitude. In the northern Andes, wild C_4 plants are more common in the lowlands. There are only two species − *Andropogon sp.* And *Pennisetum purpurem* − above 2,000 m altitude (Szpak et al. 2013). In the high-altitude grassland environment (above 4,000 m), known as the *Puna*, C_4 plants are almost nonexistent. The climate is cold and the carbon and nitrogen isotope ratios of the plants are low.

As camelids' body tissue reflects the isotopic ratios of the plants they consume, it is possible to infer management strategies from the differences in the region where they were pastured and the feed selectively provided by humans.

1.3 Isotopic Studies on Camelid Husbandry

Modern camelids, pasturing on highlands above 4,000 m, depend on C_3 plants and have low carbon and nitrogen isotope ratios (Dufour et al. 2014; Thornton et al. 2011). The first domesticated camelids on the highlands of the Central Andes, with the same C_3 vegetation, probably had a similar diet. In the *Puna* region, it is difficult to distinguish between wild and domestic animals based on isotopic ratios alone. However, if camelids with similar diets are found below 4,000 m, then they had been pastured on the highlands and were brought there by humans. For example, the archaeological site of Torata Alta, at 2,300 m altitude, along the Moquegua valley, showed evidence of camelids with a striking diet with low carbon and nitrogen isotope ratios similar to those of modern highland camelids, which are assumed to have been brought from the highlands (Thornton et al. 2011).

Few camelids are reared in coastal areas; however, archaeological samples show elevated nitrogen isotope ratios. For example, camelids with high carbon and nitrogen isotope ratios have been reported in Chilca and La Paloma and represent a coastal diet (DeNiro 1988). This was presumably due to the consumption of plants and seaweed with high nitrogen isotope ratios in coastal areas. At Cerro Baul, at an altitude of 2,500 m in the upper Moquegua valley, camelids with high carbon and nitrogen isotope ratios have been reported, suggesting that they may have come from the coastal area (Thornton et al. 2011).

The *Yunga* and lower *Quechua* zones, which are ecologically classified by Pulgar Vidal (2014), are suitable environments for C_4-cultivated plants. In these ecological zones, C_4 plants consumption is focused. The diet is detected as a combination of high carbon and low nitrogen isotope ratios. This pattern has been reported at Conchopata during the Wari period and at Machu Picchu during the Inca period (Finucane et al. 2006; Turner et al. 2010). Since maize cultivation was common during the Wari and Inca periods, it is assumed that maize was the C_4 plant ingested by the camelids. Camelid herding with maize foddering is established on the northern coast during the Early Intermediate Period as well (Dufour et al. 2014; Szpak et al. 2014, 2019). Our previous studies have reported on camelid husbandry, using C_4 plants in the Late Formative Period, which is one of the oldest pieces of evidence of maize foddering camelids (Takigami et al. 2020, 2021). These studies, using carbon, nitrogen, oxygen, and strontium isotope analyses, show that camelid husbandry, using C_4 plants, was introduced at Pacopampa in the northern highlands during 700–400 BCE (the Pacopampa Phase II; hereby, PC-II phase). During 1200–700 BCE (the Pacopampa Phase I; hereby, PC-I phase), a few camelids were present at the site; however, partial skeletal remains were excavated, which indicated that their diet depended strongly on C_3 plants, suggesting that they were brought from an area where they pastured on C_3 plants, probably the highland *Puna*. The management strategy, using C_4 plants, is estimated to have been introduced around the site as early as 700 BCE. It is believed that Pacopampa represents the transition of camelid husbandry from the second stage to the third. Investigating the universality of this change in camelid management and husbandry stages during the Middle to Late Formative Period would be important to understand the social changes,

such as the development of wide-area networks and large ceremonial centers, during the Late Formative Period. We examined camelid husbandry at Kuntur Wasi by isotope analysis to test whether the temporal change in camelid management strategies at Pacopampa was common to the northern highlands of Peru during the Formative Period.

2. Materials and Methods

2.1 Kuntur Wasi

The Kuntur Wasi archaeological site is a huge ceremonial architecture, belonging to the Formative Period, in the Department of Cajamarca, the northern highland, Peru (Figure 13-1). The site is located in the upper Jequetepeque Valley, at an altitude of 2,300 m, and in the border areas of the *Yunga* and *Quechua* zones. A research team from the University
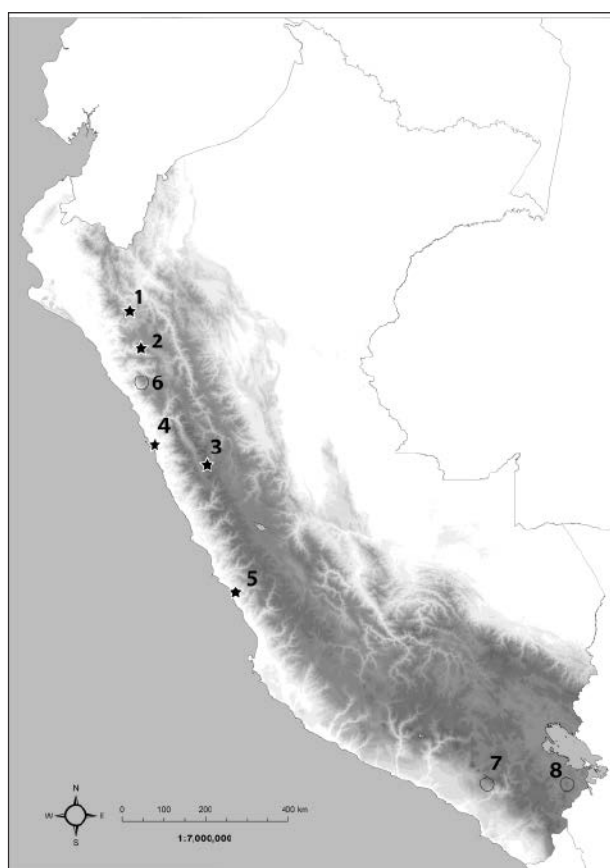

Figure 13-1   Map of the sites in the Formative Period and modern pastures for which isotopic data for the camelids are used in this study. 1–5 are archaeological sites and 6–8 are modern camelid sites. 1. Pacopampa 2. Kuntur Wasi 3. Chavín de Huántar and La Banda 4. Caylán and Huambacho 5. La Paloma 6. Quiruvilca 7. Tocra 8. Chilligua (produced by Mai Takigami)

of Tokyo excavated the site from 1988 to 2002 and found several special tombs buried in ceremonial architecture, which were associated with elaborate golden funeral goods (Onuki 1995).

