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Fibre Medullation Characteristics in Peruvian Llamas (*Lama glama*)

Francisco Halley Rodríguez-Huanca[1], Cesar Alberto Nina Mojo[1], Luis Alberto Carlo Lozada[1], Marvin Pablo Quispe Huanca[1], Uri Harold Perez-Guerra[1], Yan Pierr Manrique Quispe[1], Ali William Canaza-Cayo[2,3], Luis Roque Almanza[4]

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ABSTRACT

Background: The textile use of llama fiber, achieved through genetic improvement, llama selection and management, shows great potential for producing high-quality clothing and fabrics; providing an alternative income to highland residents who raise llamas. The aim of this research was to determine the fiber medullation of white Ch´aku and Q´ara color varieties of Llamas (*Lama glama*) from the communities of the Macusani district, Puno Peru.

Methods: A total of 88 Llamas from the Ch´aku and Q´ara white color varieties, including males and females, from the age of milk teeth and two teeth, were used. Fiber samples of approximately 10 g were taken from the thigh, middle rib and shoulder, totaling 264 samples. Samples were analyzed at the Fiber Laboratory of the District Municipality of Corani, using the FIBER MED equipment. Data were analyzed in a completely randomized design (CRD) with a 2(variety) × 2 (sex) × 2 (age group) × 3 (body area) factorial arrangement.

Result: The percentage of fiber medullation types in Ch´aku and Q´ara Llamas averaged 46.02% and 47.38%, showing no significant difference ($p>0.05$). In Ch´aku Llamas, a statistical difference was observed by sex ($p<0.05$) for the percentage of medullated, non-medullated and continuous fibers in males and females. In Q´ara variety, there was a significant difference in the percentage of medullated, non-medullated and continuous fibers between milk teeth and two teeth age groups. There was no significant difference ($p>0.05$) between body area samples.

Key words: Age, Ch´aku, Fiber medullation, Llama, Q´ara, Sex.

INTRODUCTION

Peru is the world's second largest producer of llamas with 746,269 animals spread across more than 55,000 farming units. Nearly half are Ch'aku llamas and the other half are QÈara llamas. The region of Puno holds the highest llama population at 32% (INEI, 2013). Llama fiber protects the animals from temperature changes, frost and heat due to its hollow core that traps air, providing insulation and warmth without adding weight. These qualities are sought after for garment comfort (COTEXBO, 2018). The textile use of llama fiber, achieved through genetic improvement, llama selection and management, shows great potential for producing high-quality clothing and fabrics; providing an alternative income to highland residents who raise llamas (Mueller *et al*., 2010). The factors influencing fiber characteristics in domestic camelids production include genetic component, environmental conditions, nutritional quality of diet, age of the animal and specific breeding and management practices (Canaza-Cayo *et al*., 2022). Access to the technology to determine fiber medullation remains costly for individual or associated llama breeders. Innovative fiber measurement equipment has been developed to make technology accessible to breeders. The medullometer is gaining importance as a selection criterion for improving fiber diameter in genetic improvement programs, aiming to reduce medullation rates (Cruz *et al*., 2019).

[1]Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional del Altiplano, Av. Floral 1153, Puno, Perú.
[2]Facultad de Ciencias Agrarias, Escuela Profesional de Ingeniería Agronómica, Universidad Nacional del Altiplano, Av Floral 1153, Puno, Perú.
[3]Departamento de Estatística, Instituto de Ciências Exatas e Tecnológicas, Universidade Federal de Lavras, Código postal 3037, CEP 37200-900, Lavras, MG, Brazil.
[4]Facultad de Ciencias Agrarias, Escuela Profesional de Medicina Veterinaria, Universidad Nacional San Antonio Abad del Cusco, Perú.

Corresponding Author: Francisco Halley Rodríguez-Huanca, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional del Altiplano, Av. Floral 1153, Puno, Perú.
Email: fhrodriguez@unap.edu.pe

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It is possible to reduce itching caused by llama fibers by decreasing the medullation percentage. This would lead to better positioning of llama fiber in the textile market of natural fibers, promoting its consumption and potentially

surpassing other noble fibers, motivating and encouraging the entire production chain, ultimately impacting the economic income of disadvantaged producers dedicated to breeding llamas (Cruz *et al*., 2019). New technologies, such as FIBER MED, are being used as a new option for determining the medullation percentage directly and objectively (Torres, 2020).

Currently there are different degrees of medulla in flame fibers, so they can be classified into five categories, non-medullated (NoMed), fragmented medullated (Med_Frag), discontinuous medullated (Med_Disc), continuous medullated (Med_Cont) and strongly medullated (F_Med) as reported by Frank *et al*. (2011) for llamas by (Pinares *et al*., 2018). The medulla in llama fiber causes the fiber to be makes it have a higher level of itchiness. To increase the value of llama fiber, researchers have proposed using medullation percentage of fibers as a selection criterion (Gutiérrez, 2018). However, there is limited information available. The research that is available is insufficient; highlighting the need for further studies on medullation. The objective of this study was to determine the medullation of llama fiber Ch´aku and Q´ara white color from the Macusani district.

