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A PILOT STUDY OF THE EFFECTS OF DIET ON HUACAYA AND SURI ALPACA FIBRE

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ABSTRACT

A two-year pilot study was undertaken to uncover whether a difference in calories and protein influences alpaca health or fibre quality in ways that override differences that stem from colour, age, or breed. Thirty-six huacaya and suri animals were divided into low and high nutrition groups. The low nutrition diet was a low protein, trace mineral supplemented diet, while the high diet was a protein and energy supplemented one. Animal health was monitored throughout the study; extreme cold and naturally occurring diseases resulted in some attrition from the groups. Fibre was collected at approximate 3-month intervals from the midside of each animal. Fibre diameter was evaluated quarterly, while growth rate, scale length, and bundle tensile strength was evaluated at the end of 12 and 24 months. Fibre diameter was thinner after growth in the winter months but thickened again through the summer. Huacaya fibre was stronger than Suri but it was not clear whether diet influenced strength. Growth rate was not affected by diet. Scale length was not affected by diet nor could scale length be used as a reliable measure to distinguish Huacaya and Suri.

Key words: Alpaca, fibre diameter, fibre growth rate, fibre scale length, huacaya, staple tensile strength, suri

The effect of nutrition on fibre growth in alpacas has received little attention in the literature, particularly when addressing alpacas residing in North America. Owners and breeders report a thickening of fibre diameter after importation, construed to be due to increase in feed intake as well as to an overall consistency in food supply compared to the variability of diet encountered by animals in South America (Hoffman and Fowler, 1995). There also are anecdotal reports of an increase in diameter with an increase in animal age in animals imported to New Zealand and Australia (Hoffman and Fowler, 1995; Martinez *et al*, 1997). Weakening of fleeces, known as "tendering", is noted to be a result of stress. Higher levels of nutrition result in a higher clean fibre weight, and a higher fibre growth rate but have no effect on fibre diameter (Russel and Redden, 1997). On the other hand, Newman and Paterson (1994) reported that level of nutrition had no effect on fibre diameter but fibre growth rate was higher and fibre diameter coarser in summer. Percentage of medullated llama fibres and the average fibre diameter increases significantly with the age of the animal (Martinez *et al*, 1997). All of these studies were done during extremely short periods of time (e.g. < 2 months) and may not have provided sufficient time for animal adaptation to the diet over long-term conditions. This study was designed to examine the effect of long-term feeding conditions with environment as a confounding variable.

Owners and breeders of alpacas in North America typically judge the quality of alpaca fleece by the average fibre diameter and the range of diameters determined from a sample of the fleece shorn from the midside of the animal (i.e., "blanket" area). The finest alpaca fibres and narrowest range of diameters is considered to be of the highest quality. The American Society for Testing and Materials provides a specification for assessing the fineness of alpaca fibre (ASTM, 2002a). The presence of coarse fibres over 30 μm in diameter can result in a yarn with a "prickle" factor that would make the garment uncomfortable to wear (Garnsworthy *et al*, 1988).

The length of the fibre produced annually indicates animal productivity while tensile strength of fibre bundles is an indicator of commercial processability and fitness for use in textile products. For example, fleece tenderness has a recognised economic cost in the sheep's wool industry (Bigham *et al*, 1983; Plate *et al*, 1987; Hansford and Kennedy, 1990; Gourdie *et al*, 1992) because tender fleeces break in the spinning and weaving processes. Staple bundle tensile strength has been shown to be linked to sheep

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breed, stress, diet, pregnancy and lactation, and season of shearing. Tender sheep's wool shows decreased fibre diameter, and a higher proportion of ortho-cortex in the cell structure (Bigham *et al*, 1983). In alpacas, a nutritionally poor diet has been speculated to be related to tenderness of the fibre (Hoffman and Fowler, 1995).

Thus a research project was initiated to determine the effect of two different diets fed under identical environmental conditions for a 2-year period on fibre quality.