Kuntur Wasi comprises four architectural phases – the Ídolo phase (950–800 BCE), the Kuntur Wasi phase (800–550 BCE), the Copa phase (550–250 BCE), and the Sotera phase (250–50 BCE). In terms of the northern highland chronology, the Ídolo phase corresponds to the Middle Formative Period, the Kuntur Wasi and Copa phases to the Late Formative Period, and the Sotera phase to the Final Formative Period. Kuntur Wasi started as a small, local center during the Ídolo phase and became a ceremonial center during the Kuntur Wasi and Copa phases, connecting surrounding regions (Kato 2014). Several precious offerings, such as Bolivian sodalite, obsidian, and cinnabar from the Central Andes and *Spondyllus* shell artifacts from the Ecuadorian coast, were discovered during the Ídolo phase. The site became a center for the production of ritual artifacts after the Kuntur Wasi phase. Hence, Kuntur Wasi changed its position within the trade network from an importer to an exporter (Kato 2010, 2014). Furthermore, characteristic ceramics and metal artifacts, believed to have come from coastal areas, were excavated from the Kuntur Wasi phase, suggesting a strong relationship with the area (Inokuchi and Druc 2019).

2.2 Zooarchaeological Study at Kuntur Wasi

From Kuntur Wasi, approximately 4,000 animal specimens were identified through the zooarchaeological investigation. There were 13 taxa identified and cervid (*Odocoileus virginianus*) and camelids were dominant, accounting for over 80% of the archaeological remains (Uzawa 2019). Although the camelid ratio of artiodactyla was low in the Ídolo phase, it increased remarkably after the Kuntur Wasi phase. Finally, during the Sotera phase, the rate rose to 40%. Therefore, it can be concluded that camelid husbandry began during the Late Formative Period and gradually expanded (Uzawa 2019).

2.3 Samples

We analyzed 24 cervid bones and 23 camelid bones (Table 13-1). The phase of the samples was estimated based on archaeological information gleaned from the site, such as types of ceramics and the relationship between architectural structures and excavated layers. Most samples were extracted from the jawbones and dentine of disengaged teeth, taking care not to cause duplicate samples from individuals. Since the number of individuals in the Ídolo phase is limited, two samples were selected from different bone parts; hence, the possibility of a duplicate sampling cannot be ruled out. However, given the distance between the excavation areas, we can surmise that they were used in different rituals.

2.4 Methods

After the samples were selected and photographed in the laboratory adjacent to the Kuntur Wasi Museum, the quantities for analysis (300–600 mg for bone and 30–400 mg for dentin) were collected with a cutting drill. We requested permission from the Ministry

Table 13-1 Summary of collagen quality indicators and carbon and nitrogen isotope ratios of animal specimens (cervid and camelid) from Kuntur Wasi

Specimen ID	Group	Bone	Sample ID	Period [a]	Collagen yield (%)	%C	%N	C:N	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)	% C$_4$ plants
KW2019-1	Camelid	mandible	94KW-B-101	KW	8.2	39.9	15.3	3.0	-15.6	5.1	40
KW2019-2	Camelid	dentine	94KW-B-119	KW	14.0	39.4	15.0	3.1	-15.5	8.0	40
KW2019-3	Camelid	mandible	94KW-B-122	KW	5.2	38.0	14.5	3.1	-14.9	6.4	44
KW2019-4	Camelid	dentine	94KW-B-125	KW	11.9	37.4	14.4	3.0	-15.6	4.5	39
KW2019-5	Camelid	mandible	94KW-B-18	KW	5.1	39.8	15.0	3.1	-13.0	7.0	57
KW2019-6	Camelid	mandible	99KW-G-12	CP	4.9	39.6	15.0	3.1	-14.9	5.4	44
KW2019-7	Camelid	dentine	96KW-A-120	CP	11.3	39.0	14.7	3.1	-12.9	7.7	58
KW2019-8	Camelid	mandible	96KW-A-126	CP	5.5	38.4	14.5	3.1	-14.7	6.6	45
KW2019-9	Camelid	mandible	89KW-C-61	CP	5.1	39.8	15.0	3.1	-12.6	6.5	59
KW2019-10	Camelid	mandible	96KW-A-70	CP	7.0	41.3	15.3	3.2	-16.9	5.2	31
KW2019-11	Camelid	mandible	96KW-A-70	CP	3.6	38.7	14.5	3.1	-16.4	6.6	35
KW2019-12	Camelid	mandible	96KW-A-167	CP	2.9	37.6	14.1	3.1	-10.1	5.6	76
KW2019-13	Camelid	dentine	96KW-A-61	CP	13.1	39.4	14.7	3.1	-12.9	7.6	57
KW2019-14	Camelid	dentine	96KW-A-61	CP	12.8	41.3	15.5	3.1	-14.9	9.2	44
KW2019-15	Camelid	mandible	96KW-HS-16	CP	10.4	41.8	15.7	3.1	-14.5	8.0	47
KW2019-16	Camelid	mandible	89KW-C-60	ST	3.5	39.0	14.8	3.1	-14.8	7.7	45
KW2019-17	Camelid	mandible	96KW-A-39	ST	6.9	39.1	14.7	3.1	-16.5	5.0	33
KW2019-18	Camelid	mandible	96KW-A-41	ST	7.6	41.0	15.4	3.1	-13.6	6.2	53
KW2019-19	Camelid	mandible	96KW-A-62	ST	6.3	40.0	15.0	3.1	-12.1	7.7	62
KW2019-20	Camelid	dentine	01KW-R-67	ST	8.4	40.4	15.1	3.1	-12.2	6.1	62
KW2019-21	Camelid	dentine	01KW-R-67	ST	11.2	41.6	15.5	3.1	-13.8	7.1	51
KW2019-23	Cervid	mandible	94KW-B-N1097	ID	5.1	39.4	14.9	3.1	-19.5	5.4	
KW2019-24	Cervid	mandible	98KW-C-N88	ID	1.2	37.9	14.2	3.1	-19.5	6.0	
KW2019-25	Cervid	mandible	94KW-B-N1090	ID	4.6	39.6	15.3	3.0	-19.4	5.0	
KW2019-26	Cervid	mandible	94KW-B-N31	ID	8.1	41.0	15.5	3.1	-20.5	4.1	
KW2019-27	Cervid	dentine	97KW-C-N95	ID	13.9	38.3	14.5	3.1	-20.7	4.9	
KW2019-28	Cervid	mandible	94KW-B-N130	KW	1.1	37.6	14.4	3.0	-19.3	4.7	
KW2019-29	Cervid	mandible	94KW-B-N171	KW	6.6	41.2	15.6	3.1	-19.3	4.8	
KW2019-30	Cervid	mandible	94KW-B-N1662	KW	7.9	41.0	15.5	3.1	-20.4	4.5	
KW2019-31	Cervid	dentine	97KW-A-N221	KW	12.2	38.8	14.7	3.1	-19.4	5.2	
KW2019-32	Cervid	dentine	94KW-B-N152	KW	4.6	37.2	14.0	3.1	-20.1	5.5	
KW2019-33	Cervid	mandible	94KW-B-N116	KW	3.2	38.8	14.6	3.1	-20.4	3.0	
KW2019-34	Cervid	mandible	94KW-B-N107	KW	3.4	37.9	14.6	3.0	-19.8	4.7	
KW2019-35	Cervid	mandible	94KW-B-N119	KW	4.5	39.5	14.9	3.1	-15.4	5.3	
KW2019-36	Cervid	dentine	94KW-B-N113	KW	10.2	37.9	14.4	3.1	-18.3	6.7	
KW2019-37	Cervid	mandible	94KW-B-N119	KW	2.7	38.5	14.8	3.0	-19.6	4.4	
KW2019-38	Cervid	mandible	96KW-A-N1027	CP	4.7	38.2	14.4	3.1	-20.6	3.5	
KW2019-39	Cervid	mandible	97KW-A-N222	CP	8.3	40.1	15.0	3.1	-19.0	4.9	
KW2019-40	Cervid	dentine	94KW-B-N1635	CP	16.3	38.7	14.6	3.1	-19.7	6.0	
KW2019-41	Cervid	mandible	96KW-H-N70	CP	10.8	40.5	15.2	3.1	-20.3	4.9	
KW2019-42	Cervid	mandible	96KW-K-N77	CP	4.5	39.1	14.6	3.1	-19.1	5.6	
KW2019-43	Cervid	mandible	01KW-R-N208	ST	9.9	40.5	15.1	3.1	-17.4	6.5	
KW2019-44	Cervid	mandible	01KW-R-N212	ST	7.0	39.8	14.9	3.1	-18.7	5.9	
KW2019-45	Cervid	dentine	01KW-R-N359	ST	8.0	39.4	14.7	3.1	-19.0	4.7	
KW2019-46	Cervid	mandible	01KW-R-N17	ST	8.0	38.3	14.3	3.1	-19.4	4.3	
KW2019-47	Camelid	calcaneus	99KW-C-N15	KW (ID[b])	9.5	39.4	14.9	3.1	-13.8	5.8	51
KW2019-48	Camelid	scapula	04KW-B-N1045	KW (ID[b])	4.3	38.7	14.5	3.1	-14.7	5.8	46

