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Effect of Age and Sex on Medullation Types and Fiber Characteristics in Huacaya Alpacas

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ABSTRACT

Background: Fiber is a distinctive attribute of the alpaca due to its softness qualities; it contains less grease and has a finer cuticle compared to sheep's wool. Therefore, the types of medullation were estimated: non-medullated fibers (NoMed), fragmented medulla (FragMed), discontinuous medulla (DiscMed), continuous medulla (ContMed) and strongly medullated fibers (StrMed), considering the age and sex of Huacaya breed alpacas (*Vicugna pacos*) under extensive management conditions in high Andean pastures.

Methods: Six grams of fiber samples were collected from the mid-side region (located above the third last rib, halfway between the midline of the belly and the midline of the back) of 240 Huacaya alpacas from the district of Macusani, province of Carabaya, Puno, during the year 2022. They were then processed in the Fiber Laboratory of the Faculty of Textile Engineering and Garments at the National University of Juliaca using the FIBER EC V4.0 and FIBER MED V1.0 equipment.

Result: The results obtained show that the percentage of non-medullated fibers decreases as the animal's age increases (1 year= 75.60%, 2 years=69.43%, 3 years=69.05% and >4 years=66.25%) (P≤0.05). The percentage of medullated fibers in animals of 1 year was 24.40%; 2 years, 30.57%; 3 years, 30.95% and >4 years, 33.59% (P≤0.05). The mean fiber diameter in 1-year-old alpacas is 17.32 μm, 2 years=19.49 μm, 3 years = 19.91 μm and 4 years=20.10 μm (P≤0.05). The comfort factor in 1-year-old animals is 99.47%, 2 years with 98.02%, 3-year-olds with 97.01% and those older than 4 years with 96.45% (P≤0.05). Regarding the curvature index, values of 55.86°/mm were obtained for 1-year-old animals, 53.43°/mm for 2-year-olds, 53.99°/mm for 3-year-olds and 52.23°/mm for those older than 4 years (P≤0.05). In conclusion, Huacaya alpacas exhibit low values for the percentage of strongly medullated fibers due to the age and sex of the animal, demonstrating very good fleece uniformity.

Key words: Alpaca, Comfort factor, Fiber, Medulation, Vicugna pacos.

INTRODUCTION

Peru concentrates the largest alpaca population with 3.8 million alpacas. South American camelids are characterized by the fact that they efficiently convert nutrient-depleted and stature-poor pastures into high quality products such as fiber and meat, in addition to producing by-products such as hides and skins that have industrial and artisanal uses. Likewise, their manure is a by-product that is used as fuel for cooking and as fertilizer for crops (FAO, 2005).

Alpaca fiber is considered a luxury item due to its characteristics of fineness, softness and has a high valuation in the market, as well as Cashemire, Mohair, Yak and Musk Ox (Wang *et al*., 2003). There are reports that fiber diameter is affected by: age, breed, sex, physiological state, fiber color, nutritional status (Bustinza, 2001; Canaza *et al*., 2022; Frank *et al*., 2006; McGregor and Butler, 2004; Omachea *et al*., 2015; Olarte *et al*., 2023; Quispe *et al*., 2009; Roque and Ormachea 2018; Wuliji *et al*., 2000). However, there are fleeces in alpacas that present objectionable or medullated fibers related to the itch factor and it has been shown that fibers with continuous and strongly medullated pith have an effect on fiber diameter variability (McGregor *et al*., 2013).

In this regard, there are studies in which they affirm that the presence of medullated fibers favors the thermoregulation of the alpaca in rather frigid climates, because the medulla has the ability to retain heat (Moore *et al*., 2011; Wang *et al*., 2005). Currently, several researchers are trying to explain the behavior of the presence of pith in the fiber, among which the percentage of pith in the fibers has even been proposed as a selection criterion (Cruz *et al*., 2019; Pinares *et al*., 2018, 2019; Quispe *et al*., 2022), in addition,

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the heritability for wool is moderate to high (Lalit *et al*., 2017). In this sense, the research work has been planned with the purpose of determining the percentage of medulation and the characteristics of the fiber in Huacaya alpacas (*Vicugna pacos*).