Materials and Methods

Animals and nutrition groups

Healthy alpacas (n = 36) were randomly assigned to one of two feeding groups using a Latin Square design so that an equal number of animals were represented in each group for each breed (Huacaya and Suri). The study commenced in summer 1999, and ended in 2001. Twenty-two animals remained through the entire duration of the study, with 8 Huacaya and 4 Suri in the high diet group, 7 Huacaya and 3 Suri in the low diet group. The study was designed to uncover whether a simple difference in calories and protein influences animal health and fibre produced in ways that override other differences that might stem from colour, age, or breed. All animals were housed in grass lots with free access to fresh water.

Limited animal numbers restricted the study to two nutrition groups: 1) low protein and energy and 2) high protein and energy. In the first group ("low" nutrition), all alpacas were fed grass, hay, water, and a trace mineral supplement *ad libidum*. The trace mineral supplement was a commercially prepared mix designed to meet basic requirements of alpacas determined by previous nutrition studies at Ohio State University. This was a low crude protein (CP) (range 7 to 8 % CP) and low total digestible nutrients (TDN) (range, 50 to 55%) diet and the trace mineral was supplemented free choice. In the second group, ("high" nutrition), all alpacas were fed grass, hay, water, and a commercially prepared alpaca diet designed to provide 15% crude protein (overall diet 12% CP), 65 to 75% total digestible nutrients, and trace minerals. This was a protein and energy supplemented group.

Animal and environmental monitoring

All alpacas were weighed and body condition score evaluated monthly. BCS provides a qualitative assessment of the appropriateness of the body weight and was evaluated on a 1 to 10 scale; 1 was dangerously thin, 10 was excessively fat, 5 was considered "ideal". Any alpacas losing more than 20% body weight during the study or having a BCS < 3 were removed from study and returned to nutrition appropriate for weight gain. Medical treatments were done as needed but these alpacas were not returned to study.

Fibre sampling and analyses

Fleece samples covering an area approximately 10 cm x 10 cm square on the animal's midside were sampled at approximate 3-month (approximately a quarter year) intervals over the 2-year period of the research. Half of this fibre was examined visually under controlled illumination using a MacBeth Spectralight viewing booth. The other half of each of the fleece samples was sent to Yocom-McColl Testing Laboratories (Denver CO) for fibre diameter determination using the Laserscan method.

At the end of 12 and 24 months, all animals were sheared and larger quantities of fleece obtained. Fibre from the 10 cm by 10 cm midside section of the animal was selected for diameter measurement in a comparable manner to the other periodic samples. Fibre from the second midside of the animal was divided to obtain random samples for additional testing including optical microscopy, scale length measurement, and tensile strength. To accomplish this sampling, large sections of fibre from the midside region of each animal were subdivided into 150 individual locks with each lock placed on a velvet-covered board marked with a grid. Using a random number table, 25 locks were randomly selected for preparation for tensile testing, 5 for optical microscopy, 5 for amino acid analysis. Additional samples of 5 locks were taken for other potential tests.

Growth rate measurement

The average length of the locks in the fleece samples was measured by laying 10 randomly chosen and straightened locks on the velvet board, and measuring the maximum length of each. Growth rate of mm per day was determined by dividing the average length measured by the number of days of growth.

Optical microscopy and scale length measurement

Thirty fibres, removed from one lock, were mounted on microscope slides with Permount© (Fisher Scientific). Casts of 30 more fibres were prepared by semi-embedding them in clear nail polish, curing the polymer and removing the fibre to view the cast (Wildman 1954; Curl and Jakes 2003). Each of the prepared fibres was examined with brightfield and differential interference contrast (DIC) techniques using a Zeiss Axioplan research microscope. Digital images were taken of three locations (left, center, right) on each of 5 fibre casts using a ProgRes 3008/3012 digital camera. Using Zeiss Axiovision Image analysis software version 3.0, a marking tool was used to draw a line running the length of the center of each fibre cast image. The edges of the scales that intersected this bisecting line were used to calculate the number of scales over a particular length and the distance between the scales.