Note: a: Phase abbreviation – ID (Ídolo), KW (Kuntur Wasi), CP (Copa), and ST (Sotera), b: speculated period based on the archaeological information (produced by Mai Takigami)

of Culture, Peru, to export samples for analysis. Once the permission was granted, we brought them back to Japan. The collagen extraction experiment was conducted at the National Museum of Japanese History where Mai Takigami was affiliated.

Collagen was extracted using the method established by Longin (1971) as a base. In addition, the extraction was modified by referring to the reports of Yoneda et al. (2004) and Tsutaya et al. (2017). The bone surface was physically cleaned with a dental drill and washed and ultrasonicated with ultrapure water to remove adhered bone powder and soil deposits. The samples were freeze-dried and weighed. The dry weight of the samples, before collagen extraction, used to calculate the collagen yield, was the weight at this point. The chunk sample was placed in a test tube and soaked in 0.6 M hydrochloric acid. The solution was changed every day to remove inorganic bone components. Although the speed of demineralization varied, depending on the sample condition, most reactions were complete within 2–5 days. For dentin, which took more time to react, and bone samples, which required constant attention due to the small sample size, demineralization was conducted in 1–2 days in cellulose tubes with continuous stirring. After demineralization, the samples were soaked in 0.1–0.2 M sodium hydroxide solution to remove extraneous organic matter from the soil and non-collagenous proteins. The solution was changed every hour and returned to neutral when the solution was no longer brown. A dilute hydrochloric acid solution of pH4 was added to the test tube and heated at 90°C for 24 hours to extract soluble gelatin collagen. The solution was purified by vacuum filtration and dried with a freeze-dryer for 48 hours.

A 500 μg collagen sample was weighed and packed in a tin cup. Carbon and nitrogen isotope ratios were measured, using an elemental analyzer, coupled with an isotope ratio mass spectrometer (EA–IRMS) (Flash EA1112, open split interface ConFlo III, and Delta V Advantage), at the Research Institute for Humanity and Nature (RIHN), Kyoto, Japan.

In addition, radiocarbon dating was conducted on the six Ídolo samples. The collagen sample was burned and carbon dioxide gas was separated through an elemental analyzer before being reduced to graphite. This graphite was used to measure the carbon-14 concentration by accelerator mass spectrometry. Graphite purification and measurement were performed at the AMS Center for the Kaminoyama Research Institute, Yamagata University (Kato et al. 2014; Tokanai et al. 2013). To calculate calibrated ages, we used the OxCal 4.4 calibration program and the IntCal20 dataset (Bronk Ramsey 2009; Reimer et al. 2020).

The condition of extracted collagen was assessed by collagen yield, carbon content, nitrogen content, and carbon and nitrogen atomic ratios. The acceptable range of collagen quality control indicators was collagen yields greater than 1%, wt% C greater than 13%, wt% N greater than 4.5%, and C:N$_{Atomic}$ between 2.9 and 3.6 (DeNiro 1985; Van Klinken 1999). In the bone collagen of modern samples, collagen quality control indicators were reported as follows: $41.91 \pm 0.39\%$ for wt% C, $15.40 \pm 0.20\%$ for wt% N, and 3.17 ± 0.17 for C:N$_{Atomic}$ (Guiry and Szpak 2020). Since only archaeological materials were analyzed in this study, the collagen condition was estimated by the former criteria; however, the

closer the criteria were to the modern samples, the less contamination or deterioration was noted.

Calibration of the carbon and nitrogen isotope ratio measurement was performed using standard samples owned by the RIHN. The standard deviation of standard samples was $\pm 0.03 - \pm 0.05$‰ for the carbon isotope ratio and $\pm 0.04 - \pm 0.05$‰ for the nitrogen isotope ratio (Supplementary Table 13-1). Duplicate or triplicate measurements of the same sample varied, ranging from $\pm 0.001 - \pm 0.09$‰ for the carbon isotope ratio and $\pm 0.003 - \pm 0.08$‰ for the nitrogen isotope ratio (Supplementary Table 13-2). Although the extracted collagen was homogenized once because the soluble components were extracted and filtered, there was variation in crystallization in the vial during the freeze-drying process, which may have caused variation during repeat measurements.