MATERIALS AND METHODS

Sampling

The research was conducted in the district of Macusani, Carabaya province, Puno region. A total of 240 Huacaya alpacas used, were distributed across different age groups (1 year = 60, 2 years = 60, 3 years = 60 and older than 4 years = 60), including both sexes (males = 120 and females = 120). Fiber samples were collected before shearing the animals during the months of October and November 2022. Each collected sample was labeled with the breed, sex, ear tag number and the age of the animal

Fiber analysis

Fiber samples were collected from the midrib region at the level of the third to fourth rib on the left side of the alpaca (Mid-side), which is representative for evaluating the mean fiber diameter (Aylan and McGregor, 2002; Radzik *et al*., 2021). Each collected sample contained approximately 6 grams of fiber. Subsequently, the samples were stored until analysis in the Fiber Laboratory of the School of Textile Engineering and Apparel at the National University of Juliaca using the FIBER MED V 1.0 and FIBER EC V 4.0 equipment, under standard laboratory conditions at 20±2°C temperature and 65±5% relative humidity.

Fiber Med is an artificial intelligence-based device that recognizes different medullation types. Before the evaluation, the samples were washed for 3 minutes using a solution composed of 7 parts of 96% alcohol and 3 parts of benzine. After washing, the samples were placed on an absorbent towel for drying. Subsequently, fiber fragments were prepared using the Hardy microtome. These fiber fragments were then mounted on glass slides, homogenized with immersion oil, covered with a cover slip and placed in the medulometer (Fiber Med) for their respective analysis. Medullation types were classified as follows: Non-medullated fibers (NoMed), fragmented medulla (FragMed), discontinuous medulla (DiscMed), continuous medulla (ContMed) and strongly medullated (StrMed) (Quispe *et al.,* 2022).

The fiber characteristics in alpacas, such as mean fiber diameter, standard deviation, coefficient of variation, comfort factor and curvature index, were analyzed according to the standards described by the International Wool Textile Organization for wools and other fibers of animal origin. Under standard laboratory conditions at 20±2°C temperature and 65±5% relative humidity, following IWTO-52 procedures (IWTO-52, 2006). Dirty fiber samples were washed with detergent and baking soda in water at 50-60°C; afterward, they were placed in an oven at 70°C for 24 hours. The clean and dry samples were mounted on slide for their respective analysis using the FIBERT EC V 4.0 equipment.

Statistical analysis

Descriptive statistics and a statistical analysis based on a linear model that included the effects of age and gender were used:

$$Yijm= \mu+Ai+Sj+eijm,$$

Considering the age (Ai); sex (Sj)

For creating the graphs, the (Rcmdr) library and the packages: ggplot2, plyr, carData and stats were employed. The Tukey test was used for multiple comparisons of fiber characteristics means and the Wilcoxon test was used to compare medullation percentages in Huacaya alpaca fiber. The statistical analysis was performed using R software, version 4.1.1 (R Core Team, 2021).

RESULTS AND DISCUSSION

Fiber medullation in Huacaya alpacas

Table 1 and Fig 1 display the types of medullated fibers, such as non-medullated fibers (NoMed), fragmented medulla (FragMed), discontinuous medulla (DiscMed), continuous medulla (ContMed) and strongly medullated

Table 1: Types of Medullation in Huacaya alpaca fiber by the age and gender of the animal.