Fibre bundle tensile strength

Each group of locks sampled for strength measurement was washed gently in ethanol to remove superficial dirt. Bundle preparation, conditioning, and tensile strength evaluation were conducted according to ASTM D 1294-95a (ASTM, 2002b) using an Instron Model IX tensile testing instrument, and a 10 inch/minute extension rate. The broken fibres were placed in a preweighed aluminum dish, conditioned for 24 hours and weighed, to determine the mass of the sample that had been broken. Breaking tenacity was calculated as grams-force per Tex.

Statistical Analysis of Fibre Data

Multivariate analysis of variance techniques and post hoc Tukey's multiple comparisons were used to explore the effect of diet and breed on fibre bundle strength, diameter, growth rate, and scale length.

Results and Discussion

Table 1 summarises the characteristics of the 22 animals that remained in the diet study at the end of the 2-year period. As analysis of data ensued, some effort was given to distinguish differences based on colour, age, or gender within each breed. Because this was an opportunistic study, in which the animals available in the research herd were the ones selected for the diet groups and no consideration for colour, age, or gender was given in assignment of animals to groups, there are some confounded variables. For example there was only one eleven-year old animal, and only one black animal. Limitation to analysis of white fibre only allowed a smaller but somewhat more controlled group of animals to be studied, not only in colour but also in age. The 12 animals with white fibre are summarised in Table 2.

Fibre appearance

There were no significant visible differences in fibre samples removed from the same animal over the 8 quarters of the study. No obvious chalkiness or discolouration developed. Many locks from the annual shearing of white animals showed a darker band along the length of the lock, but these contained dirt that was readily removed in cleaning with ethanol.

Fibre diameter

Mean fibre diameters of the 22 animals that completed the entire diet study ranged from 22.3 mm to 36.6 mm (Table 3). Analysis of variance, including only the main effects of diet, breed, subject, and quarter of fibre collection, was conducted for the entire group of animals. Sequential sums of squares techniques were employed to illustrate the effect of adding subsequent variables to the model given the effects of the preceding variables. The factors of

Table 1. Inventory of all animals in the two-year study.

Colourv	Huacaya			Total	Suri		Total	Grand Total
	Age in 99	Low diet	High diet		Low diet	High diet		
White	2					1	1	1
	3	1	1	2				2
	4				1	3	4	4
	5	1	2	3	1		1	4
	6	1		1				1
White Total		**3**	**3**	**6**	**2**	**4**	**6**	**12**
Beige	1	1		1				1
	2				1		1	1
Beige Total		**1**		**1**	**1**		**1**	**2**
Medium fawn	2		1	1				1
Med fawn Total			**1**	**1**				**1**
Dark fawn	5	1		1				1
Drk fawn Total		**1**		**1**				**1**
Light brown	2	1		1				1
	3		1	1				1
	4	1		1				1
	5		1	1				1
Light brown Total		**2**	**2**	**4**				**4**
Bay black	8		1	1				1
Bay black Total			**1**	**1**				**1**
Dark brown	11		1	1				1
Dark brown Total			**1**	**1**				**1**
Grand Total		7	8	15	3	4	7	22

breed and diet showed no significant independent or interaction effects on the response variable. Both quarter of collection and its interaction with diet showed significant impact on diameter ($p < .0001$, $p = 0.0059$, respectively).

Fibre diameter was influenced by season of growth with fibre from all of the groups becoming somewhat finer at the end of 9 and 12 months (3rd and 4th quarter). The samples taken at the end of 9 months reflect that fibre which grew in the winter months of

Table 2. Inventory of white animals in the two-year study.

	Males				Females				Total
	Low diet		High diet		Low diet		High diet		
	Huacaya	Suri	Huacaya	Suri	Huacaya	Suri	Huacaya	Suri	
Age in 1999									
2				1					
3	1						1		
4		1		3					
5		1	1		1		1		
6					1				
Total	1	2	1	4	2	0	2	0	12

Table 3. Average Fibre Diameter, fibre removed at end of 6 months and 18 months (2nd and 6th quarter).

