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Comparison of llama fiber obtained from two production regions of Argentina

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Abstract

The Puna is an arid region running along the Andes mountains, more than 3600 m above sea level. Overgrazing has severely degraded much of this ecosystem, and this has dramatically reduced agricultural production and resulted in poverty for human inhabitants. Llamas are native to the Puna and are well suited to live there. Their grazing habits and digestive system make efficient use of native forages, and their padded feet keep soil disturbance to a minimum, thereby reducing erosion. Uncontrolled llama breeding over the last 500 years has degraded the quality of the fiber they produce, so today it is generally of low quality. Analysis of llama fibers obtained from two production regions of Argentina showed that some llamas possess sufficiently fine mean fiber diameters (less than 23 μm if guard hairs are excluded) to allow their fleeces to be sold at a premium. A higher price would make llamas more attractive to raise than the goats and sheep commonly found in the Puna today. Switching to llama production would increase grower income and sustainability of agriculture in the region.

Keywords: Llama; Fiber; Argentina; Punal; Camelid

1. Introduction

Argentina has 211 million hectares which are considered arid (75% of its land area). Of the arid regions, 12.8 million are in the Puna which is located in the northwest of the country, more than 3600 m above sea level. Vast areas in this ecosystem have been severely degraded, principally through overgrazing by goats and sheep (Ayerza, 1992; Wehbe et al., 1995). As a consequence forage, and hence

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animal production have decreased dramatically, and many families now live in poverty (Roman and Santos, 1988).

The Puna of Argentina is the driest part of the South American Puna ecosystem. Annual rainfall, which is concentrated between December and March, does not exceed 350 mm on the border with Bolivia, and decreases to 50 mm in the south, in the province of Catamarca. Rainfall is unpredictible, and annual periods of 7–8 months without precipitation are common. These climatic conditions not only reduce forage production, but also result in grass of a lower quality compared with the humid and sub-humid regions of Argentina. The occurrence of frosts, snow, and strong winds reduce production as well, and can also be very dangerous for the herds (Gobel, 1993; Wehbe et al., 1995).

South American camelids (alpaca, llama, vicuña, and guanaco) are native to these regions, and are well suited to the climate and vegetation found in the Puna (Ayerza, 1991). Of these four species, only alpacas and llamas have been domesticated, and in Argentina, only llamas are bred commercially to any degree.

1.1. Llamas and alpacas

When Francisco Pizzarro arrived in South America, the arid and semi-arid zones of Argentina, Bolivia, Chile, Paraguay and Peru had a population of 30–50 million wild guanacos, plus millions of vicuñas, as well as their domesticated relatives, the llamas and alpacas. The number of llamas and alpacas has been estimated at 11 and 7 million, respectively (FIDA, 1990, Wheeler, 1995).

Today, of the total population of 135,000 domesticated camelids in Argentina, 134,000 are llamas, with only 1000 being alpacas (INDEC, 1991a-c). Typically in Peru and Bolivia the alpaca is raised for fiber production, while the llama is used primarily as a pack animal and for meat production (Wheeler, 1995). In Argentina the llama is raised for both meat and fiber, with the fiber having a lower value than alpaca fiber because of its coarser, heterogeneous nature (Frank, 1996; Martinez et al., 1997).

Although llamas and alpacas can often be seen grazing together, the llama is better adapted to aridity than the alpaca. Hence, there are more alpacas in the humid zones, which have protein-rich grasses, and more llamas in the arid zones, which have grasses containing more fiber (FIDA, 1990; Wautters et al., 1996; Sponheimer et al., 2003).

Adaptation of the llama to arid climates has allowed them to take advantage of protein deficient and fibrous forages compared to alpaca, goats and sheep. This adaptation has been attributed to factors such as: better predisposition to eating browse; less selection of species when grazing; higher capacity to travel long distances to find pasture; less feed intake and retention of food for a longer time; and lower energy and protein requirements for maintenance and production (San Martin, 1991; Gobel, 1993; Alagon et al., 1999; Pfister et al., 1999). These characteristics, combined with the "cushion" found on the bottoms of their feet which lessens their impact on the land and considerably decreases soil erosion, makes them ideal for the Puna.

