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Original Article

Effects of Supplementing a Low Quality Diet with Desert Shrub (*Kochia prostrata*) on Alpaca (*Vicugna pacos*) Nutritional Status

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Abstract

This study determined the effects of supplementing a low quality (straw) diet with forage kochia (*Kochia prostrata*) on the nutritional status of alpacas (*Lama pacos*). Two experiments were conducted with this objective. The first experiment (Exp A), 20 adult male alpacas were randomly assigned to 1 of 5 treatment diets, including 100% straw, straw plus 20%, 40% and 60% forage kochia, or straw plus 15% alfalfa. Each alpaca received a 2-week all-straw diet before we placed each in a metabolism crate with the treatment diet for 2 weeks (1 week acclimation period). Feed, orts, feces, and urine were measured daily and samples taken for analysis. Blood was collected every 30 min for 6 h at the end of treatment period and analyzed. In the second experiment (Exp B), 25 adult, male alpacas were assigned to 5 treatment groups. All animals received 6 weeks of an all-straw diet before 15 days of the same 5 treatments previously described. Data were collected on weights, feed given and refused and blood drawn twice per day on days 1-7, 9, 11, 13, and 15. Blood serum was analyzed for electrolytes (Na, K, and Cl) and metabolites (glucose, urea-N, and creatinine). In Exp A, the dry matter digestibility significantly increased across the treatments indicating that forage kochia was more digestible than straw. The data showed a significant increase in N intake with an increasing amount of forage kochia as well as a significant increase in N digestibility, but not enough to compensate for the period of low quality feed intake. The high urine output and high BUN values indicate that N was still being mobilized from muscle catabolism in order to compensate for the lack of nutrition. In Exp B, there were no significant differences due to diet alone. Day showed significance with respect to creatinine. Creatinine showed a significant decrease over time particularly in the diets with greater supplementation suggesting that with a longer treatment period, differences among diets may have been significant.

Keywords: Dry-season supplementation, nutrient requirements, camelid, alpacas.

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Introduction

Camelids are an essential part of the livelihood of many native Andean people. There are four species of New World camelids: the alpaca (*Lama pacos*) and llama (*L. glama*) which are domesticated and the vicuña (*Vicugna vicugna*) and guanaco (*L. guanicoe*) which are wild and free-roaming Bryant and Farfan (1984). Since large-scale cultivation is not feasible for the people of the Bolivian Altiplano, llama and alpaca production supports much of the highland economy Bryant and Farfan (1984). Alpacas are valuable specifically for their high-quality wool which is exported and their meat for local consumption. Approximately 200,000 campesino (peasant) families depend on alpacas and their products San Martin and Bryant (1989).

On winter ranges, shrubs supply a significant source of protein to both cattle and sheep. While most grasses plunge to 3 or 4% crude protein (CP) during dormancy, shrubs such as forage kochia (*Kochia prostrata* Linnaeus, Schrader), can end the dry season with as much as 10% CP (Memmott, 1995). Younger forage kochia plants can have as much as 15% CP (Davis, 1979). The purpose of this study was to determine the effect of supplementing a low quality diet with the desert shrub forage kochia (*Kochia prostrata*) on alpaca nutritional status determined using metabolism crates and in a feedlot setting.

Materials and Methods

The nutritional status of alpacas fed a low protein/energy diet and supplemented with forage kochia (Kochia prostrate) was determined in two experiments as outlined below.

Experiment A

Twenty male, adult alpacas (3+ years, 65 kg BW), were randomly allocated to five groups. Each alpaca received an all-straw diet (6% CP; table 1) for a 2 week acclimation period prior to the initiation of the experiment. During week one of the acclimation period the alpacas were housed in a drylot setting, while the second week the animals were acclimating to metabolism crates. Following the 2 week acclimation period, each animal received one of 5 treatment diets (table 1); straw only (STW), straw + 20% kochia (20K), straw + 40% kochia (40K), straw + 60% kochia (60K) and straw + 15% alfalfa (ALF). Treatment period was for 14 days; day 1 to 7 for diet adjustment and day 8 to day 14 for sample collection. Forage kochia was obtained from two established crops. The forage kochia was harvested five centimeters above ground, air dried and mixed in equal proportions within the 20K, 40K, and 60K forage kochia diets. The samples for analysis of each diet were a mix of grab samples taken at each feeding.

Table 1: Chemical composition of diet components.