	Diameter, µm, 6 months				Diameter, µm, 18 months			
	Huacaya		Suri		Huacaya		Suri	
Colour	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
White	29.967	27.367	28.500	29.750	28.800	28.700	27.500	32.950
Beige	23.500		29.500		22.300		28.000	
Medium fawn		29.500				32.400		
Dark fawn	32.000				29.900			
Light brown	34.250	33.500			33.300	34.400		
Bay black		32.400				31.400		
Dark brown		35.100				36.600		
All colours	30.557	30.775	28.833	29.750	29.314	31.912	27.666	32.950

Table 4. Fibre Growth Rate, white animals only.

	Year One Average Growth Rate, mm/day				Year Two Average Growth Rate, mm/day			
	Huacaya		Suri		Huacaya		Suri	
Animal ID	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
B 89				0.382				0.392
B 99	0.268				0.200			
B 440				0.445				0.382
R 227				0.308				0.300
R 30		0.148				0.179		
R 43		0.207				0.236		
W 35				0.406				0.442
W 37			0.375				0.373	
W 43			0.282				0.338	
Y 29		0.226				0.377		
Y 32	0.280				0.237			
Y 33	0.282				0.259			
Group average	0.277	0.193	0.328	0.385	0.232	0.264	0.355	0.379

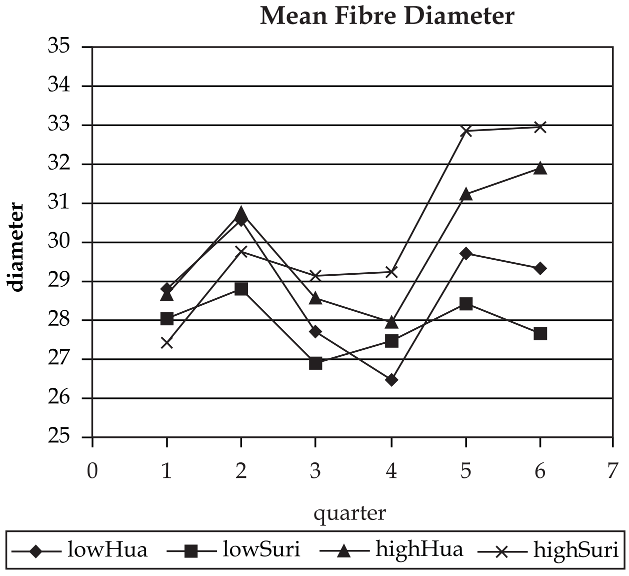

Fig 1. Mean fibre diameter plotted by quarter of growth, all animals and colours included