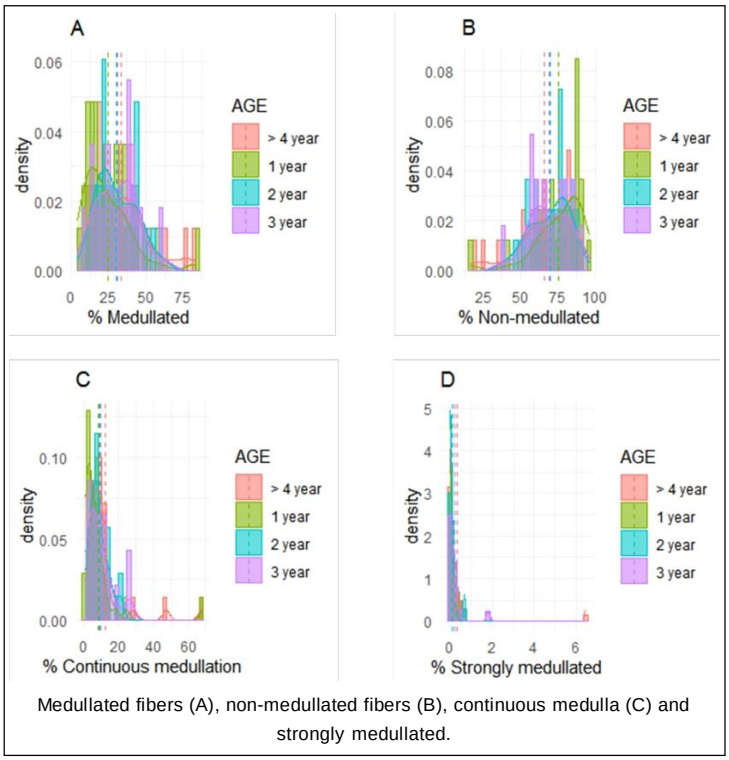
		Types of medulation					
Variables	n	No Med (%)	Medullated (%)	Frag Med (%)	Disc Med (%)	Cont Med (%)	Str Med (%)
Age							
1 year	60	75.60^{c}	24.40^{a}	13.02^{a}	2.80^{a}	8.14^{a}	0.10^{a}
2 year	60	69.43^{b}	30.57^{b}	17.15^{b}	4.20^{b}	8.64^{a}	0.11^{a}
3 year	60	69.05^{b}	30.95^{b}	16.20^{b}	5.06^{b}	9.19^{a}	0.21^{a}
> 4 year	60	66.25^{a}	33.59^{c}	16.53^{b}	4.37^{b}	11.95^{a}	0.34^{a}
Sex							
Male	120	68.77^{a}	31.12^{a}	14.83^{a}	4.01^{a}	11.73^{a}	0.28^{a}
Female	120	70.78^{a}	29.22^{a}	15.97^{a}	4.22^{a}	8.34^{a}	0.13^{a}

Where: Non-medullated fibers (NoMed), fragmented medulla (FragMed), discontinuous medulla (DiscMed), continuous medulla (ContMed) and strongly medullated (StrMed). Different superscripts in column (lower case) are significant P≤0.05, similar letters Non Significant at P>0.05.

(StrMed), found in Huacaya alpacas, considering the age and sex of the animal. The percentage of non-medullated fibers decreases as the age of the animal increases (1 year = 75.60%, 2 years = 69.43%, 3 years = 69.05% and >4 years = 66.25%) (image B). The highest proportion of fibers with a discontinuous medulla was found in animals older than 4 years and 3 years (>4 years= 4.37, 3 years= 5.06). The presence of fibers with a continuous medulla was greater in alpacas older than 4 years, at 11.95%. The percentage of strongly medullated fibers increases with the age of the animal (1 year= 0.10, 2 years= 0.11, 3 years= 0.21, >4 years = 0.34) (image D). Likewise (Table 1 and Fig 2), the results obtained demonstrate that no statistical difference was found in medullation types based on the gender of the animal (P>0.05).

Table 1 shows that image (A) corresponds to the percentage of medullated fibers. In the case of 1-year-old animals, it was 24.40%; 2 years was 30.57%; 3 years was 30.95% and >4 years was 33.59%. Therefore, it can be stated that the percentages of medullated fibers increase as the age of the animal and the number of shearings performed increase.

Fig 2 displays the density histograms, where image (E) corresponds to the percentage of medullated fibers, being 31.12% for males and 29.22% for females. Image (F) represents non-medullated fibers, with percentages of



Medullated fibers (A), non-medullated fibers (B), continuous medulla (C) and strongly medullated.

Fig 1: Density histograms of medullation types in alpacas considering the age of the animal.

Table 2: The fiber characteristics in Huacaya alpacas by the age and gender of the animal.

