Botanical Composition and Nutritional Quality of Alpaca Diets in Two Andean Rangeland Communities

RICHARD J. REINER AND FRED C. BRYANT

Abstract

Our objectives were to measure alpaca *(Lama pacos)* diet quality and botanical composition seasonally on 2 high elevation rangesites (bofedal and Altiplano) in the Andes Mountains of Peru. The bofedal site was a perennially green sedge and forb community located at 5,000 m elevation. The Altiplano site, located at 3,190 m, was predominately bunchgrass. We collected diets from free-ranging, esophageally fistulated alpacas at each site. Alpaca diets at both sites were highest in grasses during the wet and early dry season. As the dry season progressed, bofedal alpaca diets were comprised largely of sedges and reeds (78%) while Altiplano diets remained predominantly grasses (68%). Forb consumption varied annually between 8 and 29% of the diet on both sites. Crude protein (CP) in bofedal diets (12.3%) averaged higher than on the Altiplano (10.2%). Values were lowest during August (6.1%) on the Altiplano and in July (8.0%) on the bofedal. In vitro organic matter digestibility (IVOMD) of alpaca diets on the bofedal (63%) was similar to the Altiplano site (64%) when averaged for all seasons. IVOMD was lowest during August (49%) at the Altiplano site and in October (50%) on the bofedal. Low dietary CP and IVOMD during the late dry season (Aug.–Oct.) denote this period as nutritionally critical for both sites.

Alpacas are important fiber- and meat-producing livestock for highland inhabitants of the Andes mountains of southern Peru and northern Bolivia (Reiner and Bryant 1983). Approximately 2.5 million alpacas graze high-elevation grassland in Peru and Bolivia (Fernandez Baca 1975). Alpacas are physiologically adapted for life at high elevation and are able to graze much of the Andean range where sheep and cattle production is unprofitable.

Alpaca grazing sites are primarily chosen in response to forage availability and tradition. Range management in the form of grazing systems or diet supplementation is rare. Little is known about nutritional quality and botanical composition of alpaca diets on the varied range sites they graze. Implementing effective grazing systems or diet supplementation schemes requires this knowledge. We describe the botanical composition and nutritional quality of alpaca diets relative to seasonal forage availability for 2 important rangeland sites (bofedal and Altiplano) in southern Peru.

High-elevation rangeland in southern Peru is characterized by 2 major grassland zones: the Altiplano (high plains) of the Lake Titicaca basin (3,100 m elevation) and the mountains surrounding the basin. Mountain rangeland occasionally exceeds 5,800 m. The Altiplano is primarily a zone of sheep production although alpaca numbers are increasing due to a favorable market for alpaca wool. The mountain zone is grazed primarily by alpacas.

The wet growing season occurs in November through April in southern Peru. During the rest of the year, there is no precipitation and little forage production. Alpacas grazing in the mountains during the dry season are herded to perennially green, tundra-like pastures called bofedales. Bofedales are scarce on the Altiplano and are often over-grazed.

Physiological differences between alpaca and sheep preclude adapting established sheep management techniques for alpaca. For example, the gestation period for alpacas is almost 1 year (345 days). Females are bred and give birth during January when nutritious forage is available. Alpacas survive the nutritionally stressful dry season while in the late stages of lactation and supporting gestation (Sumar 1983). Weight loss, impaired wool production, and low fertility have been attributed to inadequate dry season nutrition (West 1981).

Study Sites

Bofedal Site

The bofedal study site was located at *Instituto Veterinario de Investigaciones Tropicales de Altura's* research station at La Raya, Peru (14° 30'S 71°W). Two study bofedales were located in glacial cirques at approximately 5,000 m. Melt water from ice fields that lie above 5,200 m irrigate the mat-like plant community of low-growing forbs, sedges, and reeds throughout the year. Bofedal soils described in central Peru are typic cryohemists (Wilcox 1982). They are characterized by dark epipedons with between 60 and 70% organic matter. Soils are poorly drained and moderately permeable. Annual precipitation at the bofedal site averages 952 mm (Holgado et al. 1979). Precipitation during the study period (May 1983–Apr. 1984) was 866 mm. Temperatures averaged from –5° C to 15° C with highest values occurring in the wet season.