Items	**Diet Composition[a]**		
	Straw	**Kochia**	**Alfalfa**
DM	93.2	94.2	92.3
CP	2.6	12.7	17.8
NDF	74.6	NA	42.4
ADF	42.6	NA	31.9
Fat	2.5	NA	3.1
Ash	11.8	NA	10.5
Diet	Nitrogen	Crude Protein[b]	
100% straw	0.41	2.6	
20% kochia	0.68	4.3	
40% kochia	0.91	5.7	
60% kochia	1.40	8.8	
15% alfalfa	0.99	6.2	

[a]Values are expressed on a percent dry matter basis.
[b] Crude protein calculated by multiplying nitrogen values by 6.25.

The alpacas had access to water and were fed *ad libitum* throughout the experiment. During the 2-week treatment period, alpacas were fed once a day. Feed and feed refused were measured daily throughout the experiment. On days 8 through 14, feces and urine were collected. On day 14, blood was drawn every 30 min for 6 h to provide an accurate measure of metabolites. Initial feed and refused feed samples were dried at 60° C for 24 h and ground using a Wiley Mill with a 1 mm screen. Nitrogen content was determined by combustion gas analysis (LECO, St. Joseph, MO) performed at the BYU Soil and Plant Analysis Laboratory, Department of Plant and Wildlife Sciences, Brigham Young University.

Blood samples were centrifuged to obtain plasma samples which were analyzed using a NOVA 16 blood analyzer (Nova Biomedical, Waltham, MA) to determine glucose and blood urea N (BUN). Non-esterified fatty acid (NEFA) was determined using the NEFA-C kit (#990-75401, Wako Chemical USA Inc., VA), creatinine, total plasma protein (TPP) and albumin using the TECO kits (# C515-480, #T528-480 and #A502-480 TECO, Diagnostics, CA).

Experiment B

Twenty-five adult, male alpacas (3+ years), were randomly allocated to five groups. An all-straw diet (same as EXP A) was administered for 6 weeks prior to the initiation of the experiment. Following the 6 weeks, each pen received a randomly selected treatment diet (STW, 20K, 40K, 60 K or ALF) for 15 days.

The alpacas had access to ad libitum water and feed throughout the experiment. During the treatment period, the alpacas were fed once daily. Feed intake was measured daily. On days 8 and 15, feed refused was measured. Feed and feed refused samples were handled and analyzed as outlined in EXP A. Alpacas were weighed on days 1, 8, and 15 to compute average daily gain/loss. Ten ml of blood was drawn twice a day from each animal from indwelling jugular catheters (Micro-Renathane®, Braintree Scientific, Braintree, MA) on days 1-7 then 9, 11, 13 and 15. Blood samples were centrifuged to obtain plasma which were analyzed following the procedures outlined in EXP A.

Statistical Analysis

Mixed model analysis in SAS (Proc Mixed; SAS, Inst., Cary, NC) was used to analyze all data. Metabolite and electrolyte variables were analyzed using a linear mixed model designating treatment, day and the treatment by day interaction as fixed effects. Replications (animals) were designated as a random effect. Kenward-Roger adjustment was used for denominator degrees of freedom in the hypothesis tests of fixed effects because of missing data. The covariance structure was specified for the repeated measurements over time for each animal-diet combination as the spatial-power structure, with correlation depending on the time interval between measurements. Least squares means were calculated and compared for each diet day and diet by day interaction with unadjusted t-tests. The alpaca weights were also analyzed using a linear mixed model with Kenward-Roger adjustment for unbalanced data in the denominator degrees of freedom. Diet was designated as a fixed effect and animal as random and computed compared least squares means by diet with unadjusted t-tests.

Results

Experiment A

Difference in dry matter intake between diets was not significant ($P = 0.22$), but there was a numerical increase from 278 g/day for STW to 438 g/day for ALF (table 2). Dry matter digestibility between diets was significant ($P < 0.01$) ranging from 17.4 % for STW to 52% for 60K (table 2), with the 60K diet having a higher dry matter digestibility than the ALF diet.

There is a significant increase ($P < 0.01$) in N intake with increasing amounts of forage kochia (table 2) as planned, accompanied by a numerical increase in fecal N excreted (1.8 to 3.0 g N/day for STW to 60K). There was also a numerical increase in N retention and a significant increase in N digestibility across treatments.

Table 2: Intake, nitrogen excretion and digestibility of mature male alpacas fed straw or straw with 20, 40 or 60% forage kochia, or 15% alfalfa housed in metabolism crates.