3. Results

3.1 Collagen Quality

The extract collagen yield was between 3−14% (see Table 13-1). The lowest yield was 1.1% for the specimen ID of KW2019-28. In the collagen quality indicators of carbon and nitrogen concentrations, wt%C was 37−42%, wt%N was 14−16%, and $C:N_{Atomic}$ was 3.0−3.2. All the collagen criteria indicated acceptable ranges.

3.2 Radiocarbon Dating

Since the excavated layers of the Ídolo phase were thin and often excavated near typical ceramics of the Kuntur Wasi phase, it was necessary to focus on the samples from the

Supplementary Table 13-1 Standard sample measurement results for calibration in EA-IRMS measurements. The reported values were obtained from Tayasu et al. 2011.

Standard	Material	n	Measured value		Reported value	
			Mean ± 1σ $\delta^{13}C$ (‰, VPDB)	Mean ± 1σ $\delta^{15}N$ (‰, AIR)	Mean ± 1σ $\delta^{13}C$ (‰, VPDB)	Mean ± 1σ $\delta^{15}N$ (‰, AIR)
CERKU-01	DL-Alanine	12	-25.34 ± 0.05	-2.89 ± 0.05	-25.36 ± 0.08	-2.89 ± 0.04
CERKU-02	L-Alanine	12	-19.14 ± 0.03	22.34 ± 0.04	-19.04 ± 0.04	22.71 ± 0.06
CERKU-05	L-Threonine	12	-9.69 ± 0.03	-2.89 ± 0.05	-9.45 ± 0.05	-2.88 ± 0.01

Supplementary Table 13-2 Carbon and nitrogen isotope compositions of samples analyzed in duplicate or triplicate

Specimen ID	$\delta^{13}C$ (‰, VPDB)						$\delta^{15}N$ (‰, AIR)					
	A	B	C	Mean ± 1σ			A	B	C	Mean ± 1σ		
KW2019-5	-12.93	-12.99		-12.96	±	0.04	7.00	7.07		7.03	±	0.05
KW2019-10	-16.86	-16.87	-16.87	-16.87	±	0.01	5.20	5.17	5.23	5.20	±	0.03
KW2019-12	-10.10	-10.10		-10.10	±	0.00	5.66	5.63		5.65	±	0.02
KW2019-20	-12.05	-12.24	-12.18	-12.16	±	0.09	6.21	6.06	6.10	6.12	±	0.08
KW2019-47	-13.86	-13.81		-13.84	±	0.03	5.80	5.79		5.79	±	0.00
KW2019-48	-14.66	-14.69		-14.67	±	0.03	5.87	5.80		5.84	±	0.06
KW2019-40	-19.68	-19.76		-19.72	±	0.06	5.93	5.99		5.96	±	0.05

(produced by Mai Takigami)

Ídolo phase. Therefore, we conducted radiocarbon dating of samples from the Ídolo phase. The results showed that the five cervid samples belonged to the Ídolo phase, whereas the camelid samples belonged to the Kuntur Wasi phase (Table 13-2 and Figure 13-2). It means that the available camelid samples currently do not include individuals from the Ídolo phase. However, it remains a possibility that new samples will be obtained as excavations of the Ídolo phase progresses further in the future.

3.3 Carbon and Nitrogen Isotope Ratios

The minimum carbon isotope ratio ($\delta^{13}C$) of cervid was -20.7‰ in KW2019-27 from the Ídolo phase and the maximum was -17.4‰ in KW2019-43 from the Sotera phase (except for KW2019-35) (see Table 13-1). KW2019-35, alone, showed a high carbon isotope ratio (-15.4‰). The minimum nitrogen isotope ratio ($\delta^{15}N$) was 3.0‰ in KW2019-33 and the maximum was 6.7‰ in KW2019-36, both of which were from the Kuntur Wasi phase. The mean values for each phase were approximately -19‰ for the carbon isotope ratio and approximately 5‰ for the nitrogen isotope ratio (Table 13-3). The isotope ratios were constant throughout the four phases, suggesting that there was no gradual change in

Table 13-2 Radiocarbon dating of artiodactyla in the Ídolo phase

| Specimen ID	Group	Sample ID	^{14}C ages (BP)	AMS Lab. Code	Calibrated ages (calBC)	
					(1σ)	(2σ)
KW2019-47	Camelid	99KW-C-N15	2520±20	YU-14903	775-570	780-545
KW2019-48	Camelid	94KW-B-N1045	2478±20	YU-14904	755-540	770-515
KW2019-23	Cervid	94KW-B-N1097	2868±21	YU-14905	1110-1005	1125-935
KW2019-24	Cervid	98KW-C-N88	2818±21	YU-14906	1005-930	1045-905
KW2019-25	Cervid	94KW-B-N1090	2853±21	YU-14907	1055-935	1110-930
KW2019-26	Cervid	94KW-B-N31	2864±22	YU-14908	1110-995	1120-930
KW2019-27	Cervid	97KW-C-N95	2729±22	YU-14909	900-830	920-815

(produced by Mai Takigami)
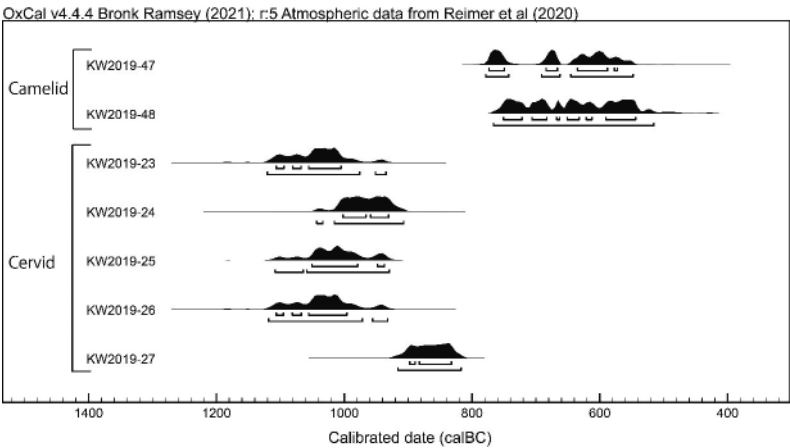
Figure 13-2 Calibrated radiocarbon ages of artiodactyla in the Ídolo phase (produced by Mai Takigami)

