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The Prickle Effect Comes From Fabrics Made of South American Camelid (Alpaca and Lama) Fibers. Mechanical and/or Genetic Solutions. A Review

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ABSTRACT

In this paper we intends to analyze the physical attributes that determine the comfort of fabrics made of South American Camelid fibers (Lama and Alpaca), the effect on their value and their possible mechanical and/or genetic solutions. While emphasis has always been on mean fiber diameter, the fiber frequency exceeding 30 microns has a key role in quality. This is essential for light fabrics, where the effect of prickle plays a critical part in consumer´s choice. Yet the genetic solution of the problem lies in the slow selection response. Dehairing provides an immediate solution, though excessive fiber breakage should be addressed. It is concluded that the textile fiber quality of South American Camelids is promissory if the presence of objectionable fibers is solved, resulting in a tolerable frequency for consumers (<3%). This process could be explored via genetic selection or applying dehairing

technology. This implies a true paradigm shift with regard to the classic textile processing of Alpaca and Lama fibers. This would enhance the fiber softness to touch, together with other important features that would render the fiber price more competitive.

Keywords: Camelid fiber, prickling, dehairing, breeding, new approach

INTRODUCTION

The textile fiber group to which Camelids belong is more commonly known as luxury fibers. The main attributes and characteristics that give a particular added value to these fibers have been summarized in the subjective variables of softness and brightness [1].

The diameter of the fiber is the attribute with the greatest weight when it comes to determining the price of the fiber, given its relation with softness or 'hand' [2]. Nonetheless, consumers have little direct interest in the properties or attributes of the fiber, being the subjective quality of the fabric what mainly determines their opinion on the various fibers [3]. The textile scientist, on the other hand, needs to understand the contribution of fiber attributes to such quality assessment [4].

Quality can be defined from a final consumer perspective by the 'hand' in order to indicate the relationship of quality to the degree of fabric acceptance. This term has been defined as the subjective assessment of a textile material obtained from the sense of touch. It is also a psychological phenomenon that involves the fingers, on the one hand, in order to be able to make a sensible and demanding evaluation and the mind, on the other, to integrate and express the results in a value judgment. It is common to define the 'hand' of a fabric as the mean of the scores of a certain number of observers or panelists, or these same differences become an important attribute to evaluate it [4]. The concept of hand encompasses several attributes: comfort on the skin (itching), stiffness, bulkiness, smoothness and softness [5]. The notion of prickle (itching) applies to garments used in contact with the skin (directly or indirectly), placed on the forearm or pressed with the palm of the hand and fingers when the garment is purchased [6]. The fibers of domestic Camelids is seriously compromised, from a commercial standpoint, by this feature [7].

Several studies have shown that pruritus or prickle sensation comes from the coarser fibers of the right tail of the distribution of fiber diameter (´coarse edge´) [8] [9]. The last author also determined that the percentage of fibers over 30 μm is a good predictor of itching sensation in knitted fabrics and still much more pronounced in weaving.

Moreover, it should be considered, that not only the diameter is a determining factor for a fiber to cause prickle, but also its stiffness, which is crucial and is influenced by the type of medulla of the fiber [10]. Even though emphasis has historically been placed on the percentage of fibers over 30 microns to induce itching, a recent study reports that much finer fibers (20 microns) may trigger the response if the free length of the protruding fiber on the surface of the fabric is sufficiently short [11].