Variable	n	MFD (µm)	SD (µm)	CV (%)	CF (%)	CI (°/mm)
Age						
1 year	60	17.32^{a}	3.69^{a}	21.29^{ab}	99.47^{a}	55.86^{a}
2 year	60	19.49^{b}	4.11^{b}	21.15^{ab}	98.02^{ab}	53.42^{a}
3 year	60	19.91^{b}	4.05^{ab}	20.31^{b}	97.01^{b}	53.99^{a}
>4 year	60	20.10^{b}	4.38^{b}	21.80^{a}	96.45^{b}	52.23^{a}
Sex						
Male	120	18.67^{a}	3.99^{a}	21.31^{a}	97.94^{a}	53.86^{a}
Female	120	19.55^{a}	4.10^{a}	21.03^{a}	97.60^{a}	53.88^{a}

Where: MFD = Average fiber diameter; SD = standard deviation; CV = coefficient of variation; CF = comfort factor; CI = curvature index. Different superscripts in column (lower case) are significant at P≤0.05, similar letters Non Significant at P>0.05.

68.77% for males and 70.78% for females. Image (G) illustrates fibers with continuous medulla, showing 11.73% for males and 8.34% for females. Image (H) depicts strongly medullated fibers, with values of 0.28% for males and 0.13% for females.

Statistical differences were found based on the age effect in the percentages of medullation. In animals of 1 year old, values of 24.40% were obtained compared to alpacas of 2, 3 and older than 4 years, results that demonstrate an increase in the proportion of medullated fibers due to age. The results obtained corroborate the findings of other researchers (Aruquipa, 2015; Contreras, 2010; Lupton *et al*., 2006; McGregor, 2006; Pinares, *et al*., 2019; Quispe *et al*., 2022). The increase in medullated fibers due to age is explained by the increase in mean fiber diameter, the decrease in the number of actively growing skin follicles and the ratio of primary to secondary follicles as a result of the animals' aging (Antonini *et al*., 2004; Khan *et al*., 2012; McGregor, 2002). In this regard, McGregor *et al*. (2012) mention that medullation is related to altered keratinization in the hair follicle bulb, which is associated with insufficient protein synthesis. The results obtained in the study regarding strongly medullated fibers range from 0.10% to 0.34%, which represents a good indicator as a criterion for selecting future alpaca breeders with the aim of eliminating strongly medullated fibers from the fleeces, as recommended by other researchers (Cruz *et al*., 2019; Pinares *et al*., 2018, 2019; Quispe *et al*., 2022). From a textile industry perspective, garments made from fibers with high percentages of continuous medulla and strongly medullated fibers are the ones that cause discomfort or itching when they come into contact with the skin (Frank *et al*., 2014; Quispe *et al*., 2022), as they emerge from the surface of the thread (Mamani- Cato *et al*., 2022). This process leads to a decrease in the price of the product (McGregor and Butler, 2004).

The percentages of medullated fibers, also known as objectionable fibers (Lupton *et al*., 1991), found in the study were 29.22% in males and 31.12% in females. No statistical differences were observed based on gender and these findings are consistent with results from other researchers (Aruquipa, 2015; Quispe *et al*., 2022; Radzik, Pofelska and Rant, 2018), which support our obtained results. However, our reports differ from the results of Radzick-Rant and Wierckinska (2021), who obtained values of 60.13% in females and 77.7% in males. We attribute this difference to the origin of the animals and the number of animals used in the study.

Fiber characteristics in huacaya alpacas

Table 2. It presents the mean fiber diameter in Huacaya alpacas, where 1-year-old animals exhibit a smaller diameter with a value of 17.32 μm compared to the other age groups: 2 years = 19.49 μm, 3 years = 19.91 μm and 4 years= 20.10 μm (P≤0.05). However, no difference was observed regarding the gender of the animal (males = 18.67 μm and females = 19.55 μm). The results obtained regarding the coefficient of variation of fiber in alpacas were as follows: 1 year= 21.29%; 2 years= 21.15%; 3 years= 20.31%; >4