Table 13-3 Statistical summary of the isotope ratios of animal specimens excavated
from Kuntur Wasi

Period	n	Mean ± 1σ δ¹³C (‰, VPDB)			Mean ± 1σ δ¹⁵N (‰, AIR)		
Camelid							
KW	7	-14.73	±	1.01	6.09	±	1.19
CP	10	-14.06	±	1.99	6.84	±	1.27
ST	6	-13.83	±	1.67	6.65	±	1.04
Cervid							
ID	5	-19.93	±	0.62	5.08	±	0.71
KW	10	-19.20	±	1.49	4.88	±	0.94
CP	5	-19.74	±	0.71	4.97	±	0.96
ST	4	-18.61	±	0.87	5.36	±	1.02

(produced by Mai Takigami)

the diet (one-way ANOVA: $F_{(3, 20)} = 1.238$, $p = 0.322$ for $\delta^{13}C$, $F_{(3, 20)} = 0.263$, $p = 0.851$ for $\delta^{15}N$). Therefore, it was assumed there were no major environmental changes, such as wetting or drying, and no change in deer hunting areas. This implied that the appearance of camelids in Kuntur Wasi was not caused by external factors affecting the available ecological environment. The KW2019-35 specimen, which showed the only high carbon isotope ratio, was close to that of camelids, suggesting that the animals may have been raised with C_4 plant feed for specific purposes or may have sneaked into C_4 plant fields to graze.

The minimum carbon isotope ratio of camelids was -16.9‰ in KW2019-10 and the maximum was -10.1‰ in KW2019-12, both of which were from the Copa phase (see Table 13-1). The minimum nitrogen isotope ratio was 4.5‰ in KW2019-4 from the Kuntur Wasi phase and the maximum was 9.2‰ in KW2019-14 from the Copa phase. The mean values for each phase were approximately -14‰ for the carbon isotope ratio and 6–7‰ for the nitrogen isotope ratio (see Table 13-3). Carbon and nitrogen isotope ratios were significantly higher for camelids than cervids, suggesting remarkable dietary differences and certain ingestion of C_4 plants (Levine's test: $p = 0.031$ and t-test: $t_{(39)} = -12.481$, $p = 3.083E-15$ for $\delta^{13}C$) (Levine's test: $p = 0.092$ and t-test: $t_{(45)} = -5.076$, $p = 0.714E-06$ for $\delta^{15}N$) (Figure 13-3). The isotopic ratios of the camelids were almost constant throughout the three phases, suggesting that there was no gradual change in diet (one-way ANOVA: $F_{(2, 20)} = 0.520$, $p = 0.602$ for $\delta^{13}C$, $F_{(2, 20)} = 0.835$, $p = 0.449$ for $\delta^{15}N$). This indicates that camelids who consumed C_4 plants were present on site from the early Late Formative Period.

4. Discussion

4.1 Comparison with Pacopampa

A comparison of the diet of cervids and camelids at Pacopampa shows that the cervids had a similar diet (Figure 13-4), whereas the camelids had different dietary trends (Figure 13-5). Cervids indicated low carbon and nitrogen isotope ratios at both sites during the
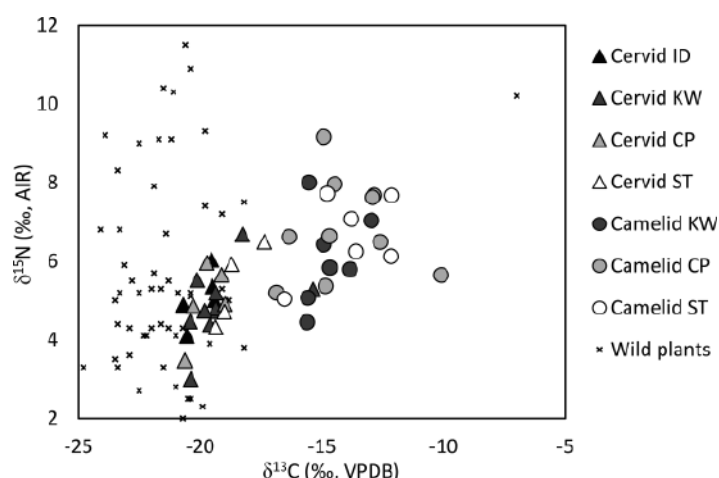
Figure 13-3 Comparison of the isotopic ratios between cervids and camelids at Kuntur Wasi. Modern wild plant data are plotted only above 2,000 m altitudes, referenced from previous studies in northern Peru (Szpak et al. 2013). Corrections for isotopic fractionation with animal body tissues (+4‰ for δ¹³C and +3‰ for δ¹⁵N) and the Suess effect (+1.5‰) are added to the data for modern wild plants (Friedli et al. 1986; Keeling 1979; Takigami et al. 2021). (produced by Mai Takigami)
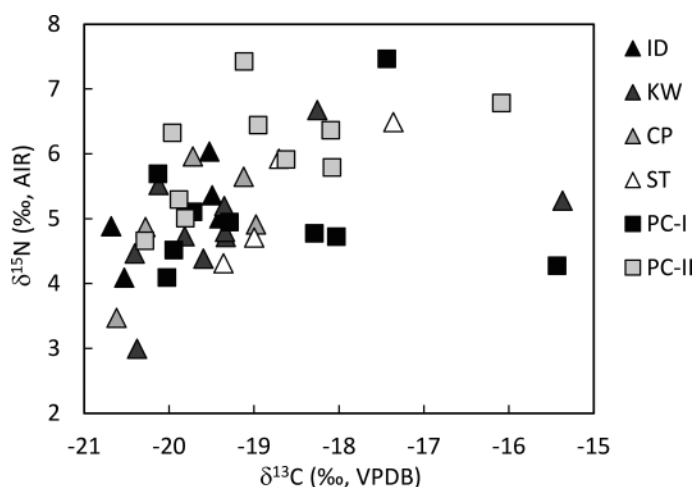

Figure 13-4 Comparison of the isotopic ratios of the cervids at Kuntur Wasi and Pacopampa (produced by Mai Takigami)