	Diet[a]					
	STW	20K	40K	60K	ALF	SEM
DM Intake, g/d	278[b]	242[b]	302[b]	421[b]	438[b]	74.3
N Intake, g/d	1.1[b]	1.8[bc]	3.0[c]	6.4[d]	5.1[d]	0.52
Fecal N, g/d	2.1[b]	1.8[b]	2.3[b]	3.0[b]	2.7[b]	0.44
Urine N, g/d	2.9[b]	5.8[c]	4.7[bc]	6.9[c]	4.7[bc]	0.94
N Retained, g/d	-3.9[bc]	-5.8[b]	-4.0[bc]	-3.5[bc]	-2.3[c]	0.90
DM Digestibility, %	17.4[b]	38.3[cd]	31.7[bc]	51.9[d]	43.2[cd]	6.22
Urine N, % of total	59.6[b]	72.5[b]	67.3[b]	70.1[b]	63.3[b]	6.21

[d]STW = straw; 20K, 40K and 60K = 20, 40 and 60% forage kochia with straw; ALF = 15% alfalfa with straw.
[bcd]Superscripts that differ within row are significantly different at P<0.05.

Metabolites were not different across treatment diets (table 3). NEFAs show a downward trend from 985 µmol/L for STW to 760 and 627 for 60K and ALF, respectively. Urea N was 15.1 and 16.5 mmol/l for STW and 20K, but numerically was lower for 40K at 7.7 mmol/l, rising to 12.1 and 11.6 for 60K and ALF. Plasma glucose, creatinine, TPP, and albumin all remained within normal ranges.

Table 3: Plasma concentrations of electrolytes and metabolites of mature male alpacas housed in metabolism crates and fed straw or straw supplemented with 20, 40 or 60% forage kochia or 15% alfalfa.

Items	Diet[a]					
	STW	20K	40K	60K	ALF	SEM
Glucose, mmol/l	7.3[b]	7.7[b]	7.7[b]	8.7[b]	8.2[b]	0.8
Urea N, mmol/l	15.1[b]	16.5[b]	7.7[b]	12.1[b]	11.6[b]	4.8
NEFA[c], mmol/l	985[b]	742[b]	914[b]	760[b]	627[b]	158
Creatinine, µmol/l	177[b]	150[b]	186[b]	133[b]	194[b]	24.3
Total Plasma Protein, g/l	69[b]	67[b]	66[b]	62[b]	68[b]	5.4
Albumin, g/l	39[b]	37[b]	40[b]	39[b]	39[b]	1.7

[a]STW = straw; 20K, 40K and 60K = 20, 40 and 60% forage kochia with straw; ALF = 15% alfalfa with straw.
[b]No differences were noted between diets at P<0.05.
[c]NEFA=nonesterified fatty acids.

Experiment B

Due to limited space, the pens were not replicated and subsequently statistics were not computed on feed consumption. However, average dry matter intake and N intake was computed per animal (see table 4). Values range from 200 g/day during week 1 for STW to 550 g/day during week 2 for ALF. No significant differences were found in average daily gains among the treatments. All animals lost weight on average (160 g/day) (table 4). Metabolite and electrolyte variables were not different between diets (table 5).

Table 4: Initial weight, daily gain and feed consumption of straw and straw supplemented with 20, 40 or 60% forage kochia or 15% alfalfa by mature male alpacas (five alpaca/group) fed in a feedlot setting.

	Diet[a]					
	STW	20K	40K	60K	ALF	SEM
Live Wt, kg	55.5	59.5	60.5	53.6	56.4	NA
Gain, kg/d	-0.20[b]	-0.06[b]	-0.24[b]	-0.12[b]	-0.18[b]	-0.08
Dry matter intake, g/d	247	407	538	412	514	NA
Nitrogen Intake, g/d	1.1	2.8	5.1	5.7	5.3	NA

[a]STW = straw; 20K, 40K and 60K = 20, 40 and 60% forage kochia with straw; ALF = 15% alfalfa with straw.
[b]No differences were noted between diets at P<0.05.

Table 5: The effect of straw and straw supplemented with 20, 40 or 60% forage kochia or 15% alfalfa on blood metabolites of mature male alpacas (five alpaca/group) fed in a feedlot setting.

	Diet[a]					
	STW	**20K**	**40K**	**60K**	**ALF**	**SEM**
Glucose, mmol/l	6.7[b]	6.9[b]	6.4[b]	7.0[b]	7.7[b]	0.4
Urea N, mmol/l	15.9[b]	13.4[b]	12.1[b]	15.1[b]	11.6[b]	1.5
Creatinine, µmol/l	300[b]	292[b]	283[b]	309[b]	248[b]	27
NEFA[c], mmol/l	780[b]	586[b]	330[b]	631[b]	530[b]	135.5
Sodium, mmol/l	155.1[b]	153.1[b]	153.5[b]	150.4[b]	155.3[b]	1.5
Potassium, mmol/l	4.5[b]	4.8[b]	5.0[b]	4.7[b]	4.7[b]	0.2
Chloride, mmol/l	120.7[b]	121.9[b]	122.3[b]	125.0[b]	122.7[b]	1.3

[a]STW = straw; 20K, 40K and 60K = 20, 40 and 60% forage kochia with straw; ALF = 15% alfalfa with straw.
[b]No differences were noted between diets at $P<0.05$.
[c]NEFA=nonesterified fatty acids.