Recent archeological research has shown llamas were previously bred to produce fine fiber for the pre-Columbian textile industry, rather than for transport as was generally believed. Studies have demonstrated the existence of animals having uniform colors with twice the capacity of present day animals to produce fiber, a high uniformity of fiber diameter, and mean diameters of 22.2 μm. This fiber fineness is similar to that found with the best quality alpacas (Wheeler et al., 1995; Pringle, 2001).

Comparing fiber production of llamas (*Lama glama* L.) and alpacas (*L. pacos* L.) that are raised today shows that llamas produce a coarser fiber, having an average diameter of 32 μm, compared to alpaca at 21–28 μm (Martinez et al., 1997). Because of the coarseness of the fleece, the primary value of the Bolivian llama today lies in its use as a pack animal and meat producer, rather than as a fiber producer. Variability in fiber diameter is another problem. This is due to the presence of guard hairs in the coat, which contributes to an overall coarsening of the fleece. The increase in coarseness probably began at the time of the Spanish conquest, and arose because of a lack of controlled breeding, indiscriminate crossing between fine fiber llamas and coarse fiber llamas, and hybridization with alpaca, some of which have coarse fibers (Wheeler, 1993). Today only about 50% of the llamas in Argentina, and 40% in Peru, can be considered genetically "pure" and hence able to transmit to their offspring selected characteristics (Wheeler, 1995; Wheeler, personal communication, Lima, Peru, 2001).

Five centuries of exploitation of both wild and domestic South American camelids produced not only a reduction in the total number of animals, but also a genetically mixed population. This genetic variability in the Argentine llama population supports using it as a basis from which a breeding program could be developed (Bustamante et al., 2002).

1.2. *Llama fiber diameter and fineness*

Few technical reports were located which discuss llama fiber diameter. Von Bergen (1963) provided data for adult and baby llama fiber. After dehairing adult fiber was found to have a mean diameter of 26.5 μm (S.D. = 10.4, CV = 39.2%) and baby llama to have a mean diameter of 20.3 (S.D. = 6.4, CV = 31.7%). Delgado-Santivanez et al. (2001) found average fiber diameter of a meat-oriented llama population in Bolivia to be 27.2 μm. Martinez et al. (1997) found average fiber diameter of another Bolivian herd to be 31.6 μm (S.D. = 5.29, CV = 17%). They noted that 2 year old llamas had the smallest mean fiber diameter, averaging 25.5 μm (S.D. = 3.23, CV = 13%). Frank et al. (1985) measured the fiber diameter for llamas ranging in age from 2, to greater than 5 years. They found average diameter increased up to 4 years of age, then decreased. Animals that were older than 5 years of age had the lowest mean fiber diameter, that being 23.8 μm. They also noted that color affected mean diameter, with black having the smallest diameter, and white the largest.

Frank and Wehbe (1988) studied fiber samples obtained from llamas raised in Neuquen province of Argentina. For six of the samples the sex and animal identification is provided, with mean fiber diameter determined to be 29.3 μm

(CV = 32.3%). A seventh animal is listed without identification, and the sex is unknown; its mean fiber diameter is 19.4 μm (CV = 23.7%). Whether this is simply a young animal, or is a different breed of llama, cannot be determined based on the information presented. If however, it is equivalent in age, sex, etc. to the others, it might be a significant finding.

Iñiguez et al. (1998) discussed two types of llamas, raised in the Southern Potosí region of Bolivia, identified as Thampullis and Kjaras. The paper states that these llamas were found to have mean fiber diameters of 21.1 and 21.9 μm, respectively, and an overall mean of 21.2 μm (S.D. = 2.25, CV = 10.6%). These values are extremely low, especially if the guard hairs were left in the samples when analysed. Attempts to contact the authors and obtain additional information about the samples, the tests that were conducted, etc. failed. If these are mature animals, however, they could serve as a foundation for developing a fine fleece herd.