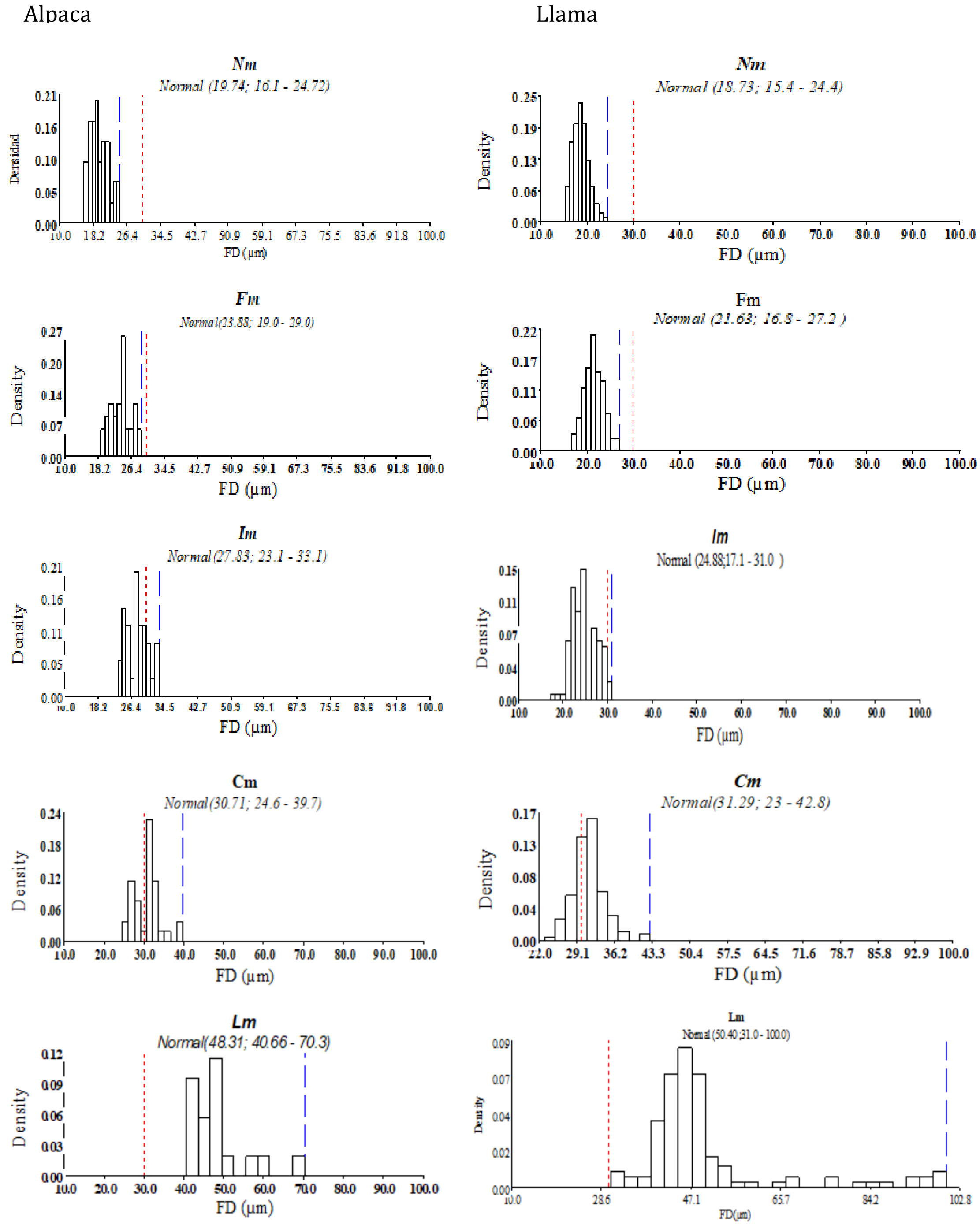
Specialty animal fibers, which are obtained from angora goats, angora rabbits, cashmere goats, and alpacas, are used to test textile desirable properties, such as softness, luster, and comfort characteristics. The results show that silk/viscose, angora/viscose, and 100% viscose fabrics are the smoothest, softest, and least prickly, while alpaca/viscose and mohair/viscose fabrics are found to be the roughest, stiffest, and most prickly surfaces according to the objective and subjective results. In the case of fabrics including 100% animal fibers, angora, cashmere, and silk fabrics are the smoothest, softest, and least prickly fabrics. However, mohair and alpaca fabrics are comparatively rougher, stiffer, and pricklier [12].

The aim of this paper is to analyze the critical physical characteristics that determine the comfort of fabrics made with Camelids fibers, the effect on its value and possible mechanical and/or genetic modification.

DIAMETER DISTRIBUTION, FIBER TYPE AND QUALITY

Fiber diameter distribution is key to determining quality, due to the effect on the appearance and comfort of the product (Holcombe, 1986) and the effect on the behavior of the fiber during textile processing [13] [14] [15].

Figure 1 illustrates the diameter distribution into the different Alpaca and Llama fiber types and the composition of the 'coarse edge' (the vertical red line shows 30 μm) almost exclusively due to the diameters of the fibers with lattice medulla and in almost half the cases to the continuous medulla [16]. The diameter is very close related between Alpaca and Llama species, within the different type of fiber identified by type o medulla.