Discussion

The typical dry matter intake for alpacas in metabolite crates fed barley hay is 1.6% BW per day, while barley+alfalfa is 2% BW per day (Davies *et al.,* 2007b). San Martin and Bryant (1989) states that in pen conditions alpacas fed oat hay ate 1.6% of their body weight. With an average weight of 56.2 kg, the study animals would have consumed about 900 g/day of oat hay. The determined DM intakes for animals on our studies were considerably lower (200-550 g/day or 0.4 to 1.0% per day) which we predict is due, in part, to palatability issues of the straw based treatment diets. Surprisingly, the alpacas on the 60K diet still only ate only 300 g/day the first week of the feedlot experiment.

Palatability of kochia in Asia and Central Europe was shown to be high when fed to all species of livestock, especially camels (Keller and Bleak, 1974). Nemati (1977) found in a study using sheep that forage kochia was more palatable than Atriplex canescens (Pursh Nuttall) and Artemisia herba alba. Our personal observations have found that when planted in a pasture where grass was established, kochia was grazed heavily by alpacas to the point that the kochia could not survive. Other studies show the plant is selected heavily by mule deer (Waller *et al.,* 1983).

Three factors may have attributed to the alpacas in this study not accepting the forage kochia supplementation as readily. First, a straw-based feed is relatively unpalatable. Second, forage kochia was unfamiliar to these specific animals. Third, and probably most important, was that drying may have greatly affected the forage kochia's palatability because the stems became sharp and brittle. Anti-quality factors, such as tannins, was not considered as a deterent for consumption. Waldron *et al.,* (2010) reported that kochia is low in tannins and oxalates and increases digestive kinetics when added to low quality grasses. Other anti-nutritive factors and their affects from feeding forage kochia need to be researched to better understand if they have an adverse effect. In Waldron's findings, kochia was a good forage supplement for late summer and fall feeding.

Using dried forage kochia allowed us to grind and mix the treatment diets for the entire experiment to ensure consistent diets, decreasing the opportunity for the animals to select diet components. The forage kochia was harvested 3-4 inches from the ground in order to let it grow back which means the succulent evergreen portion of the plant was left behind (Stevens *et al.,* 1985). In a range or pasture setting, it is this portion of the plant that the animals would select during the dry season. It is well-documented that range animals will select a more nutritious diet than is available on average (Howery *et al.,* 2001; Ramirez-Perez *et al.,* 2000) and this is true for alpacas. Bryant and Farfan (1984) found that alpacas could select for and consume grass seeds, up to 20% of their diets, to compensate for low-quality forage during the dry season.

Alpaca N requirements have been estimated by San Martin and Bryant (1984) to be 0.38 g of N (kg $W^{0.75}$)/day in a study conducted at about 4400 meters above sea level. Using the range of weights from this study, 45 - 69.1 kg, 6.6 g - 9.1 g of N/day would be the average maintenance level for the study alpacas. In a more recent study conducted at 1372 m above sea level, determined the requirement to be higher, 0.60 g N kg W0.75 (Robinson *et al.*, 2005). The resulting range would be 10.4 to14.4 g of N/day. The alpacas consumed from 0.8-6.4 g of N/day in EXP A and 1 - 7 g of N/day in EXP B. The difference between the two requirement levels was the altitude, which San Martin and Bryant (1984) concluded may be a factor to consider for nutrient requirements, but these two studies give a range for N requirement in our study.

Diets were chosen far below requirements to determine N deprivation and the alpaca's ability to recover with a forage supplement that could be implemented by South American producers. Understanding N usage by alpacas and their ability to manage nutrient deficiencies with minimal supplementation will be helpful in producer allocation of forage resources and meeting the alpaca's needs. Stevens *et al.,* (1985) found that during the winter, the CP content of the lower stems was 8.7% compared to 6.1% in the upper stems. Our effort was to target this level of CP intake, but due to palatability issues the target level was not met. Thus, in the field, alpacas would have access to more protein than what was available during this study, but total intake of required protein may not be met.