Related to fiber fineness is the issue of textile allergies and "prickle", the term used to describe the sensation many people experience when wool contacts their skin. A paper written by Garnsworthy et al. (1988) discusses the "itch" many people feel when wearing wool. This is not an allergy, as is commonly thought, rather it is due to larger diameter fibers poking the skin and activating sensors which then trigger the itch. The term "prickle" has been coined for this sensation. The authors note that this sensation generally does not develop if the mean fiber diameter is 21 μm or less and if less than 5% of the fibers are greater than 30 μm. Given these values and those that have been reported by Frank and Wehbe (1988), and Iñiguez et al. (1998), it would seem possible to breed llama herds that could compete with alpacas in terms of fiber quality, and not impart the prickle sensation which is often found with wool.

2. Objective

Development of fine-fleeced llamas could restore the prominence of llamas as the principal grazers on the Puna (replacing goats and sheep), restore the Puna to its previous productivity, and create economic opportunities for the people who live there. As the first step in this process, fiber samples from herds from two different production regions of Argentina were analysed to determine if preliminary selections could be made visually and then by tactile means, eventually leading to a controlled selection and a breeding program.

3. Evaluations conducted

Two Argentine farms were selected to provide llamas. One was in the Province of Buenos Aires (35°S latitude, 62°W longitude) in the region known as the humid pampas, and the other was in the foothills of the Andes, in Neuquen province (39°S latitude, 71°W longitude). For reference purposes, these are hereinafter referred to by the province in which they were located, Buenos Aires and Neuquen. These locations were chosen to provide animals which had been living under moderate weather conditions and eating lusher pastures (Buenos Aires), and animals which had been living under more extreme weather conditions and eating poorer pastures (Neuquen). Mean temperature and rainfall for these locations are 16.7°C and 737 mm, and 15.2°C and 552 mm, respectively.

At each location animals were first visually selected as appearing to have fine fiber, followed by a tactile analysis conducted by an individual trained to do this. From this process 14 adults (6 white females, 5 white males and 3 brown males) were selected from the Neuquen farm, and 11 adults (5 brown females, 2 brown males, 2 white males and 2 black males) from the Buenos Aires farm for sampling. In each case a selection of all available fleece colors on each farm was made, with the selection of males and females not entering into the decision. Ages of the animals ranged from 3 to 8 years.

3.1. Fiber analyses

Fiber samples were taken from both sides of each animal for analysis. The samples were taken at the middle of each animal's side, in the "blanket section" as it is called, in the location recommended to give the most representative results (Yocom-McColl, 2003). The samples were cut at skin level, which is the base of the staple, and were at least 50 mm square. Samples were kept in the staple configuration, that is in its natural growth state, and placed in small plastic bags for shipment to Yocom-McColl's laboratory in the USA for analysis.

In the laboratory, two measurements were performed on each sample. These followed the International Wool Textile Organization (IWTO) Specifications for test 12 (Measurement of the Mean and Distribution of Fiber Diameter Using the Sirolan-Laserscan Fiber Diameter Analyzer) (ASTM, 1999), and for test 47 (Measurement of the Mean and Distribution of Fiber Diameter of Wool Using an Optical Fiber Diameter Analyzer), (ASTM, 2000). IWTO test 12 provided mean fiber diameter, standard deviation, coefficient of variation and fiber content (in percent) greater than 30 μm for each sample. IWTO test 47 provided mean fiber diameter, standard deviation and coefficient of variation for the samples after excluding fibers greater than 30 μm. This diameter was chosen as the cut off value since it is generally considered to be the size corresponding to the diameter of guard hairs, and has been identified as being critical in causing the "prickle" sensation when more than 5% of the fibers exceed this value.

3.2. Statistical analysis

Each variable was compared using the generalized linear model analysis of variance technique to assess differences. When the F-value was significant ($p<0.05$), differences in means were analysed for significance using Duncan's multiple-range test (SAS Institute Inc., 2002).