Late Formative Period (Levine's test: $p=0.687$ and T-test: $t\,(23)=-0.948$, $p=0.353$ for δ¹³C) (Levine's test: $p=0.9160$ and T-test: $t\,(23)=-3.018$, $p=0.006$ for δ¹⁵N). Certain differences in the nitrogen isotope ratios reflect the results of elevated nitrogen isotope ratios during the PC-II phase in the cervids in Pacopampa (Takigami et al. 2021). A few
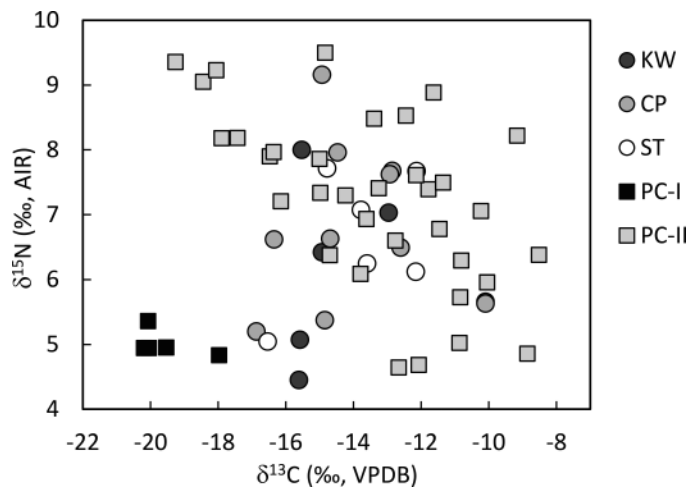
Figure 13-5   Comparison of the isotopic ratios of camelids at Kuntur Wasi
and Pacopampa (produced by Mai Takigami)

cervids showed C_4 plant consumption; a similar trend at both sites.

Camelids with a diet similar to the PC-I phase, i.e., the highland diet, were not present at Kuntur Wasi throughout the three phases. In contrast, the camelids of the PC-II phase exhibited a variation from low carbon and high nitrogen isotope ratios to high carbon and low nitrogen isotope ratios, with a negative correlation; however, this dietary trend is also slightly different from camelids in Kuntur Wasi. They had low to high nitrogen isotope ratios, whereas the carbon isotope ratios varied little and were intermediate. Statistical comparison of the camelid diet in the Late Formative Period indicated unequal variances in carbon isotope ratios and significant differences in nitrogen isotope ratios between the means (Levine's test: $p=0.011$ and T-test: t (49)$=-1.301$, $p=0.199$ for $\delta^{13}C$) (Levine's test: $p=0.521$ and T-test: t (51)$=-2.132$, $p=0.038$ for $\delta^{15}N$).

Considering the contribution of the C_4 plants to the camelid diet, and assuming that the contribution of a pure C_3 plant-eater was -21.5‰ and a pure C_4 plant-eater was -6.5‰ (Sullivan and Krueger 1981), the minimum contribution of camelids in Kuntur Wasi was estimated to be 31%. The maximum contribution was 76% and the average was 49±11% (see Table 13-1). In Pacopampa, camelids in the PC-II phase showed a large variation in the contribution of C_4 plants, with a minimum of 9%, a maximum of 86%, and an average of $56 \pm 16\%$ (Takigami et al. 2020). The camelids of Kuntur Wasi showed smaller individual differences and a slightly lower contribution rate than those of Pacopampa.

Possible explanations for this difference in camelid diet include differences in the surrounding ecological environment and management strategies. Both sites were located in the upper *Yunga* and lower *Quechua* zones. Pacopampa is on the upper eastern slope of the Andes, beyond the Andean divide, and is, therefore, somewhat humid. Numerous types of plants grow near the present site. In contrast, Kuntur Wasi is on the upper

western slope of the Andes where the climate was rather dry and the present vegetation is dominated by leguminous plants. We cannot deny the possibility that these environmental differences were reflected in the camelid diet. However, the possibility that the camelids in Pacopampa contained dietary diversity derived from human activity must be discussed. If they were raised in the same environment, they should have shown a more coherent diet, even if there were individual differences; however, they showed a characteristic distribution with a negative correlation, as if the ratio of plants eaten had been intentionally changed. A previous study in Virú valley during the Early Intermediate Period suggested that the diversity in camelid diet may be due to the differences in management strategies of small breeding groups (Szpak et al. 2014). Therefore, the inclusion of camelids with high and low C_4 plant consumption at Pacopampa may have reflected the differences in the management strategies of the husbandry group, rather than individual preference differences in the same pasture. There may have been multiple herding groups at Pacopampa. In addition, it is possible that camelid's diet was managed based on rituals or differences in the social positions of people who consumed camelids. Probably, the camelid husbandry management strategy at Pacopampa differed from Kuntur Wasi.

4.2 Which C_4 Plants did the Camelids Consume in Pacopampa and Kuntur Wasi?

In the highlands of the Atacama Desert, wild camelids ate *Amaranthaceae* and reared camelids ate *Atriplex* sp. (Cadwallader et al. 2012; López et al. 2017). However, in northern Chile, the arid desert environment continues to expand to an altitude of approximately 2,000 m, with a grassland environment from 2,000–3,000 m, which differs from the *Yunga* and *Quechua* environments of northern Peru. Since *Andropogon* sp. was the only wild C_4 plant that existed in the northern highlands of Peru, at altitudes above 2,000 m, before the Spanish conquest (Szpak et al. 2013), it would be difficult for Pacopampa and Kuntur Wasi camelids to selectively consume over 50% of this plant. Therefore, this camelid diet would not have been possible without the consumption of cultivated C_4 plants. Maize (*Zea mays*) and Amaranthus (*Amaranthus caudatus*) were the only two C_4 plants cultivated in the Andean region. Maize cultivation in the Andes is generally limited to 3,600 m altitude since it is a semi-hardy plant and can be grown from the semi-arid zone with annual precipitation of 2.5 cm to arid areas with annual precipitation exceeding 1,000 cm (Bonavia 2013). A limited variety, called *Tunku*, can be grown at high altitudes of over 4,000 m, such as near Lake Titicaca (Staller 2006). Amaranthus is a cold-sensitive plant and a summer-grown annual grass. The suitable temperature for its cultivation is from 25–40°C and the cultivation limit is 3,500 m altitude (Rastogi and Shukla 2013). It grows in warm, subtropical, and tropical climates and prefers slightly warmer areas than maize. At Pacopampa, since maize was detected in the analysis of starch grains left in human teeth and ceramics, it was assumed that maize was the C_4 plant fed to camelids (Takigami et al. 2020, 2021). At Huaca de Pueblo Tucume, in the Late Intermediate Period, a layer of camelid dung was found containing maize grains, stalks, and leaves, suggesting that the management strategies that fed maize to the camelids were established in the pre-Hispanic period (Shimada and Shimada

1985). Although there is no conclusive evidence that maize was the only plant cultivated at Kuntur Wasi, it would not be an overestimation based on the findings of Pacopampa for the same period and the herding system of the later periods. However, it is unclear how camelids acquired maize in the Late Formative Period, i.e., whether camelids were herded in maize fields or whether harvested stalks and leaves were carried to camelid pastures.