Atiplano Site

We chose *Universidad Nacional Tecnica del Altiplano's* research station at Chuquibambilla as representative of the Altiplano. The research station is located 65 km southwest of the bofedal site. We worked in the Buena Vista Pasture of the ranch. Elevation is 3,190 m and topography is flat. Average annual precipitation was 784 mm. Monthly average daily temperature at the Altiplano site closely paralleled those recorded at the bofedal site, although average dry season minimums in the Altiplano were 2° to 3° C lower at the latter site. Cool-season bunchgrasses predominated with low-growing sedges and forbs filling the interspaces. Range sites in the Buena Vista pasture were classified as Pacara and Sorani (Velarde Vilca and Astorga 1984). Soils were deep and ranged from sandy-clay to loamy in texture. Drainage was poor.

Methods

We sampled alpaca diets during 8 periods in 1983-84 at the bofedal and Altiplano sites. Sampling dates were as follows: 10–14 June (early dry season; alpaca lactation), 10–14 July (dry season; gestation, late lactation), 22–26 August (mid-dry season), 4–8 October (late dry season; weaning, shearing), 7–11 November (early wet season; last trimester of gestation for alpaca); 1–4 January (wet season; parturition, breeding for alpaca), 2–6 February (mid-west season; late breeding for alpaca), and 3–7 March (late wet season; late parturition, early lactation).

Eight adult male castrated alpacas of the huacaya breed were surgically fitted with esophageal cannulas (Cook et al. 1958). Diets were sampled from 4 alpacas at each site. Five days before a sampling period, the experimental alpacas were moved from a cultivated pasture and allowed to forage with a free-ranging herd to allow adaptation to the new environment and forage. Following

Authors are research assistant, Mississippi State University, Department of Wildlife and Fisheries, P.O. Drawer LW, Mississippi State 39762 and associate professor, Department of Range and Wildlife Management, Texas Tech University, Lubbock 79409.

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this adaptation period, diets were collected using screen-bottomed bags each morning at 9:00 a.m. for 5 days while the experimental alpacas grazed freely within the production herd. A collection period lasted 30 to 60 minutes. The production herd and the experimental alpacas were penned at night, a typical practice in the area.

Samples were hand-mixed, air dried, and individually ground to pass through a Wiley mill fitted with a 0.5-mm screen. Botanical composition was estimated by the microhistological technique (Sparks and Malechek 1968, Scott and Dahl 1980). Two slides were made per sample and 10 fields read per slide. One slide was later re-read for occurrence of seed and flower parts. Marshall and Squires (1979) showed the microhistological procedure to be a relatively insensitive measure of diet botanical composition with some tropical forages and advised that species be placed in broad consumption categories. We report observed diet composition but make statistical comparisons only between forage classes.

Extrusa was chemically analyzed for crude protein (% nitrogen × 6.25) (A.O.A.C. 1970) and in vitro organic matter digestibility (Van Soest 1970). Inoculum was obtained from a steer maintained on alfalfa. Variability between in vitro digestibility trials was reduced by including a standard of sorghum in each trial.

Percent foliar, soil, and litter cover were estimated at the Altiplano site using the Daubenmire technique (Daubenmire 1959). Cover was recorded within 36 0.5-m quadrats randomly located in the pasture. When estimating cover, the technician was given no requirement other than that total cover in each quadrat equal 100%. Composition of foliar, litter, and soil cover was later adjusted to 100%. A modified inclined point technique (Wilson 1960) was used to estimate cover at the bofedal site. Ten points angled at 45° and separated by 10 cm were placed at 1-m intervals along 2 50-m transects in the bofedal. Only the first hit on foliage, soil, or litter was recorded for each point position.