MATERIALS AND METHODS

Study of area

The research study was conducted during the period of 2023 year, in the communities of Jorge Chávez, Huaylluma, Queracucho and Ccatacancha in the district of Macusani, belonging to the province of Carabaya in the department of Puno; with geographical coordinates: Latitude: -14.0683, longitude: -70.4314, latitude: 14°4′6″South, longitude: 70° 25′53″ West, at an altitude of 4345 m. The climate is rainy and semi-cold, with low humidity in winter; the maximum temperature is around 12°C throughout the year, with minimum temperatures around 2°C in summer and -6.5°C in winter. The annual accumulated rainfall is 636 mm (SENAMHI, 2021).

Animals and management

Approximately 10 g of fiber samples were taken from 88 llamas from the thigh, middle rib and shoulder areas (Fig 1), totaling 264 samples. The samples were placed in polyethylene bags properly labeled with ear tag number, variety, sex, age class and body area.

From each sample, representative subsamples were obtained, which were attached to the base sample, then fully immersed in a solution of isopropyl alcohol and gasoline for 5 minutes for a total of 3 repetitions, in plastic containers. With tweezers, gentle pressure was applied to the fiber strand, mainly at the tips to help remove dirt and impurities. Once this process was complete, the sample was removed and placed on a paper towel, rubbed firmly and gently with a small roller to dry for subsequent analysis in the laboratory.

Recording and measurements

The fiber medullation analysis was carried out using the FIBER MED equipment (Intelligent electronic medullator of fibers of animal origin) at the fibers laboratory of the District Municipality of Corani. For the evaluation of medullation, an angular Bliss transformation was performed to convert percentage values to arcsine integers ($\sqrt{\times}$ 100).

Statistical analysis

The percentage of medullation types was conducted in a completely randomized design (CRD), analyzed under a factorial arrangement of 2 (variety) × 2 (sex) × 2 (age class) × 3 (body region) and for the mean test, the Tukey test was used at P≤0.05, using Rstudio software version 4.3.1.

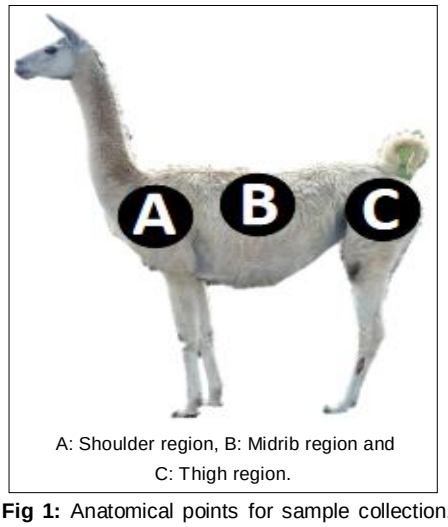
RESULTS AND DISCUSSION

Percentage of medullation types in llamas according to the variety

Table 1 displays summary measures for medullation types, showing average values, standard deviations, minimum and maximum values for the 2 varieties of Ch´aku and Q'ara Llamas.

The percentage of fiber medullation types in llamas according to the variety are shown in Table 2. There is no significant difference (p>0.05) between variables. The lack of difference is attributed to the fact that the variety does not influence the percentage of medullation, as these animals are in the same agroecological zone and share similar grass vegetation.

Martinez *et al*. (1997), reported similar results with an average medullation of 46.6% in Ch´aku Llamas. Similarly, Iñiguez *et al*. (1998) reported a total medullation percentage leof 48.1% for Q'aras. Intermedias and T'hampullis, had lower values, 38.7% and 27.1%, respectively. Conversely, lower values are reported by Poma (2018), with averages of 31.88% and 15.11% in Q´ara and Ch´aku Llamas.



A: Shoulder region, B: Midrib region and C: Thigh region.

Fig 1: Anatomical points for sample collection.

Martinez (2018) determined medullation percentages in Ch´aku Llamas and hybrids to be 21.55% and 26.56%, respectively. These differences are attributed to the variety, feeding and environment in which the Llamas of both varieties are found, influencing the variation in the percentage of medullation.