4.3 Existence of Multiple Camelid Breeding Groups

Based on the diet differences during the Late Formative Period, the camelid herding groups differed in Pacopampa and Kuntur Wasi. In addition, the strontium isotope data indicate that a juvenile was transported from a distant area, with a high strontium isotope ratio, to another pasture around Pacopampa (Takigami et al. 2020), suggesting that at least three or more herding groups were involved at the northern highland sites. Furthermore, since a camelid group with the highland diet existed during the PC-I phase, another camelid herding group has been associated with the middle of the Formative Period. Therefore, there must have been numerous groups with different camelid management strategies in the Middle to Late Formative Period, from the highland plateau to the lower elevations. However, the isotope ratios do not indicate a relationship with herding groups in coastal areas. Individuals with high carbon and nitrogen isotope ratios, which are characteristic of coastal areas, are not exhibited in the Pacopampa and Kuntur Wasi camelid groups.

The following questio arises: how were the camelid-supplying groups related to both Kuntur Wasi and Pacopampa? Camelids raised at high altitudes were transported to the lowlands in caravans to transport meat, dung, hair products, and rock salt (Inamura 1995). Camelid herders in the highlands exchanged these resources with lowland resources (mainly crops). Groups with camelids temporarily took on cargo-carrying jobs in the lowlands. However, this resource strategy was mainly observed in the southern highlands of Peru. In the northern highlands, the Andes are lower in elevation; therefore, the demand for scarce resources, due to elevation differences, is lesser, making it difficult to apply the same strategy. There are numerous possibilities for the emergence of camelid herders in the northern highlands. As the site became a ceremonial center, it may have been necessary to use pack animals to trade manufactured goods. Wool production has been cited as a motivation for introducing camelid husbandry in low-altitude areas (Mader et al. 2018; Uzawa et al. 2021). The difference in camelid groups between the periods in Pacopampa may reflect the change in usage.

4.4 Comparison of Camelid Isotope Ratios during the Formative Period

Comparing the reported isotope ratios of camelids during the Formative Period with wild coastal guanaco (La Paloma) and modern camelids in high-altitude pastures of the *Puna* and *Altiplano* (Arequipa, La Libertad, and Chilligua), show different isotope ratios in different regions (Figure 13-6). In terms of carbon isotope ratios, individuals on the highland plateau characteristically have low values, whereas those on the coast have values similar to those on other highland sites. However, nitrogen isotope ratios
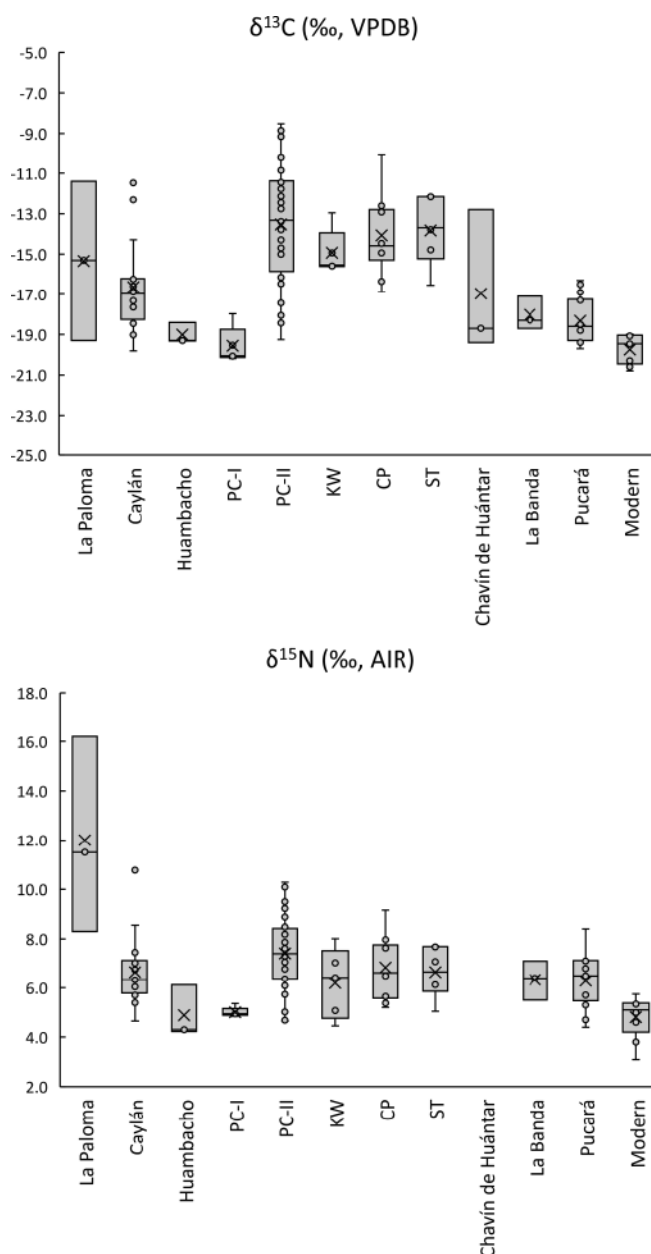
Figure 13-6 Comparison of the isotopic ratios of camelids during the Formative Period. The period and cited references for each site are as follows: La Paloma 5800 ± 1200 BP (DeNiro 1988), Caylán and Huambacho 800−150 BCE (Szpak et al. 2016), Pacopampa 700−400 BCE (Takigami et al. 2020, 2021), Chavín de Huantar 850–450 BCE (Burger and van der Merwe 1990), La Banda 2900−2400 BP (Sayre et al. 2016), and modern camelids from Tocra, Quiruvilca, and Chilligua (Dufour et al. 2014; Thornton et al. 2011). (produced by Mai Takigami)

simultaneously exhibit characteristically high values for the wild coastal group and particularly low values for the modern highland plateau group. Compared to these characteristic dietary regions, camelids in mountain areas were divided into three groups based on carbon isotope ratios − Group 1: Pacopampa I, Group 2: Pacopampa II and Kuntur Wasi, and Group 3: Chavín de Huántar and Pukará. The nitrogen isotopic ratios were similar at all sites, except for Group 1, which was remarkably low. For carbon isotope ratios, except Group 1, Groups 2 and 3 reflected differences by elevation. Therefore, there were two groups − those in the 2,000 m elevation range (Group 2) and those in the 3,000 m elevation range (Group 3). Isotope data from three camelids have been reported in La Banda, across the Mosna River, from the monumental center at Chavín de Huántar (Sayre et al. 2016). Its carbon isotope ratios are lower than Group 2, suggesting a dependence on C_3 plants. The cultivation of maize in the upper *Quechua* environment, which is above 3,200 m, was difficult and camelid herding was conducted without maize. Some have highlighted that, within a 5-km radius of Chavín de Huántar, at 3,150 m, only 8% of the land was under maize cultivation (Burger and van der Merwe 1990). Conversely, the carbon isotope ratios of the three camelid specimens excavated from the deposited layer, which covered the architectural remains, were reported 0.7 km from the Old Temple in Chavín de Huántar (Burger and van der Merwe 1990). Two of the specimens are identical to the ones at La Banda. The exception shows a higher carbon isotope ratio similar to Group 2. However, the nitrogen isotope ratio is not reported, which includes the possibility that the camelid was derived from the coastal region.