Divergent techniques were used at each site to estimate cover because of extreme differences in vegetation physical character. During pre-sampling on the bofedal, the Daubenmire technique exhibited high variability due to the observer's difficulty in estimating cover of small compacted plants within relatively large quadrats. The inclined point technique removed observer subjectiveness on the bofedal site but was inappropriate for the Altiplano where it routinely over-estimated bunchgrass cover.

A randomized (fixed effect model), split plot analysis of variance was used to test for the main effects of site and month on diet composition within forage classes. Variation among animals was considered experimental error and days as sample variation. Site (bofedal vs. Altiplano) was designated the treatment. Sample periods (months) were used as repeated measures. Mean comparisons were by Least Significant Difference Tests (Steel and Torrie 1980).

Results and Discussion

Forage Availability

Thirty-five plant species were identified at the bofedal site (Reiner 1985). Averaged across collection periods, vegetation cover was 22% grass, 42% sedges and reeds, and 33% forbs. Important grasses included *Calamagrostis antoniana, Calamagrostis rigescens,* and *Festuca dolichophylla.* Grass cover was highest during the wet season and lowest during the dry season (Table 1). The major sedge species included *Eleocharis albibracteata, Distichia muscoides,* and *Luzula peruviana. Juncus* spp. was abundant in the wet season. Forbs were most abundant at the bofedal site during the late dry season. At this time, dominant forbs included *Plantago tubulosa, Hypochoeris taraxacoides,* and *Werneria pygmaea. Alchemilla diplophilla* was the major wet-season forb.

Forty-seven plant species were identified on the Altiplano pasture; 20 of these species were also found on the bofedales. Vegetation cover averaged 68% grasses, 13% sedges and reeds, and 6% forbs. The predominate grasses at the Altiplano site were *Festuca dolichophylla, Calamagrostis antoniana,* and *Muhlenbergia fastigiata.* Sedges were mostly *Carex ecuadorica.* Small percentages of *Alchemilla pinnata, Lepidium* spp., *Hypochoeris stenocephala,* and *Geranium sessiliflorum* represented the dry-season forbs. Larger percentages of *Arenaria* spp., *Nototriches* spp., *Trifolium amabile,* and *Oxalis* spp. were present in the wet season.

Table 1. Percent forage foliar cover during eight months of 1983 and 1984 on the study sites in southern Peru.

Sites / Forage Class	Months J	J	A	O	N	J	F	M
	Dry Season					Wet Season		
Bofedal								
Grass	26	21	17	18	*	22	28	*
Sedges and Reeds	46	46	48	34	*	36	42	*
Forbs	23	30	30	44	*	38	27	*
Moss	2	2	4	3	*	2	1	*
Litter and Soil	3	1	1	1	*	2	2	*
Altiplano								
Grass	68	52	72	75	67	72	60	60
Sedges and Reeds	15	25	7	11	11	10	13	9
Forbs	3	6	1	1	1	3	16	20
Moss	T[1]	1	1	T	2	2	3	7
Litter and Soil	14	16	19	13	19	13	8	4

[1]T represents values less than 0.5%.
*No data available for this period.

Diet Botanical Composition

Alpaca diets on the bofedal were consistently higher in sedges and reeds and lower in grasses than on the Altiplano (Table 2). Annual contributions of species to bofedal alpaca diets consisted primarily of sedges and reeds, followed by grasses and forbs. Alpaca diets on the Altiplano sites were highest in grass, followed by sedges and reeds, and forbs.

Dietary composition during the early dry season (June and July) did not differ ($P>0.05$) between sites for each forage class. As the dry season progressed, the magnitude of site effects increased (site/month interaction, $P<0.05$). Grass consumption during August on the Altiplano increased while grass consumption by alpacas on the bofedal declined. At this time, bofedal diets were largely sedges and reeds. During the late dry season (Aug., Oct., and Nov.), sedges and reed consumption was higher ($P<0.05$) on the bofedal than on the Altiplano site. Sedges and reeds were eaten most frequently on the Altiplano site during the mid-wet season (Feb.). Although the forbs did not contribute a large portion of the annual diet, they were consistently eaten at both sites.