30 µm:--------; >95 % UL: -----------
under confident limit 95%

SOURCE: Frank et al., 2012

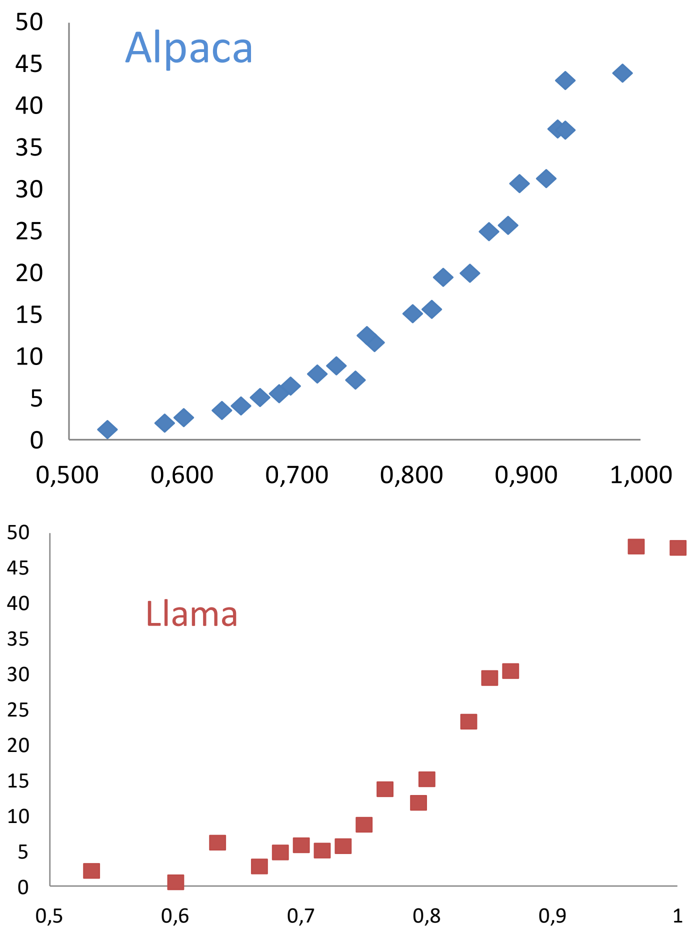
Figure 1: Histogram with Normal distribution of fiber diameter form different type of fiber defined by the type of medulla. Nm: non-medullated, Fm: fragmented medulla, Im: interrupted medulla, Cm: Continuous medulla, Lm: lattice medulla.

In addition, the differentiable appearance of these fibers with respect to the others has led to the designation of objectionable fibers or observable fibers [17] [18].

Diameter distribution both in Llamas and in Alpacas follows a biphasic pattern. This can be visually noticed depending on the types of fleece, with greater or lesser intensity in Llama fiber [19] and equally in Alpaca Huacaya fiber, even in the finest one [20]. A non-normal distribution of diameter is also showed in South American Camelids fibers as on wool fiber distribution [21.

The relationship between mean fiber diameter (DMF) and fiber percentage >30 μm (PcF) is a curvilinear potential fitting and responds in Alpaca to: Pcf=56.38*(DMF/30)6.0, R^2 =0.98 and in Llama to: Pcf= 53.6*(DMF/30)6.13, R2=0.89 [21] (see Figure 2).

It has been confirmed that the difference of Alpaca fiber in 'hand' with respect to wool means that 27 μm Alpaca is as soft as 15 μm wool [22]. A more recent research work takes reduce this value to 8.5 microns [23], which is equivalent to a 26 μm alpaca fiber diameter to 18.5 μm of wool diameter.



SOURCE: Frank et al., 2012

Figure 2: Potential relationship between prickle factor (Pcf) on fiber diameter/30 μm (DMF/30) in Alpaca and Llama fiber.

DEFINITION AND SOLUTION OF PRICKLE EFFECT OR ITCHING

The itching effect is directly correlated to Euler's theory of the bending or 'buckling' of a beam or wire, according to which the buckling force of a round structure is equal to the Young's modulus multiplied by the diameter to the fourth and divided by the length to the square grade, being independent of the type of fiber used (natural or artificial) [9]. Since most of the protruding fibers of the yarn/fabric do so in an angle lesser than straight, the assumption that the fiber actually bends laterally to contact the skin should be made. Then Euler's formula is slightly modified by raising the length of the fiber to the cube grade [24]. It has been verified that the stiffness modulus (Young) is higher in Camelids than in wool. Therefore it is expected that the load or force to achieve the fiber should be higher or the diameter smaller [25]. When Pcr=75 mgf, the results of fiber diameter calculations for different individual fiber lengths and Young's modulus values of alpaca fibers [26] are listed in Table 1.