Camelids during the Formative Period generally reflected the ecological environment around the site, indicating that camelid groups raised in different ecological environments were rarely buried in ceremonial architectures. Therefore, except for the coastal area, camelid management strategies were established to suit each ecological environment. The management strategy, using C_4 plants, seems to have been developed when camelid husbandry propagated to areas at altitudes of 2,000 m. In the coastal areas, camelid herding in the local area appears to have been in the experimental stage. In Caylán and Huambacho in the Nepeña Valley, it was reported that many excavated camelids may have been brought from highland pastures as part of caravans (Szpak et al. 2016). In addition, it was pointed out that experimental husbandry started because some camelids indicated isotope ratio characteristics of coastal areas.

Notably, the peculiarity of the camelid diet at Pacopampa stands out. Although it was at an altitude of 2,500 m, the camelid group herded on the high-altitude pastures above 4,000 m, as appeared in the PC-I phase. The camelid group of the PC-II phase exhibited a large variation in isotope ratios, which differed from the relatively homogeneous diet of the camelid groups found at other sites. This diversity of diet reflected the unique surrounding environment, such as the wet environment of the upper eastern slopes of the Andes where Pacopampa is located, the accessibility of the dry environment of the western slopes of the Andes, and the proximity to the highland *Puna* ecological environment around Incahuasi, where camelids are currently herded. Furthermore, based on the analysis of strontium isotope ratios, it is consistent to assume

that numerous camelids were herded near the site (Takigami et al. 2020). However, since there is, at least, one exotic individual, the possibility that camelids raised in other ecological environments were brought to the site cannot be ruled out.

4.5 Propagated Route of Camelid Husbandry

The third stage of propagation of camelid management and husbandry strategies, mentioned in the introduction, can be further subdivided by elevation into the following four stages: (1) The use and gradual herding of camelids began at the highland plateau, (2) the use of camelids was spread through caravans by highland groups, (3) husbandry strategies were spread to lower elevation areas in mountainous regions and the direct use of camelids was launched, and (4) herding and direct use of camelids finally started in the coastal region.

The isotope data indicate that the dietary change in Pacopampa exhibited the crucial moment of transition from stages two to three, while the Kuntur Wasi diet was on stage three. However, the propagation of stage 2 was possibly much faster in areas closer to the Central Andes. Tsurumi (2014) stated that caravans with llamas may have contributed to the trade network in the north-south direction. He speculated that the route through the highlands of the Santiago de Chuco Basin functioned during the Early to Middle Formative Period, whereas the caravan route through the middle reaches of the river functioned after the Middle Formative Period (Tsurumi 2014). It remains to be seen whether these caravans had camelid groups raised in the highland *Puna* or lower altitude areas; nevertheless, the transition from stages two to three may have been spread by these caravans throughout the Formative Period, initiating a suitable management strategy for each environmental zone. However, whereas Pacopampa started from stage two, Kuntur Wasi, according to the current results, only had stage three. Therefore, it is possible that even among the ceremonial architecture sites in the northern highlands at altitudes of 2,000 m, there were various situations that were involved with the camelids in stage two and those that began to be related to the camelids in stage three; however, it is necessary for additional investigation of the Ídolo phase of Kuntur Wasi. This may be due to the social position of each site, supported by the complexity depicted by the data for the propagation of camelid use and husbandry.

In addition, Caylán and Huambacho in the coastal areas of the lower Nepeña Valley, reported in previous studies, may have been captured during stages three to four. During the Late Formative Period, when the management strategy, using C_4 plants in stage three, spread rapidly, especially in the northern highlands, the Nepeña Valley was on the verge of moving into stage four. The Nepeña Valley is located south of the Viru and Moche valleys, where camelid husbandry began in the Early Intermediate Period, and is close to the origin of camelid husbandry in the Central Andes. It would not be inconsistent to assume that stages two, three, and four proceeded earlier in the Nepeña Valley than in the northern highlands north of Cajamarca. Uzawa and his colleagues (this volume) noted that camelid breeding was spread in a hub-and-spoke manner. Future studies must examine management strategies in the central and southern highlands at elevations of 2,000 m.

5. Conclusions

Zooarchaeological studies previously indicated that camelid husbandry was widespread in the northern highlands during the Late Formative Period. It is easy to assume that highland grasslands, where camelids are still herded (for example, Granja Porcón near Kuntur Wasi, Incahuasi near Pacopampa, etc.), may have been used as pastureland. However, the isotope analysis results in Kuntur Wasi and a previous study in Pacopampa indicated the use of C_4 plants for rearing and implied that camelids were kept in lower elevation areas, closer to the site. In addition, the isotopic data exhibited that several herding groups managed camelids in low-elevation areas and had close relationships with ceremonial centers. Furthermore, based on diet, the groups involved at Pacopampa changed from the Middle to the Late Formative Period, reflecting the social situation impacting the changing demand for camelids.

Conversely, isotopic data from a wide area indicated that camelid husbandry during the Formative Period included management strategies adapted to the ecological environment around the site. Therefore, a new camelid husbandry strategy, using C_4 plants, probably began near the 2,000 m elevation areas. Camelids reared with this management strategy would be found in various Andean societies in later periods; however, this strategy appears to have been implemented in limited regions during the Formative Period. By connecting isotopic data, we obtained the spatial and temporal transition of the camelid husbandry management strategy. Extensive information can be established by identifying the camelid-keeping groups, such as their subsistent strategies, resource trade routes, the background of the groups that gathered at the ceremonial centers, and interactions between the regions. Using isotope analysis of large livestock that supported the Andean civilization, we can establish the real image of the complex social development during the Formative Period.

Acknowledgments

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