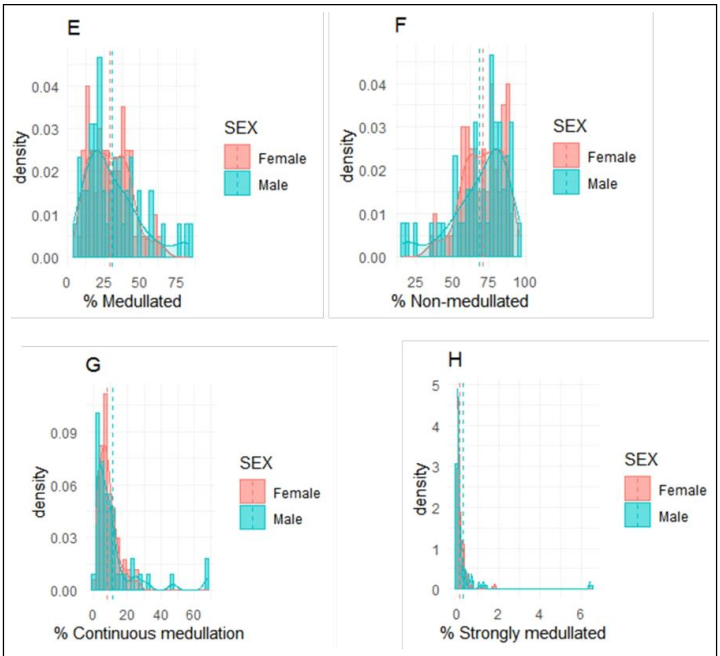


Image (E) corresponds to the percentage of medullated fibers, image (F) corresponds to the percentage of non-medullated fibers, image (G) corresponds to the percentage of fibers with continuous medulla and image (H) corresponds to the percentage of strongly medullated fibers.

Fig 2: Density histograms of fiber medullation types in alpacas according to the animal's gender.

years = 21.80%; in males, it was 21.31% and in females, 21.03% (P≤0.05). This indicates a higher uniformity in the fiber of these animals, considering both age and gender.

As for the comfort factor, considering the age of the animals, they exhibited a value higher than 95%, which is an acceptable characteristic from a textile industry perspective. 1-year-old animals showed the highest percentage at 99.47%, compared to 2-year-olds at 98.02%, 3-year-olds at 97.01% and those older than 4 years at 96.45% (P≤0.05). However, no statistical differences were found with respect to gender (males = 97.94% and females = 97.60%).

The fiber curvature index shows no statistical difference based on age; 1-year-old animals have an average of 55.86°/mm compared to 2-year-olds at 53.42°/mm, 3-year-olds at 53.99°/mm and those older than 4 years at 52.23°/mm.

The reports obtained are supported by research work carried out by: McGregor (2006), Bustinza (2001), Lupton, McColl and Stobart (2006), Ormachea *et al*. (2015), Roque y Ormachea (2018) and Paucar-Chanca *et al*. (2019), who assert that the values of mean fiber diameter in alpacas are lower in the first year of life and significantly increase as the animal ages. Franco *et al*. (2009) mention that a diet with low levels of energy and protein will decrease fiber diameter and length growth. However, there are contrasting studies, such as Bryant *et al*. (1989), who claim that when there is an abundance of natural pasture, fiber thickening occurs due to better nutrition. Furthermore, there are reports indicating that the variation in mean fiber diameter is indirectly influenced by precipitation and pasture availability (Olarte, 2022; Quispe *et al*., 2021). Thus, the presence of fibers with continuous medulla and strongly medullated fibers would affect the variability of fiber diameter in the fleece (McGregor *et al*., 2013).

Regarding the coefficient of variation in the study, values ranging from 20.32% to 21.81% were found. This demonstrates uniformity in the diameter of individual fibers within the fleece and the produced threads will be more resistant and consistent. This is a desirable aspect from the perspective of the textile industry (Frank *et al*., 2006; Lupton, McColl and Stobart, 2006). The results obtained are in line with the reports of Paucar-Chanca *et al*. (2019), who state that there is no statistical difference in the coefficient of variation due to the sex and age of the animals.

The results revealed in the study show that the comfort factor variable decreases as the age of the animal increases, therefore the comfort factor would be inversely related to the fiber diameter in alpacas, which is corroborated by the reports of, McGregor (2006); Ormachea *et al*. (2015); Vásquez *et al*. (2015); Roque and Ormachea (2018). On the other hand, as with other studies, sex did not influence comfort factor (Lupton, McColl and Stobart, 2006; Ormachea *et al*., 2015; Paucar-Chanca *et al*., 2019; Quispe *et al*., 2009).