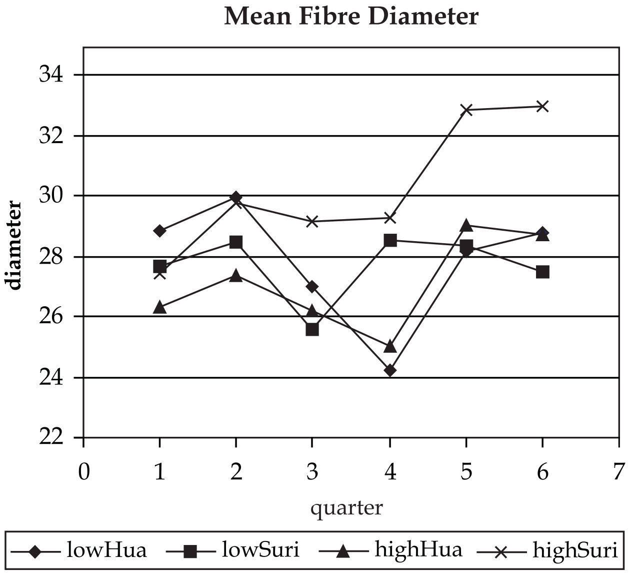

Fig 2. Mean fibre diameter plotted by quarter of growth, white animals

January through April, and the samples taken at the end of 12 months reflect the diameter of the fibre that grew in the spring months from April to July. As can be seen in Fig 1, the overall diameter is finer at the end of the 3rd and 4th quarter. Fibre samples taken in October after 15 months (5 quarters) of the study show an overall increase in diameter that occurred through the summer months. A full model that included covariates of age, gender and fibre colour was analysed and the factors of quarter of collection and quarter-diet interaction remained significant. The variability of diameter seems to be greater at extreme ages, and more stable between ages of 3 and 8, but that could be an effect of the unbalanced experimental design. In addition the darker fibres generally were larger in diameter. Although it has been noted anecdotally by others that darker fibres are coarser, statistical support for this statement is not provided herein since the colour, age, and gender are confounded in the opportunistic study that was undertaken here.

There is no apparent difference in average diameter for fibre collected at the end of 18 months between the diet or breed groups (p = .24), but when examining the difference in diameter between fibre collected at the end of 6 and 18 months (Table 3), there are some significant differences that point toward an effect that overlies the observed seasonal change in diameter (p = .00). Comparing fibre collected at the end of 6 and 18 months, the high diet resulted in some coarsening of the fibre while the low diet resulted in some thinning of the fibre (p = 0).

These effects on diameter warrant further study with distinction made between animal gender, age and colour. A seasonal effect on fibre diameter and growth rate was also noted by Newman and Paterson (1994).

Limitation to the analysis of only the white fibre in the experiment eliminates some of the confounding effects of age since the oldest and youngest animals in the study had fibres in colours other than white. Looking at white fibre alone, average fibre diameter displays a seasonal effect, with all of the groups becoming somewhat finer at the end of 9 and 12 months (3rd and 4th quarter). In addition there is a significant difference between diameters of fibre collected at the end of 6 and 18 months (2nd and 6th quarter) that overlies the seasonality effect that is related to diet (p = .008).

Growth rate

Table 4 summarises the growth rate of the white fibre for each of the two years. It must be kept in mind that the all animals were fed the high diet in the last 6 months of the second year, due to unusually cold winter weather.

In examining the effects of the high and low diet, comparison was made between the growth rate over the first year and that of the second year. Diet was not significant in resulting in a higher growth rate in white fibre (p = .096); no significant differences were found neither for breed.

Staple bundle strength

Table 5 summarises the staple bundle tensile strength at the end of each of the two years for all colours of fibre, while Table 6 displays that of the white animals only. Of the white animals, there is a

Table 5. Staple bundle tensile strength, all fibre colours included.

	Year One Average Tensile Strength, gf/tex				Year Two Average Tensile Strength, gf/tex			
	Huacaya		Suri		Huacaya		Suri	
Colour	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
white	14.106	13.513	10.986	9.473	14.959	13.469	11.567	10.357
beige	16.665		7.702		17.710		7.531	
medium fawn		16.499				12.093		
dark fawn	11.391				10.892			
light brown	12.802	12.405			11.684	11.547		
bay black		11.261				9.839		
dark brown		11.647				11.443		
all colours	13.741	13.065	9.344	9.473	13.811	11.678	9.549	10.357

Table 6. Staple bundle tensile strength, white fibre only.

	Year One Average Tensile Strength, gf/tex				Year Two Average Tensile Strength, gf/tex			
	Huacaya		Suri		Huacaya		Suri	
Animal ID	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
B 89				11.311				12.308
B 99	14.041				12.410			
B 440				9.373				9.525
R 227				10.457				11.387
R 30		13.114				13.792		
R 43		13.198				15.046		
W 35				6.373				7.780
W 37			11.745				12.069	
W 43			10.226				11.064	
Y 29		14.228				11.569		
Y 32	13.511				16.192			
Y 33	14.765				16.274			
Group average	14.106	13.513	10.986	9.473	14.959	13.469	11.567	10.357

significant difference in tensile strength between the two breeds of animal both in fibre shorn at the end of the first 12 months ($p < .0001$) and at the end of the second 12 months ($p <.0001$).