4. Results

4.1. Comparison between sexes

Table 1 presents the data for those cases in which there were sufficient numbers of animals sampled on each farm to allow a statistical comparison of fibers between sexes to be undertaken. No statistically significant differences were detected, either with the white animals from Neuquen nor the brown animals from Buenos Aires. This was the case, not only for the mean of all fiber diameters, but also for fiber diameters less than 30 μm, and for the percentage of fibers greater than 30 μm.

4.2. Comparison among colors

Table 2 presents the comparison among colors for those cases in which sufficient numbers of animals were sampled on each farm to allow a statistical analysis to be undertaken. For the males, no differences were detected between the brown and white animals from Neuquen. In the case of the Buenos Aires males, the black animals had a significantly ($p<0.05$) greater mean fiber diameter than did the brown and white animals. Comparing the fibers less than 30 μm showed the mean diameter of the brown animals to be significantly ($p<0.05$) less than that of the white or black animals. The percentage of fibers that was greater than 30 μm was significantly lower ($p<0.05$) in the brown animals than in the black animals, with no significant differences detected between the white and either the black or the brown animals. As the sample size for the black animals was small ($n=2$), these results should be viewed with caution.

Since no statistical differences within colors between sexes were detected (Table 1), the data were combined and additional analyses were conducted. For the combined data from Neuquen no significant differences between colors in mean fiber diameter or percentage of fibers greater than 30 μm were detected. However, a significant difference ($p<0.05$) between the brown and white animals was detected in mean diameter of fibers less than 30 μm. When the data from Buenos Aires was combined, the significant difference in mean diameter of fibers less than 30 μm that was found between the white and brown animals was no longer detected, with the black animals having a significantly greater ($p<0.05$) mean diameter than either the white or the brown animals.

4.3. Comparison between farms

Table 3 presents the comparison between farms. The only significant difference that was detected was with the white males. The Neuquen animals were superior in that they had significantly ($p<0.05$) lower values for overall mean diameter, and for those fibers less than 30 μm. They also had a significantly ($p<0.05$) smaller percentage of fibers that were greater than 30 μm. These differences could have arisen because of diet. When the data for all brown animals and then all females were combined and analysed, no statistical differences between farms were detected.

Table 1
Comparison of fleece characteristics between sexes for white animals at Neuquen and brown animals at Buenos Aires, and for the white and brown animals from Neuquen combined

Location/color	Mean diameter of all fibers			Mean diameter of fibers < 30 μm			Percentage of fibers > 30 μm		
	Female	Male	CR[a]	Female	Male	CV	Female	Male	CV
Neuquen white (S.D., CV)[b]	28.9 ($n = 6$) (7.0, 24.3)	27.7 ($n = 5$) (6.4, 23.0)	2.6	24.6 (3.2, 12.9)	24.2 (3.1, 12.9)	0.8	35.6	29.2	16.0
Buenos Aires brown (S.D., CV)	29.3 ($n = 5$) (6.8, 23.3)	29.0 ($n = 2$) (6.5, 22.9)	4.9	24.3 (3.4, 13.8)	24.7 (3.2, 13.2)	1.6	40.2	37.4	30.8
Neuquen (S.D., CV)[c]	28.9 ($n = 6$) (7.0, 24.3)	28.2 ($n = 8$) (6.9, 25.2)	3.6	24.6 (3.2, 12.9)	23.4 (3.2, 13.7)	1.2	35.6	38.6	18.9

[a] Critical range for mean separation in Duncan's multiple range test.
[b] Standard deviation and coefficient of variation.
[c] Since no significant ($p < 0.05$) differences between colors was detected, the data for the white and brown animals from Neuquen were combined and analysed.