CONCLUSION

The percentage of medullated fibers, mean fiber diameter, and fiber comfort factor are influenced by age, as a consequence of the number of shearings performed in Huacaya alpacas. However, gender does not influence these characteristics.

Conflict of interest

The authors declare that there are no conflicts of interest.

REFERENCES

Aylan-Parker, J. and McGregor, B.A. (2002). Optimising sampling techniques and estimating sampling variance of fleece quality attributes in alpacas. *Small Ruminant Research*. **44(1):** 53-64. https://doi.org/10.1016/S0921-4488(02)00038-X.

Antonini, M., Gonzales, M. and Valbonesi, A. (2004). Relationship between age and postnatal skin follicular development in three types of South American domestic camelids. *Livestock Prod Sci*. **90:** 241-246.

Aruquipa, M. (2015). [Evaluacion de la calidad de fibra de alpaca Huacaya en dos localidad del municipio de Catacora]. [Departamento de La Paz. Master's Thesis, Universidad Mayor de San Andres. https://repositorio.umsa.bo/handle/123456789/6906.

Bustinza, V. (2001). La Alpaca, conocimiento del gran potencial andino. Universidad Nacional Del Altiplano, Puno, 0, 493.

Bryant, F.C., Florez, A. and Pfister, J. (1989). Sheep and alpaca productivity on high andean rangelands in Peru. *Journal of Animal Science*. **67(11):** 3087-3095. https://doi.org/10.2527/jas1989.67113087x.

Canaza-Cayo, A.W., Beltrán-Barriga, P.A., Quina-Quina, E., Rodríguez-Huanca, F.H., Mota, R.R. and Fernandez-Ruelas, E.P. (2022). Fibre Characteristics of Huacaya Alpaca in Peru. *Indian Journal of Animal Research*. **56(4):** 513-517. doi: 10.18805/IJAR.B-1382.

Cruz, A., Morante, R., Gutiérrez, J.P., Torres, R., Burgos, A. and Cervantes, I. (2019). Genetic parameters for medullated fiber and its relationship with other productive traits in alpacas. *Animal*. **13(7):** 1358-1364. https://doi.org/10.1017/S1751731118003282.

Contreras, A. (2010). [Estructura y caracterısticas fısicas de la fibra de alpaca Huacaya (*Vicugna pacos*) de color blanco. Engineer's Thesis, Universidad Nacional de Huancavelica]

[FAO] Organización de las Naciones Unidas para la Alimentación y la Agricultura. (2005). Situación actual de los camélidos sudamericanos en el Perú. Proyecto de cooperación técnica en apoyo a la crianza y aprovechamiento de los camélidos sudamericanos en la Región Andina. Lima, Perú: FAO. pp. 62.

Franco, F.F., San Martín, F.H., Ara, M.G., Olazabal, J.L. and Carcelén, F.C. (2009). Efecto del nivel alimenticio sobre el rendimiento y calidad de fibra en alpacas. *Revista de Investigaciones Veterinarias Del Perú*. **20(2):** 187-195. https://doi.org/10.15381/rivep.v20i2.605.

Frank, E.N., Hick, M.V.H., Castillo, M.F. and Prieto, A. (2014). Fibre-Based Components Determining Handle/Skin Comfort in Fabrics Made from Dehaired and Non Dehaired Llama Fibre. *Int. J. Appl. Sci. Technol*. **4(3):** 51-66. Available online: https: //www.ijastnet.com/journal/index/583 (accessed on 19 December 2021).

Frank, E.N., Hick, M.V.H., Gauna, C.D., Lamas, H.E., Renieri, C., and Antonini, M. (2006). Phenotypic and genetic description of fibre traits in South American domestic camelids (llamas and alpacas). *Small Ruminant Researc*h. **61(2-3 SPEC. ISS.):** 113-129. https://doi.org/10.1016/j.smallrumres.2005.07.003.

IWTO-52 (2006). Conditioning procedures for testing textiles. Int. Wool Textile Organ.