Diet does not show an effect on tensile strength when looking at all animals that remained in the study. Looking at the data, tensile strength appeared to decrease with animal age, a point which cannot be statistically supported by the number of animals and range of ages in the group.

Looking at white animals only eliminated the broad spread in age of the animals. In the white fibres only, diet appears to influence tensile strength in fibre collected at the end of each year (first year, $p < .0001$; second year, $p < .0001$). There is no significant diet-breed interaction for tensile strength measures in either year. Overall, Huacaya fibre is stronger than Suri fibre (13.81 g/tex compared to 10.23 g/tex at the end of the first year, and 14.21 g/tex compared to 10.96 at the end of the second year).

The high nutrition diet, however, is related to somewhat weaker fibres. This result seems somewhat contradictory, since the high nutrition diet is intended to improve animal health and should yield stronger fibres. One possible cause for this result is the high growth rate observed in some animals on the high diet. Although growth rate was shown not to be statistically influenced by diet, tensile strength is negatively correlated to growth rate (Pearson's correlation coefficient -0.677, $p = 0$). Two suris on the high nutrition diet grew at rates of 0.445 and 0.406 mm/day while other animals displayed a smaller growth rate (Table 4). Further study of these individual fibres using scanning electron microscopy

Table 7. Mean scale length, all fibre colours included.

	Year One Mean Scale Length, µm				Year Two Mean Scale Length, µm			
	Huacaya		Suri		Huacaya		Suri	
Colour	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
white	8.213	7.667	10.986	8.312	8.135	8.714	9.546	9.222
beige	9.660		8.759		9.458		9.308	
medium fawn		8.071				8.753		
dark fawn	10.384				8.458			
light brown	10.479	9.430			9.087	8.735		
bay black		6.409				7.842		
dark brown		7.847				7.415		
all colours	9.684	7.885	9.872	8.312	8.785	8.292	9.427	9.222

Table 8. Mean scale length, all fibre colours included.

	Year One Mean Scale Length, µm				Year Two Mean Scale Length, µm			
	Huacaya		Suri		Huacaya		Suri	
Animal ID	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**	**Diet Low**	**Diet High**
B 89				7.935				8.444
B 99	11.299				8.894			
B440				8.908				9.826
R 227				7.905				10.151
R 30		8.015				8.962		
R 43		7.289				8.898		
W 35				8.498				8.469
W 37			9.208				10.090	
W 43			8.310				9.003	
Y 29		7.696				8.282		
Y 32	7.176				7.691			
Y 33	6.163				7.821			
Average	8.213	7.666	8.759	8.312	8.135	8.714	9.546	9.222

(Shim and Jakes, 2006), showed these fibres to contain very large paracortical cells, overall larger and more irregular in shape than paracortical cells observed in other Suri fibres obtained from two year old white animals.

Scale length

Table 7 reports mean scale length of all colours of animals at the end of each of the two years; Table 8 reports those of the white animals only. In statistical analysis of all colours of fibre, there is no effect of diet or breed on scale length, but there are some differences noted in scale length related to age, gender, and colour ($p = .0447$) and ($p = 0.077$). However, white fibre were unaffected by diet and breed. In statistical analysis of white fibre, neither diet nor breed shows an effect on scale length for fibre collected at the end of 12 months (diet, $p = 0.588$; breed, $p = .563$) nor 24 months (diet, $p = .571$, breed $p = .038$). There is no significant difference in scale length measures between different diets, ($p= .5419$), a marginal difference between breeds ($p = .0515$) and no significant differences between ages ($p = .2931$). No interactions are discernible.

Despite some evidence of scale disruption, and the possibility that the scale lengths could be shorter when animals receive poor diets, there appears to be no support for a distinction based on scale lengths between Huacaya and Suri or between the high and low diet. These results have the added consequence that identification of the Huacaya and Suri fibre appears to be impossible to achieve by standard optical microscopic examination of the fibres' surface features. These results also contradict the evidence provided in the illustration in Hoffman and Fowler (1995) that reflects an apparent difference in the scales on Huacaya and Suri.

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