Lower values for Ch´aku were reported by Sacchero and Sáenz (2017), with averages of 13.08% for continuous medulla, 6.6% for discontinuous medulla and 0.5% for strongly medullated. Mueller *et al*. (2010) also recorded medullation types in Ch´aku Llamas with percentages of 14.5% for continuous medullas, 0.90% for strongly medullated and higher values for discontinuous medullas at 16.7%. Similarly, Martinez *et al*. (1997) reported medullation types in Q´ara Llamas with 20.2% without medulla, 3.7% fully medullated or Kemps and a higher average of 36.7% for fragmented or partially medullated. However, Poma and Ayala (2022) report percentages for medullation types by variety in Llamas with averages of 36.33% and 66.38% for non-medullated fibers, 27.72% and 16.84% for discontinuous medulla and lower values of 4.06% and 1.67% for strongly medullated in Ch´akus and Q´aras. These differences are due to Ch´aku and Q´ara Llamas possibly having developed adaptations according to the agroecological zone, influencing variations in fiber medullation types, as well as selection and feeding.

Percentages of medullation types in llamas according to sex and age class

Table 3 shows the percentage of medullation types, displaying values in Ch´aku and Q'ara Llamas according to sex (male and female) and age class (milk teeth and two teeth). There is a statistically significant difference ($p<0.05$) between males and females for the percentage of medullated, non-medullated and continuous fibers. Ch´aku and Q'ara males (38.91% and 45.24%, respectively) were lower than Ch´aku and Q'ara females (53.14% and 49.51%, respectively) of medullated fibers. Males from Ch´aku and Q'ara have higher values (51.09% and 44.76%, respectively) of non-medullated fibers, but lower values of continuous medullas (29.54% and 36.33%, respectively). Ch´aku and Q'ara females have higher values of continuous medullas (43.39% and 38.48% respectively). These differences could be due to the precision used to select breeding males, resulting in a lower percentage of medullation compared to females.

Also, in Table 3, the percentage of fiber medullation types shows there is no significant difference between age in Ch´aku Llamas. While in Q´ara Llamas, there is a significant difference ($p<0.05$) in the percentage of medullated, non-medullated and continuous fibers. Milk teeth Llamas have lower percentages of medullation compared to 2-teeth Llamas. This is attributed to the fact that the animal's age influences the percentage of medullation; as the animals age medullation increases.

The results of this study were similar to those reported by Martinez *et al*. (1997), who evaluated the percentage of medullation in llamas by sex, with values of 38.2% and 42.8% for males and females. However, higher values were mentioned by Córdova (2015), who determined the effect of sex on medullation in llamas, obtaining means of 67.13% and 75.36% for males and females, respectively. Similarly,

Table 1: Summary measures for medullation types according to the variety.

Variety	Variable	n	Mean	EE	Mín	Máx
Ch´aku	%_Med	132	46.02	19.53	15.04	81.70
	%_NoMed	132	43.97	19.53	8.30	74.96
	%_Med_Frag	132	14.75	7.12	0.00	33.41
	%_Med_Disc	132	9.55	4.76	0.00	26.57
	%_Med_Cont	132	36.46	20.55	7.34	73.86
	%_F_Med	132	4.98	4.47	0.00	27.16
Q'ara	%_Med	132	47.38	19.84	15.10	81.70
	%_NoMed	132	42.62	19.84	8.30	74.90
	%_Med_Frag	132	14.99	6.52	0.00	28.75
	%_Med_Disc	132	10.55	5.60	0.00	26.57
	%_Med_Cont	132	37.41	20.56	7.34	75.26
	%_F_Med	132	4.92	3.93	0.00	27.16

Med: Medullated, NoMed: Non-medullated, Med_Frag: Fragmented medulla, Med_Disc: Discontinuous medulla, Med_Cont: Continuous medulla, F Med: Strongly medullated.

Table 2: Percentages of fiber medullation types in llamas by variety.

Variety	Med	No med	Med_Frag	Med_Disc	Med_Cont	F_Med
Ch´aku	46.02[a]	43.97[a]	14.75[a]	9.55[a]	36.46[a]	4.98[a]
Q'ara	47.38[a]	42.62[a]	14.99[a]	10.55[a]	37.41[a]	4.92[a]

Med: Medullated, NoMed: Non-medullated, Med_Frag: Fragmented medulla, Med_Disc: Discontinuous medulla, Med_Cont: Continuous medulla, F_Med: Strongly medullated.

Table 3: Percentage of fiber medullation types in Ch´aku and Q´ara Llamas according to sex and age class.

Variety	Sex/Age class	Med	NoMed	Med_Frag	Med_Disc	Med_Cont	F_Med
Ch´aku	Male	38.91[b]	51.09[a]	15.60[a]	9.17[a]	29.54[b]	4.38[a]
	Female	53.14[a]	36.86[b]	13.89[a]	9.93[a]	43.39[a]	5.58[a]
	Milk-teeth	43.79[a]	46.21[a]	14.58[a]	9.60[a]	34.49[a]	4.42[a]
	2-teeth	48.26[a]	41.74[a]	14.91[a]	9.50[a]	38.44[a]	5.55[a]
Q'ara	Male	45.24[a]	44.76[a]	14.12[a]	9.71[a]	36.33[a]	4.69[a]
	Female	49.51[a]	40.48[a]	15.85[a]	11.40[a]	38.48[a]	5.16[a]
	Milk-teeth	43.63[b]	46.37[a]	14.53[a]	9.84[a]	33.84[b]	4.84[a]
	2-teeth	51.12[a]	38.88[b]	15.44[a]	11.27[a]	40.97[a]	5.01[a]

Med: Medullated, NoMed: Non-medullated, Med_Frag: Fragmented medulla, Med_Disc: Discontinuous medulla, Med_Cont: Continuous medulla, F_Med: Strongly medullated.