Table 1: Critical Fiber diameter expected to achieve force or load (75 mgf) buckling or bending individual fiber for prickly perception in Camelids fiber.

	Buckling	Bending
Length of evoked fiber	DM p/prickle	DM p/prickle
1 mm	18.9 – 20.3	-
2 mm	26.8 – 28.9	31,9 – 34,4
3 mm	32.8 – 35.4	43.1 – 46.6
Overall fiber diameter (μm)	28.3	29.97

SOURCES: Frank et al., 2019

This effect is determined more by the structure of the protruding tips of the yarn or fabric than by the total yarn, although in general, this is determined with high accuracy by the mean diameter and the diameter dispersion in the total yarn [5]. The average diameter of the protruding fibers is 2 - 3 μm larger than that of the yarn [27] [28].

If the problem of the pruriginous effect lies in the coarse edge of the diameter distribution, two possible solutions are identified: decreasing the mean diameter (leftward shift of the normal curve with corresponding coarse-edge shift) or the range of distribution of fiber diameters (move leftwards the coarse edge leaving the mean unchanged) [29]. The latter could be achieved by dehairing or genetic selection. There is anecdotal information for the former and experimental data for the latter [16]. However, it seems that fineness alone would not correct the itching effect [21].

Hand-dehairing has demonstrated its feasibility [30], although the process is only efficient with double coated and intermediate coated fleece [31]. However, a recent work has shown that per person and per hour yield is 9.9±1.1 g/person/h, which renders it economically unviable [32].

Dehairing or separation of different fiber types by mechanical means is the alternative to be analyzed [33]. The results of South American Camelids fiber dehairing as compared to cashmere (a more studied fiber) are listed in Tables 2 [34]. The reduction of the prickle factor (expressed as undesirable coarse fiber, FG) is accompanied by a reduction in fiber length. The reduction of undesirable fibers in successive passes accounts for 30 - 50% reduction in both Alpaca and Llama.

Table 2: Mean Comparisons of reducing coarse fibers (FG) in relation to the species of origin of the fiber.

Type of fibre	FG%	EE %		LFF	EE		DMFF	EE		DFT	EE	
Alpaca	-36.6	11.3	b	-54.4	4.4	a	0.6	1.5	a	15.2	0.9	c
Cashmere	-95.3	23.1	a	-50.0	8.9	a	-8.8	1.9	a	-54.9	2.3	a
Guanaco	-74.6	19.1	a	-20.2	7.7	b	4.8	3.5	a	1.3	4.0	c
Llama	-44.6	7.8	b	-53.1	3.0	a	-0.3	0.3	a	-7.2	0.5	b

Different letters in the same column are statistically different ($p < 0.05$)

References: FG% coarse fibre percentage; LFF: fine fibre length; DMFF: fine fibre diameter; DFT: overall fibre diameter; EE: standard error.

SOURCES: Frank et al., (2009)

After an Alpaca fiber dehairing assay conducted in Australia, it was concluded that only a relatively small amount of coarse fibers could be eliminated. In addition, dehairing considerably shortens the length of alpaca fiber. Therefore, it is unlikely that dehairing alpaca fiber is a viable practice if the only goal is to reduce the diameter of the fiber and this is only useful to reclassify dehaired fiber as a finer line. The actual benefit of dehairing should be to improve the quality of the final products of alpaca [26]. A recent trial with dehairing alpaca top has yielded better results, in objectionable fiber w/w of 2.2% in 6th runs (-55.5%; Nº/weight: 0.16 (-50%) ; Fiber of > 30 μm:3.6% (a reduction of 60%) was obtained [35].

GENETIC DETERMINATION OF FIBER DIAMETER COMPONENTS

Even though there is a possibility of reducing the distribution via selection [36], this reduction would not be guaranteed by the reduction of the mean diameter [16] [21].