Diet composition at the Altiplano site resembled that reported by Bryant and Farfan (1984) and Barcena Amachi (1977) on *Festuca/Calamagrostis* pastures in southern Peru. Forage availability in these studies approximated forage found at our Altiplano site. Grass dominated dry-season diets in both studies with *Festuca dolichophylla* being the major species. Similarly, *Eleocharis albibracteata* and *Carex euadorica* were the major sedges and *Alchemilla pinnata* was the major dry-season forb. Bofedal alpaca diets from our study showed little similarity to other studies.

Although forbs were abundant on the bofedal during the late dry season, most were unpalatable. In particular, *Plantago tubulosa* was a dominant forb that alpaca did not eat. Bryant and Farfan (1984) also found *Plantago tubulosa* to be relatively unpalatable. Similarly, Altiplano forb cover increased during the late wet season due to a flush in growth of *Arenaria* spp. growing in the pasture. Contrary to Tapia Nunez and Flores Ochoa (1984), alpacas in our study consumed very little *Arenaria* spp.

Bryant and Farfan (1984) reported that alpacas' diets contained large amounts of seeds during September and hypothesized that

Table 2. Mean dietary botanical composition[1] (% ± SE_m) listed in order of annual contribution within forage classes.

BOFEDAL SITE	Annual $\bar{x}$	Month						
		Jan.	Jul.	Aug.	Oct.	Nov.	Jan.	Feb.	Mar.
Grass									
Festuca dolichophylla	10±3	13±3	6±3	1±*	8±2	13±4	4±2	14±3	18±3
Calamagrostis antoniana	9±3	27±4	29±5	1±*	6±2	6±3	0	1±*	1±*
Calamagrostis rigescens	5±2	2±*	8±2	1±*	T	T	23±4	3±1	2±*
Mulenbergia fastigiata	1±*	1±*	1±*	0	0	0	0	6±2	1±*
Other grass	2±1	0	4±1	0	1±T	4±2	0	1±*	3±*
Total	27±6	43±6	48±5	3±1	15±3	23±4	27±5	25±3	25±4
Sedges and Reeds									
Juncus sp.	28±5	9±4	11±2	60±9	33±6	29±4	16±4	39±8	30±6
Eleocharis albibracteata	21±4	7±2	13±2	12±2	31±6	24±3	31±4	24±3	27±2
Distichia muscoides	4±2	6±2	1±*	5±1	7±2	5±2	0	1±*	4±*
Carex ecuadorica	2±1	T	2±*	1±*	1±*	2±1	13±2	T	T
Other sedges and reeds	3±1	12±3	1±*	3±1	0	3±1	0	0	4±2
Total	58±9	34±4	28±5	78±9	72±8	63±8	60±7	64±5	65±6
Forbs									
Hipochoeris taraxacoides	3±1	4±1	10±2	T	2±1	0	6±2	2±*	1±*
Stylites andicola	2±1	0	T	T	4±1	9±2	0	0	0
Werneria pygmaea	2±1	0	0	11±2	2±1	1±*	0	0	0
Other forbs	7±2	16±3	9±1	2±*	2±*	3±*	2±*	6±2	7±2
Total	14±3	20±4	19±3	13±2	10±2	13±2	8±2	8±1	8±2
ALTIPLANO SITE									
Grass									
Festuca dolichopylla	18±4	16±4	4±3	31±5	16±4	31±4	19±3	10±2	15±4
Muhlenbergia fastigiata	13±3	21±3	14±2	9±2	15±2	8±2	5±1	18±4	16±3
Calamagrostis antoniana	8±2	0	14±3	10±1	11±2	11±1	9±2	2±*	4±1
Poa gymnantha	4±2	2±*	6±2	0	0	T	4±1	1±*	0
Horidum muticum	2±*	1±*	8±2	2±1	5±1	0	1±*	1±*	1±*
Poa gilgiana	2±1	8±1	2±*	6±2	0	0	2±1	0	12±2
Calamagrostis curvula	2±*	12±2	T	0	0	T	0	0	0
Calamagrostis vicunarium	1±*	0	0	5±2	1±*	0	0	4±2	0
Distichlis humilis	1±*	0	0	5±2	0	0	0	0	0
Other grass	2±*	1±*	3±1	0	0	0	0	1±*	7±2
Total	53±7	61±7	51±9	68±7	48±5	50±6	40±4	37±3	55±5
Sedges and reeds									
Eleocharis albibracteata	16±3	3±1	10±2	16±4	22±4	18±3	25±4	16±1	21±3
Carex ecuadorica	14±2	20±4	2±T	7±3	17±4	18±3	18±5	16±4	16±4
Juncus sp.	2±*	T	2±1	0	0	0	0	11±1	T
Other sedges and reeds	0	0	0	0	0	0	0	0	0
Total	32±6	23±5	14±3	23±	39±5	36±7	43±7	43±6	37±5
Forbs									
Alchemilla pinnata	10±2	5±2	20±4	8±2	11±2	10±2	16±3	5±2	1±*
Other forbs	5±1	8±3	9±2	0	0	0	3±1	13±3	6±2
Total	15±4	13±4	29±5	8±2	11±3	10±3	19±4	18±4	7±2