Table 4: Percentage of fiber medullation types in Ch'aku and Q'ara Llamas by body region.

Variety	Body region	Med	NoMed	Med_Frag	Med_Disc	Med_Cont	F_Med
Ch´aku	Shoulder	45.42[a]	44.58[a]	14.98[a]	9.24[a]	35.78[a]	5.13[a]
	Midrib	45.39[a]	44.61[a]	13.56[a]	10.11[a]	34.84[a]	5.39[a]
	Thigh	47.27[a]	42.73[a]	15.69[a]	9.30[a]	38.78[a]	4.44[a]
Q'ara	Shoulder	48.32[a]	41.68[a]	14.02[a]	10.89[a]	38.82[a]	5.07[a]
	Midrib	45.60[a]	44.40[a]	16.59[a]	11.41[a]	34.75[a]	4.97[a]
	Thigh	48.21[a]	41.79[a]	14.36[a]	9.36[a]	38.65[a]	4.73[a]

Med: Medullated, NoMed: Non-medullated, Med_Frag: Fragmented medulla, Med_Disc: Discontinuous medulla, Med_Cont: Continuous medulla, F_Med: Strongly medullated.

Checalla (2021) reported medullation percentages in Suri alpacas with means of 67.49% and 67.83% for males and females. Lower values were described by Poma (2018), who obtained medullation percentage values by sex of 22.87% and 21.92% in males and females. Likewise, Torres (2020) reported medullation percentages in alpacas by sex with values of 26.64% and 30.79% for males and females. Cutiri (2019) also reported medullation percentages in alpacas with means of 36.40% and 42.60% for males and females, respectively. In other species, no differences between sexes were reported. Bharathesree *et al*. (2019) reported medullation percentages in the Sandyno and Nilagiri breeds of sheep from India, with means of 4.66% and 3.77% for males and females, respectively. These differences could be attributed to the influence to genotype × environment interactions or changes in gene expression levels due to environmental factors (Kadirvel *et al*., 2020).

Poma (2018) reported similar values by sex in llamas for non-medullated fibers; however, partially medullated fibers and strongly medullated fibers were higher. Similarly, Mamani (2023) determined types of medullation by sex in Huacaya alpacas, with percentages of non-medullated fibers, higher values fragmented and discontinuous medulla and lower means for continuous and strongly medullated medulla.

On the contrary, Suri alpacas show higher percentages of non-medullated and lower percentages of fragmented, discontinuous, continuous and strongly medullated medullas. These variations are attributed to the species, agroecological zone, environment, selection and diet; all of which influence the types of medullation.

Several studies have compared medullation in milk teeth and 2-tooth age class llamas with varying results (Checalla, 2021; Alvarado, 2021; Poma and Ayala, 2022; Cutiri, 2019; Quispe-Peña *et al*., 2014). Younger animals typically have less medullation. Differences between age groups are due to class factor, where young animals have a lower percentage of medullation compared to adults and are also influenced by the number of shearings and the environment. Variations between species are attributed to environmental and nutritional conditions, management, selection, number of shearings and time of year.

Percentages of types of medullation in llamas by body region

Table 4 shows the percentage of fiber medullation types in Ch´aku and Q´ara Llamas by body region. There is no significant difference between body regions. It is noted that the midrib region has the lowest percentage of medullation compared to the others. This is likely due to the body region not influencing the percentage of medullation in these llama species.

CONCLUSION

There was no difference between the percentage of fiber medullation types in Ch´aku versus Q´ara Llamas; indicating that the variety of llama does not influence the variation of medullation. There was a difference between male and female Ch´aku Llamas for the percentage of

medullated, non-medullated and continuous fibers. In the Q´ara variety, there is no difference between males and females. No difference was observed by age class of Ch´aku Llamas. However, there is a difference in the percentage of medullated, non-medullated and continuous fibers in Q´ara Llamas. The percentages of fiber medullation types in Ch´aku and Q´ara Llamas according to the body region do not show a significant difference.

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Conflict of interest

All authors have participated in (a) conceptualization, design and/or analysis and interpretation of the data; (b) drafting or editing the article, meaningfully contributing to intellectual content; and (c) approval of the final version. This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue. The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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