Table 3 shows the heritability of the diameter components of the fiber types that are identified by the type of medulla. Additionally components are correlated with average fiber diameter and coefficient of diameter variation, both vital statistical parameters to describe the quality that consumers appreciate the most. The conclusions drawn indicate that there are unfavorable correlations between the coefficient of variation and the diameter of non-medulated fibers, and fragmented and continuous fibers, being the heritability of high frequency and diameter of fibers mid to very high and null to low the heritability of diameter variation of the fiber types [16]. This would indicate the possibility of selecting by fiber type, achieving a reduction of the average diameter as well as of the variation coefficient of the diameter, though not in a separated way but simultaneously by unfavorable correlations. There would also be the possibility of selecting from these parameters depending on the capacity of 'dehairablity', seeking ratios of diameter and frequency of the types of fibers more suitable for this purpose.

Table 3: Means, phenotypic and genetic correlations and heritability of mean fibre diameter, mean fiber diameter coefficient of variation and its component variables

		Phenotypic correlations		Genetic correlations		h^2
Coef. Var.	Mean ±SE	AFD	AFDCV	AFD	AFDCV	
AFD	12.7 ±0.01	-0,05	0.07**	0.001	0.001	0.028
FFD	13.4 ±0.10	0.008	0.06*	0.002	0.008	0.005
IFD	13.3±0.14	0.05	0.02	0.001	0.003	0.000
CFD	16.8±0.14	0.05	0.42***	0.003	0.05	0.11
LFD	12.0±0.22	0.27***	0.25***	0.08	0.02	0.22
Fiber diameter						
AFD	21.3±0.01	0.37***	-0,37***	0.79	-037	0.21
FFD	25.0±0.10	0.35***	-0.31***	0.82	-0.37	0.31
IFD	28.5±0.11	0.21***	-0.27***	0.39	-0.09	0.43
CFD	34.6±0.12	0.31***	-0.11***	0.51	-0.47	0.49
LFD	51.0±0.31	0.30***	0.42***	0.50	0.83	0.77
Fibre freq.						
AFF	36.2±0.6	-0.6***	-0.03	-0.8	-0.32	0.33
FFF	22.1±0.3	0.3***	-0.05	-0.92	-0.26	0.02
IFF	13.1±0.2	0.2***	-0.03	0.46	0.30	0.27
CFF	23.8±0.4	0.7***	-0.01	0.76	0.17	0.38
LFF	4.9±0.2	0.6***	0.3***	0.85	0.84	0.39
Overall variables						
AFD	0,27±0.2	-	0.07***	0.43	-	0.53
AFDCV	29.2±0.2	0.07***	-	-	0.43	0.42

References: AFD; amedulated fibre ; FFD: fragmented medulla fibre; IFD: interrupted medulla fibre; CFD: continuous medulla fiber; LFD: lattice medulla fibre.
SOURCE: Frank et al. (2008)

The heritability's for percentage of medulation and medulated fiber diameter obtained in Peruvian Alpacas, were 0.225 and 0.237 in Huacaya genotype and 0.664 and 0.237 in Suri type, respectively. The genetic correlations between percentage of medulation and between mean fiber diameter and medulated fiber diameter were high and favorable in both genetic types, between 0.531 and 0.975. The genetic correlation between medulation and medulation diameter was 0.121 in Huacaya and 0.427 in Suri. The repeatabilities were 0.556 and 0.668, and 0.322 and 0.293 in Huacaya and Suri genotypes, respectively [37].

The Selection Indices methodology simulates the effects of using several variables at once in relation to production and fiber quality, including the possibility of improving fiber 'dehairablity'. This has been explored applying the Lama parameters by Frank et al., (2008) [16], yielding a possible decrease of 0.7%/year of objectionable fiber if the constant average fiber diameter [38], were maintained in Table 4. However, in a recent study (Figure 3) negative genetic correlations between the fiber diameter of the fiber of the primary/secondary follicle, with overall fiber diameter (Frank, E.N. unpublished data) were obtained.

Table 4: Response to selection (R) per generation (gen), per year or per 10 year (10yr.) for fibre variables components

Variables	RxGen	Rxyear	Rx10yr.
AFD	-3.4	-0.8	-8.2
AFDCV	-1.9	-0.5	-4.6
AFD	-0.3	-0.1	-0.8
AFF	8.2	2.0	19.8
IFD	0.1	0.0	0.2
IFF	-1.3	-0.3	-3.1
CFD	-0.6	-0.1	-1.5
CFF	-5.6	-1.3	-13.3
LFD	-6.4	-1.5	-15.5
LFF	-2.8	-0.7	-6.8

References: : AFD; amedulated fibre ;FFD: fragmented medulla fibre ; IFD: interrupted medulla fibre; CFD: continuous medulla fiber; LFD: lattice medulla fibre.
SOURCES: Frank (2015)

The response per generation and response per years should not be interpreted with the unit of measurement of the variable, but as response in ARpesos ($). Given the absence of rational relative economic values assigned to each variable only a relative value of the response can be given, lattice medulla diameter (LFD) would be reduced almost 2 times in relation to the non-medulated fiber diameter (AFD) (-15.5 / -8.2 = 1.89) and so on with the other variables. A good genetic response, but only an 8.2% reduction in ten years it is not such an auspicious matter if you plan to reach the level of thick fibers identified by the panelists [10].