Robinson *et al.,* (2005) found that glucose in adult male alpacas on energy and protein sufficient diet averaged 7.5 mmol/l, similar to that found by Davies *et al.,* (2007b) in alpacas fed barley hay. Burton *et al.,* (2003) found that pregnant females averaged 7.2 to 7.5 mmol/l. The treatment diets did not affect blood glucose levels significantly in either experiment attributed to the alpaca's ability to maintain plasma glucose levels. However, in EXP B, there was a non-significant downward trend as time progressed (7.5 mmol/l on day 1 to 6.3 mmol/l on day 15). Compared to the above numbers this may be biologically significant. Still, the animals were able to maintain blood glucose levels.

Neither diet nor day affected urea N levels. The values ranged from 7.1 - 16.4 mmol/l in EXP A and 12.3 - 14.5 mmol/l in EXP B. This range was high compared to the average for adult males (9.4 mmol/l) found by Robinson *et al.,* (2005) which may suggest muscle catabolism in animals from this study. However, these numbers coincide with Burton *et al.,* (2003) study for pregnant females (13.4 - 13.8 mmol/l) and falls within the normal range of 9.2 to 22.8 mmol/l given by Navarre *et al.,* (2001).

High levels of creatinine, an end product of muscle catabolism, indicate an energy deficiency. The average creatinine found in the Robinson *et al.,* (2005) and Burton *et al.,* (2003) studies were 221 and 133 µmil/l, respectively. The normal range of creatinine in llamas (Lama glama), a closely related species with similar blood chemistry, is 177 to 248 µmol/l (Lassen *et al.,* 1986). In EXP A, the levels of creatinine were within or below the normal range (133 - 194 µmol/l) and there were no significant differences. Creatinine levels in EXP B ranged from 221 to 354 µmol/l which is above normal, but showed a significant decrease over time. Although the diet by day interaction was not significant ($p = 0.13$), the 15% alfalfa diet had the lowest values throughout the treatment period, which is slightly below the normal upper limit. Animals fed the 60K diet showed a large overall decrease and probably would have done better if the feed were accepted as well in the first week as in the second. As expected, animals consuming the other diet rations maintained higher creatinine values.

These creatinine data in conjunction with the negative N balance and UN values are indicative of muscle catabolism. As indicated, if the palatability had been better the animals on the higher kochia diets may have reached positive nitrogen balance and overcome the muscle catabolism.

The Burton *et al.,* (2003) study recorded values of 287 and 289 µmol/l for NEFAs in pregnant females and Robinson *et al.,* (2005) study recorded 184 µmol/l. The pregnant females Burton *et al.,* (2003) were caught from a pasture setting before each blood draw while the males Robinson *et al.,* (2005) were housed in metabolism crates. The greater stress of being caught may have increased the epinephrine, cortisol or other hormones which control lipolysis Robinson *et al.,* (2003). The alpacas in EXP B were also caught before each blood draw which may have affected the NEFA levels. However, the method was consistent throughout the experiment and the data show trends in the diet by day interaction ($p < 0.08$). The animals on STW experienced an overall increase from 621 mmol/l on day 3 to 1137 mmol/l on day 15. The other diets decreased overall, particularly 15% alfalfa and 60% forage kochia, suggesting that these animals may not have been mobilizing as much body fat towards the end of EXP B. Alpacas on EXP A showed no significant differences between diets but the overall high levels indicated mobilization of body fat due to the shorter period on the straw prior to initiation of the experiment.

Body weight changes were not measured in EXP A, but were in EXP B. The fact that all animals lost weight in EXP B confirms the blood analysis findings that animals on all diets were in an energy deficit compounded by the reduced DM intake. The blood analyses, shows that there was a mobilization of body lipids but portion of the weight loss could be due to muscle catabolism (Davies *et al.*, 2007a&b). The high urine output and high UN values indicate that N was still being mobilized from muscle catabolism in order to compensate for the lack of nutrition (tables 2 and 3; Robinson *et al.*, 2005).

The dry matter digestibility as well as N digestibility, both variables only measured in EXP A, did significantly increase across the treatments indicating that forage kochia, even though dried and chopped, improved digestibility over the STW alone (table 2). The digestibility increase was not enough to compensate for the period of low-quality feed intake (Davies *et al.*, 2007a&b).

Conclusion

The issue of dry season supplementation of alpacas on the South American Altiplano, where the majority of alpacas are found, is an important management issue that has not been thoroughly studied. The overall purpose of this area of research was to find an economical way to adequately supplement livestock through the dry season, which will improve alpaca production as well as prevent further degradation of the rangelands. The solution will probably include a wide variety of practices depending on the local situations. The hope was that supplementation with these valuable shrub species will be a useful answer in many situations. All the data presented here indicates increasing nutrients status due to supplementation with forage kochia but not to a level that overcome the poor nutrition prior to the collection period.

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