[1]Includes species contributing more than 5% of the diet during any collection period.
T = <1% of the diet.
* = standard error is less than 1.

seeds were energetically important for alpacas during the dry season. Alpacas grazing the bofedal site in our study also consumed many seeds during the dry season (Table 3); however, seed consumption peaked in July and August. In contrast, consumption of grass seeds at the Altiplano site was greatest in the late wet season when seeds were most abundant. The decline of seeds in Altiplano alpaca diets during the dry season may have been due to seeds becoming unavailable after heavy grazing.

Table 3. Frequency of grass seeds and flower parts in the diets of alpacas grazing the study sites.

Site	Months							
	J	J	A	O	N	J	F	M
	Dry Season					Wet Season		
Bofedal	14	22	20	7	13	7	5	8
Altiplano	11	3	5	7	9	15	20	17

Diet Quality

On average, CP in alpaca diets on the bofedal (12.3%) was higher than in Altiplano diets (10.2%). Dietary CP was lowest during August (6.1%) and July (8.0%) on the Altiplano pasture and bofedal, respectively (Fig. 1). Diets on the bofedal had higher ($P<0.05$) CP content than in the Altiplano during the nutritionally critical late dry season (Aug., Oct.). The minor increase in CP observed during July on the Altiplano site can be explained by a sudden increase in algae consumption (6% of the diet). During July, alpacas consumed algae growing in flooded irrigation ditches which crossed the pasture.