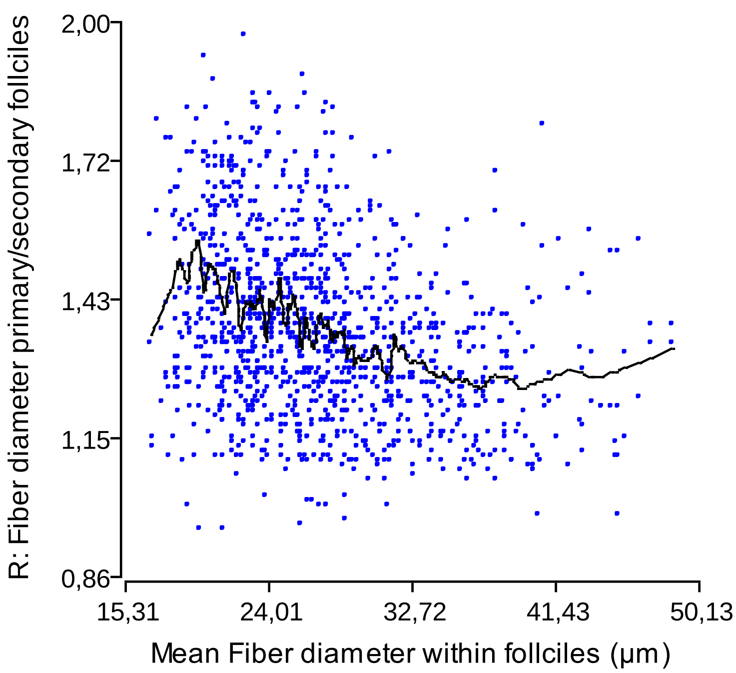


Figure 3: Relationship between fiber diameter into primay/seconday follicle ratio on mean fiber diameter measured into all follicle

It is clear that the relationship between expected progeny deviations (EPD´s) of primary fiber diameter/secondary fiber diameter (Pfd/Sfd) ratio on mean fiber diameter in Argentine Lamas skin sections is negative and of medium magnitude. It would imply that the reduction of the total fiber diameter would lead to an increase or maintenance of the primary/secondary diameter high ratio. This refutes the favorable response estimated previously from fiber genetic parameters by Pinares et al. (2018) [39].

CONCLUSIONS AND IMPLICATIONS

The textile fiber quality of South American Camelids appears highly promising provided the presence of undesirable or objectionable fibers, leading to a tolerable frequency by consumers of <3% is solved. This process could be explored by way of genetic selection, by applying dehairing technology or a combination of both.

Nonetheless, this implies a true paradigm shift with respect to the classic textile fiber processing of Alpaca and Llama, leading to the implementation of carding textile technology (woolen) or short fiber cotton processing.

This would translate into greater softness to the touch ('hand') and other important characteristics that would turn the value of this fiber competitive with respect to other luxurious fibers better known in the market, such as cashmere.

As an implication of this Review it can be stated that the genetic change seems very slow to solve the current alpacas and llamas fiber profitability problem for both Peruvian and Argentine growers, indicating that the application of dehairing technology could be a solution in the meantime.

Referencies

[1] Watkins, P. and Buxton, A. (1992). Luxury fibres-rare materials for higher added value. The Economist Intelligence Unit Special Report No. 2633. Business International, London.

[2] von Bergen, W. 1969. Wool Handbook, Interscience Publishers, New York, Vol. 2, Part 1, 380 p.

[3] Mack Swinburn, D.J., Laing, R.M., & Niven, B.E., 1995. Development of Alpaca and Alpaca/wool blend knitwear fabrics. In Proceedings of the 9th International Wool Textile Research Conference on fine animal fibres sec. (Vol. 2, pp. 536–544).