Khan, M., Abbas, A., Ayaz, M., Naeem, M., Akhter, M. and Soomro, M. (2012). Factors affecting wool qualilty and quantity in sheep. *African Journal of Biotechnology*. **11(73):** 13761-13766.

Lalit, Malik, Z.S., Dalal, D.S., Patil, C.S. and Dahiya, S.P. (2017). Genetic studies on growth, reproduction and wool production traits in Harnali sheep. *Indian Journal of Animal Research*. **51(5):** 813-816. doi: 10.18805/ijar.10984.

Lupton, C.J., McColl, A. and Stobart, R.H. (2006). Fiber characteristics of the Huacaya Alpaca. *Small Ruminant Research*. **64(3):** 211-224. https://doi.org/10.1016/j.smallrumres.2005.04.023.

Mamani-Cato, R.H., Frank, E.N., Prieto, A., Castillo, M.F., Condori-Rojas, N. and Hick, M.V.H. (2022). Effect of fibre diameter, prickle factor and coarse fibre bias on yarn surface hairiness in South American Camelids (SAC) *Fibre. Fibers*. **10(2)**. https://doi.org/10.3390/fib10020018.

McGregor, B. (2012). Properties, processing and performance of rare natural animal fibres. *Rural Industries Research and Development Corporation. RIRDC Publication*. pp. 103. https://dro.deakin.edu.au/view/DU:30051117.

McGregor, B.A., Naebe, M., Stanton, J., Speijers, J., Beilby, J., Pieruzzini, S. and Tester, D. (2013). Relationship between wearer prickle response with fibre and garment properties and wool comfort meter assessment. *Journal of the Textile Institute*. **104(6):** 618-627. https://doi.org/10.1080/00405000.2013.780764.

McGregor, B.A. and Butler, K.L. (2004). Contribution of objective and subjective attributes to the variation in commercial value of Australian mohair: Implications for mohair production, genetic improvement and mohair marketing. *Australian Journal of Agricultural Research*. **55(12):** 1283-1298. https://doi.org/10.1071/AR04107.

McGregor, B.A. (2002). Comparative productivity and grazing behaviour of huacaya alpacas and peppin merino sheep grazed on annual pastures. *Small Ruminant Research*. **44(3):** 219-232. https://doi.org/10.1016/S0921-4488(02)00050-0.

McGregor, B.A. (2006). Production, attributes and relative value of alpaca fleeces in southern Australia and implications for industry development. *Small Ruminant Research*. **61(2-3 SPEC.ISS.):** 93-111. https://doi.org/10.1016/j.smallrumres.2005.07.001.

Moore, K.E., Blache, D. and Maloney, S.K. (2011). Fibre diameter and insulation in alpacas: The biophysical implications. *Small Ruminant Research*. **96(2-3):** 165-172. https://doi.org/10.1016/j.smallrumres.2011.01.012.

Ormachea, E., Calsín, B. and Olarte, U. (2015). Características textiles de la fibra en alpacas huacaya del distrito de Corani Carabaya, Puno. *Revista Investigaciones Altoandinas -Journal of High Andean Investigation*. **17(2):** 215. https://doi.org/10.18271/ria.2015.115.

Olarte Daza, C.U. (2022). Efecto de la edad y estado fisiológico reproductivo en el perfil del diámetro de la fibra en alpacas Huacaya. *Revista de Investigaciones Veterinarias Del Perú*. **33(4):** e23336. https://doi.org/10.15381/rivep.v33i4.23336.

Olarte, D., Ceferino, U., Calsin, C., Bilo, Oros, B., Oscar, O. and V., Edwin. (2023). Variación del diámetro y porcentaje de medulación en la fibra de alpacas Huacaya (Vicugna pacos). *Revista de Investigaciones Veterinarias del Perú*. **34(6):** e26957. Epub 31 de diciembre de 2023. https://dx.doi.org/10.15381/rivep.v34i6.26957.

Paucar-Chanca, R., Alfonso-Ruiz, L., Soret-Lafraya, B., Mendoza-Ordoñez, G. and Alvarado-Quezada, F. (2019). Textile characteristics of fiber from Huacaya alpacas (*Vicugna pacos*). *Scientia Agropecuaria*. **10(3):** 429-432. https://doi.org/10.17268/sci.agropecu.2019.03.14.