Dietary IVOMD at the bofedal site (63%) was similar to the

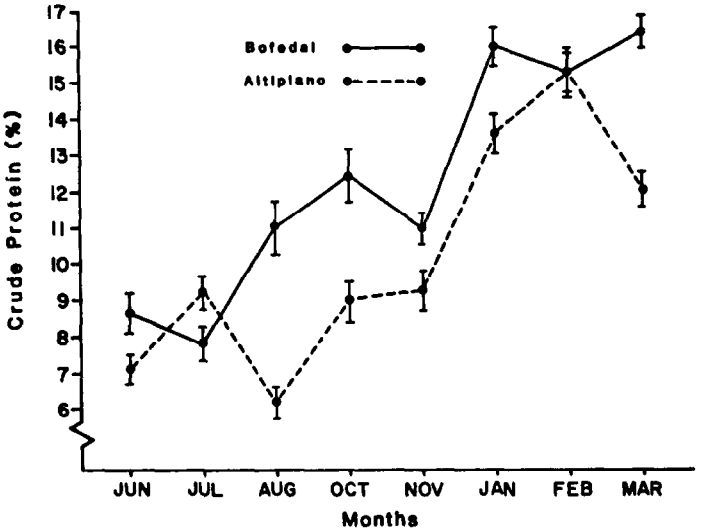

Fig. 1. *Percent crude protein in the diets of alpacas grazing the bofedal and Altiplano sites (vertical bars = 95% confidence limits).*

Altiplano (64%) when averaged across collection periods (Fig. 2). Rittenhouse et al. (1971) reported a strong positive relationship between organic digestibility and in vitro digestible energy. Depressed digestibility at both sites during the nutritionally critical mid- and late-dry season might indicate energy deficiency during these months. Low energy values in October at the bofedal site

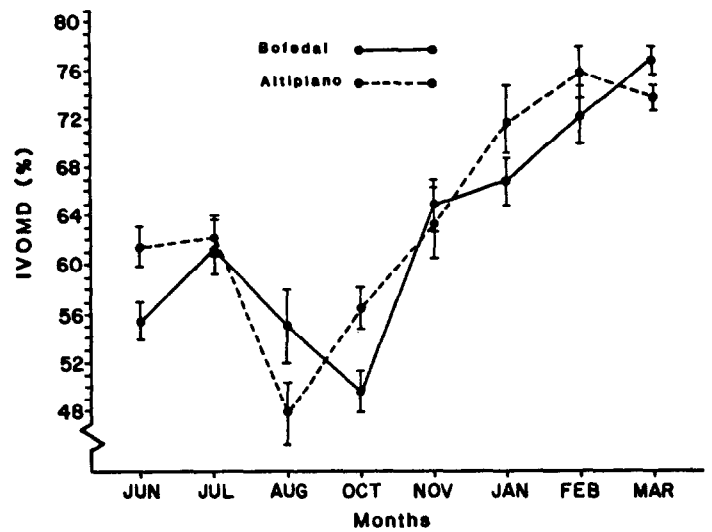

Fig. 2. *Percent in vitro organic matter digestibility (IVOMD) in the diets of alpacas grazing the bofedal and Altiplano sites (vertical bars = 95% confidence limits).*

would be detrimental to alpacas entering their last trimester of gestation.

Management Implications

A major problem in alpaca production is excessive embryonic mortality. Average reproductive success in southern Peru is about 50% (West 1981). Sumar (1983) suggested that poor nutrition during embryonic growth contributed to low fertility. We surmise that females are under considerable nutritional stress during the dry season, a period when they are carrying a fetus and lactating. This hypothesis is reinforced by records of female alpaca weight loss during the dry season (unpublished ranch records, La Raya, Peru). Management should emphasize supplying sufficient nutrition to meet the needs of reproducing females during this season.

Alpacas grazing the Altiplano may be deficient in CP during the entire dry season (July–Nov.) and energy deficient during the late dry season (Aug.–Oct.). For optimal CP nutrition, alpacas grazing the Altiplano site could have been moved to the bofedal in mid-July. Otherwise, diets should have been supplemented with protein. Cultivated pasture might be used in rotation with the Altiplano site to provide a better balance of protein and energy. Dietary protein might also be supplemented by algae and other aquatic plants harvested from nearby Lake Titicaca.

Although the bofedal site offered higher CP nutrition than the Altiplano, dry-season diets of alpacas grazing this site may be energy-limited due to suboptimal organic matter intake. The tundra-like nature of bofedal plants and overgrazing of the site likely limits the amount of leaf material alpacas can harvest. Grazing management of a bofedal might include reduction of alpaca numbers and frequent rotation of the band to nearby upland bunchgrass sites. These plant communities appear more easily grazed and would offer a needed source of energy.

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