Table 2
Comparison of fleece characteristics within farms, among colors

Location/sex	Mean diameter of all fibers				Mean diameter of fibers $<30\,\mu m$				Percentage of fibers $>30\,\mu m$			
	Brown	White	Black	CR[a]	Brown	White	Black	CR	Brown	White	Black	CR
Neuquen males (SD, CV)[b]	28.9 ($n=3$) (7.9, 28.9)	27.7 ($n=5$) (6.4, 23.0)	n/a	6.5	22.8 (3.4, 15.0)	24.2 (31, 12.9)	n/a		38.6	29.2	n/a	33.2
Buenos Aires males (SD, CV)	29.0b ($n=2$) (6.6, 22.9)[c]	32.9ab ($n=2$) (8.4, 25.6)	34.0a ($n=2$) (7.3, 21.5)	4.4	24.7b (3.2, 13.2)	26.0a (2.7, 10.3)	26.3a (2.9, 11.1)	1.08	37.4b	56.7ab	68.0a	25.5
Neuquen (SD, CV)[d]	28.9 ($n=3$) (7.9, 28.9)	28.4 ($n=11$) (6.7, 23.7)	n/a	4.4	22.8b (3.4, 15.0)	24.4a (3.1, 12.9)	n/a		38.6	32.7	n/a	22.7
Buenos Aires (SD, CV)[d]	29.2b ($n=7$) (6.8, 23.2)	32.9ab ($n=2$) (7.8, 25.5)	34.0a ($n=2$) (7.3, 21.5)	4.5	24.4b (3.3, 13.7)	25.0ab (3.0, 12.1)	26.3a (2.9, 11.1)	1.44	39.4b	45.3ab	68.0a	26.8

[a] Critical range for mean separation in Duncan's multiple range test.
[b] Standard deviation and coefficient of variation.
[c] Means within a fiber group followed by the same letter are not statistically different at the 0.05 level according to Duncan's multiple range test.
[d] Values for males and females combined.

Table 3
Comparison of fleece characteristics between farms

Color/sex	Mean diameter of all fibers			Mean diameter of Fibers $<30\,\mu$			Percentage of fibers greater than $30\,\mu$		
	Buenos Aires	Neuquen	CR[a]	Buenos Aires	Neuquen	CR	Buenos Aires	Neuquen	CR
Brown males (S.D., CV)[b]	29.0 ($n=2$) (6.6, 22.9)	28.9 ($n=3$) (7.9, 28.9)	10.6	24.7 (3.2, 13.2)	22.8 (3.4, 15.0)	3.5	37.4	38.6	50.8
White males (S.D., CV)	32.9a ($n=2$) (8.4, 25.6)[c]	27.7b ($n=5$) (6.4, 23.0)	4.3	26.0a (2.7, 10.3)	24.2b (3.1, 12.9)	1.4	56.7a	29.2b	25.7
Brown animals (S.D., CV)	29.2 ($n=7$) (6.8, 23.2)	28.9 ($n=3$) (7.9, 28.9)	5.7	24.2 (3.3, 13.7)	22.8 (3.4, 15.0)	1.9	39.4	38.6	29.8
All Females (S.D., CV)	28.8 (n = 5) (6.8, 23.6)	28.9 (n = 6) (7.0, 24.3)	2.7	24.1 (3.4, 14.2)	24.6 (3.2, 12.9)	0.9	37.2	35.6	16.7

[a] Critical range for mean separation in Duncan's multiple range test.
[b] Standard deviation and coefficient of variation.
[c] Means within a fiber group followed by the same letter are not statistically different at the 0.05 level according to Duncan's multiple range test.

5. Summary and recommendations

Ways to develop environmentally friendly and commercially acceptable methods to manage the fragile lands in the Puna are needed, not only to allow farmers to increase production, and hence their income, but also to ensure long term sustainability of farming in the region. Developing sustainable production systems using llamas is both a logical and a natural option for the Puna. The greater ability of llamas to adapt to very poor lands, and given that they have a larger body, gives them a considerable advantage over alpacas as a production alternative for these arid zones.

In order to be successful, however, sustainable production systems must be developed along with enhanced market opportunities. Enhanced market opportunities will come about if llama fiber quantities and qualities are increased. This can only be done through rigorous selection and culling programs.

The work presented in this paper shows that large differences in fiber diameter exist among llamas. It is therefore recommended that a more comprehensive study be undertaken to identify a larger number of animals which possess fine fiber characteristics. Once this has been completed, DNA testing must be undertaken to identify which of the fine fleece animals are truly purebred llamas. Those that are identified as being purebred can then be used to develop fine fleeced llama herds.

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