Pinares, R., Gutiérrez, G.A., Cruz, A., Burgos, A. and Gutiérrez, J.P. (2019). Variabilidad fenotípica del porcentaje de fibras meduladas en el vellón de alpaca Huacaya. *Revista de Investigaciones Veterinarias Del Perú*. **30(2):** 699-708. https://doi.org/10.15381/rivep.v30i2.16098.

Pinares, R., Gutiérrez, G.A., Cruz, A., Morante, R., Cervantes, I., Burgos, A. and Gutiérrez, J.P. (2018). Heritability of individual fiber medullation in Peruvian alpacas. *Small Ruminant Research*. **165:** 93-100. https://doi.org/10.1016/j.smallrumres.2018.04.007.

Quispe Coaquira, J.E., Apaza Zúñiga, E. and Olarte Daza, C.U. (2021). Características físicas y perfil de diámetro de fibra de alpacas Huacaya del Centro Experimental La Raya (Puno, Perú), según edad y sexo. *Revista de Investigaciones Veterinarias Del Perú*. **32(2):** e20004. https://doi.org/10.15381/rivep.v32i2.20004.

Quispe, E.C., Alfonso, L., Flores, A., Guillén, H. and Ramos, Y. (2009). Bases to an improvement program of the alpacas in highland region at Huancavelica-Peru. *Archivos de Zootecnia*. **58(224):** 705-716. https://doi.org/10.21071/az.v58i224.5060

Quispe, E., Quispe, M., Quispe, C., Poma, A., Paucar-Chanca, R., Cruz, A. and McGregor, B.A. (2022). Relationships between the incidence and degree of medullation with the diameter of alpaca fibers evaluated using a novel device based on artificial intelligence. *Journal of the Textile Institute*. https://doi.org/10.1080/00405000.2022.2105110.

Radzik, A., Pofelska, O. and Rant, W. (2018). Characteristics of alpaca wool from farmed animals located on differente continents. *Annals of Warsaw University of Life Sciences - SGGW - Animal Science*. **57(2):** 151-158. https://doi.org/10.22630/aas.2018.57.2.15.

Radzik-Rant, A. and Wierciñska, K. (2021). Analysis of the wool thickness and medullation characteristics based on sex and color in a herd of alpacas in Poland. *Arch. Anim. Breed*. **64:** 157-165. https://doi: 10.5194/aab-64-157-2021.

Roque, Gonzales, L.A. and Ormachea, Valdez, E. (2018). Características productivas y textiles de la fibra en alpacas huacaya de Puno, Perú. R*evista de Investigaciones Veterinarias Del Perú*. **29(4):** 1325-1334. https://doi.org/10.15381/rivep.v29i4.14117.

R Core Team (2021). R: A language and environment for statistical computing (Vienna, Austria: R Foundation for Statistical Computing). Available at: http://www.R-project.org/.

Vásquez, O.R., Gómez-Quispe, O. and Quispe, P.E. (2015). Características Tecnológicas de la fibra blanca de Alpaca Huacaya en la zona Altoandina de Apurímac. *Revista de Investigaciones Veterinarias Del Perú*. **26(2):** 213. https://doi.org/10.15381/rivep.v26i2.11020.

Wang, Wabg, L. and Liu, X. (2003). The quality and processing performance of alpaca fibres. *RIRDC*, *3*(RIRDC publication no 03/128), 128. Retrieved from http://www.rirdc.gov.au.

Wang, H., Liu, X. and Wang, X. (2005). Internal structure and pigment granules in colored alpaca fibers. *Fibers and Polymers*. **6(3):** 263-268. https://doi.org/10.1007/BF02875652.

Wuliji, T., Davis, G.H., Dodds, K.G., Turner, P.R. andrews, R.N. and Bruce, G.D. (2000). Production performance, repeatability and heritability estimates for live weight, fleece weight and fiber characteristics of alpacas in New Zealand. *Small Ruminant Research*. **37(3):** 189-201. https://doi.org/10.1016/S0921-4488(00)00127-9.