[4] Naylor, G.R.S. and D.G. Phillips, 1997. Fabric-Evoked Prickle in Worsted Spun Single Jersey Fabrics. Part III: Wear Trial Studies of absolute fabric acceptability. Textile Res. J.; 67: 413 - 416.

[5] De Boos, A.G., Naylor, G.R., Slota, I.J. & J. Stanton, 2002. The effect of the Diameter Characteristics of the Fibre Ends on the Skin Comfort and Handle of Knitted Wool Fabrics. Wool Tech. Sheep Breed., 50: 110 – 120.

[6] Frank, E.N., M.V.H. Hick and O. Adot 2010. Descriptive differential attributes of Llama fleece types and its textile consequence. 2- Consequences from dehairing processes. The Journal of the Textile Institute, 102(1) 41-49.

[7] Vallely, P., 2010. Premium fibre: Taking alpacas to the next level ´being at the crossroads´ is a cliché used far too often. Alpacas Aus.; 60: 44 - 45.

[8] Garnsworthy, R. K., Gully, R.L., Kandiah, R.P., Kenins, P., Mayfield, R.J. and R.A. Westerman, 1988. Understanding the causes of prickle and itch from skin contact of fabrics. CSIRO Division of Wool Technology Report G4. www.tft.csiro.au

[9] Naylor, G.R.S., 1992a. The relationship between the Fibre Diameter distributions of wool top, fibre ends and yarn surface fibres. Wool Tech. Sheep Breed., 40: 40 - 43.

[10] Frank E.N., Hick M.V.H., Castillo M.F., Prieto, A and O. Adot, 2014. Fibre-Based Components Determining Handle/Skin Comfort in Fabrics Made from Dehaired and Non Dehaired Llama Fibre. International Journal of Applied Science and Technology, 4, (3):51 – 66.

[11] Naebe, M., McGregor, B. A., Swan, P., & Tester, D. 2015. Associations between the physiological basis of fabric-evoked prickle, fiber and yarn characteristics and the Wool ComfortMeter value. Textile Research Journal, 85(11), 1122-1130.

[12] Süpüren Mengüç, G., Özdil, N. and L. Hes, (2015). Prickle and handle properties of fabrics produced from specialty animal fibers. Textile Research Journal, 85(6): 561 – 670.

[13] Burgman, V.D., 1965. Progress in textile Physics. Wool Tech. Sheep Breed., 12: 9 – 28

[14] Mayo, O., Crook, B., Lax, J., Swan, A. and T.W. Hancock, 1994. The determination of Fibre Diameter Distribution. Wool Tech. Sheep Breed., 42 (De Boos et al.,2002), 231-236.

[15] Bow, M.R., Hansford, K.A., Naylor, G.R.S., Phillips, D.G., Piper, L.R. and Rottenbury, R.A., 1992. Specification for Marketing. In: The Significance of Fibre Diameter Distribution to the Wool Industry. Textile and Fibre Technology www.tft.csiro.au

[16] Frank, E.N., Hick, MH.V., Molina, M.G., Prieto, A. y Castillo, M.F.2008. Correlaciones genéticas, fenotípicas y heredabilidades de los componentes del diámetro de la fibra en llamas [Genetic, phenotypic correlations and heritabilities of the fiber diameter components of llama fibre]. 31º Cong. Arg. Prod. Anim. (summary).

[17] Smuts, S. & Hunter, L. 1987. Medulation in Mohair. Part II: Geometrics and the relationship between various measures of Medulation, SAWTRI Tech. Report Nº 508.

[18] Balasingam, A. 2005. The Definitions of Medullation Threshold Values used by Different Testing Methods to define an Objectionable Medullated Fibre in Merino Wool. In: Aust. Wool Innovation Proj. EC651, 32pp.

[19] Frank, E.N., Hick, M.V.H. and Adot, O. 2007. Descriptive differential attributes of type of fleeces in Llama fiber and its textile consequence. 1-Descriptive aspects. The Journal of the Textile Institute 98: 251-259.

[20] Davison, I.M. Fleece factors. Alpacas Aust. 2010, 12 - 14.

[21] Frank E.N., Adot, O.G. Hick, M.V.H.., Prieto, A. y Castillo, M.F.2012. Relación entre el diámetro de la fibra y el factor de picazón en alpaca y llama. [Relationship between fiber diameter and prickle factor in alpaca and llama].In: IV Cong. Inter.Cam. Sud, Arica, Chile.

[22] Wang, X., Wang, L. and X. Liu, 2003. The Quality and Processing Performance of Alpaca Fibres. RIRDC publication Nº 03/128: 66 – 76.

[23] Hillbrick, L. K., 2012. Fibre Properties affecting the Softness of Wool and other Keratins. Doctoral Thesis Deakin University, 254 pp.

[24] Ramsay, D.J., Fox, D.B. and G.R.S. Naylor. An instrument for assessing fabric prickle propensity. Text. Res. J. 2012, 82: 513 - 520.

[25] Liú, X., Hurren, C.J. and X. Wang, 2005. A comparative study of the mechanical properties of Wool and Alpaca fibres. In: 11th Textile Wool Res. Conf. (proc.): 72 (Summary).

[26] Wang, L, Singh A. and X. Wang, 2008. Dehairing Australian alpaca fibres with a cashmere dehairing machine. Journal of the Textile Institute, vol. 99 (6): 539-544.

[27] Naylor, G.R.S., 1992b. The role of coarse fibres in fabric prickle using blended acrylic fibres of different diameters. Wool Tech. Sheep Breed., 40: 14 – 18.

[28] Anonymous, 2012 – Non published Llama fibre data from program SUPPRAD, Córdoba, Argentina.

[29] Naylor, G.R.S., Phillips, D.G. and C.J. Veitch, 1995. The Relative importance of Mean Diameter and Coefficient of Variation of sale lots in determining the potential Skin Comfort of Wool fabrics. Wool Tech. Sheep Breed., 43(von Bergen, 1969): 69 – 82.

[30] Cochi, N., 1999. Determinación del rendimiento y calidad de la fibra descerdada de llamas (Lama glama). [Hairing yield and quality in llamas (Lama glama)]. Tesis de Ingeniero Agrónomo. La Paz. Bolivia: Univ. Mayor de San Andrés. 120 p.

[31] Frank, E.N., 2001. Descripción y Análisis de segregación de fenotipos de color y tipos de vellón en Llamas argentinas [Description and Segregations Analysis of color and type of fleeces phenotypes in argentine Llamas]. Tesis doctoral. Universidad de Buenos Aires (UBA) [PhD Dissertation], Argentina.

[32] Quispe, E.C., Chipa, L., Pinares, R. 2015. Análisis económico y de la producción del descerdado manual de la fibra de llamas (Lama glama) Chaku. llamas [Economical and Productivity analysis of hand-dehaitring of Llama Chaku fibre]. Archivos de Zootecnia, 64 (246): 191-198.

[33] Batten, G., 2003. Goat Cashmere. Producing the finest fibre from New Zealand goats. New Zealand Cashmere Association. 68pp.

[34] Frank, E.N., Seghetti Frondizi, D.G., Hick, M.V.H., Castillo, M.F. 2019. Results of Dehairing Process on Alpaca Fibres with a New Dehairing Technology. International Journal of Polymer and Textile Engineering (SSRG-IJPTE), 6 (1): 1-3

[35] Frank, E.N., Hick, M.V.H., Prieto, A. y Castillo, M.F.2009. Efectos del descerdado sobre la calidad de la fibra obtenida de camélidos sudamericanos y cabra criolla patagónica [Dehairing effects on fibre quality of fibre obtained from south american camelids and patagonian creole goats]. En: 32º Cong. Arg. Prod. Anim. (summary). Revista Argentina de Producción Animal Vol 29 Supl. 1: 134-135.

[36] Taylor, P.J. and Atkins, K.D., 1997. Genetically improving fleece weight and fibre diameter of the Australian Merino — The Trangie QPLU$ Project, Wool Technology and Sheep Breeding 45, 92-94.

[37] Cruz, A., R. Morante, J. P. Gutiérrez , R. Torres , A. Burgos and I. Cervantes, 2018. Genetic parameters for medullated fiber and its relationship with other productive traits in alpacas. Animal, 13(7): 1358-1364.

[38] Frank, E. N., 2015. El problema de la picazón en telas de fibras de Camélidos Sudamericanos. 2 . Bases y parámetros genéticos. [Prickle factor problem in South American Camelids fiber fabrics] Simposio Inter. de prod. de fibra. Univ. Nac. Micaela Bastidas, Abancay, Perú.

[39] Pinares R, Gutiérrez GA, Cruz A, Morante R, Cervantes I, Burgos A, Gutiérrez JP. 2018. Heritability of individual fiber medullation in Peruvian alpacas. Small Ruminant Res 165: 93- 100.