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The Problem of Prickling on Fabrics of South American Camelids Fibers: Possible Approaches for Mechanical Solutions

E. N. Frank[1,2*], M. H. V. Hick[1,2] and L. A. Riva de Neyra[2]

[1]*SUPPRAD Program, IRNASUS – CONICET-UCC, Córdoba, Argentina.*
[2]*UCHA – Universidad Nacional de La Rioja, Sede Chamical, La Rioja, Argentina.*

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this minireview it is to analyze the physical attributes that determine the comfort of fabrics made of South American Camelid fibers (Lama and Alpaca), discuss the effect on their textile value and evaluate an possible approache on their possible mechanical solutions. Taking the distribution of all fibers do not respond to a normal distribution, but the different fiber types identified by the type of medulla, they do respond to a normal distribution. While emphasis has always been on mean fiber diameter, the fiber frequency exceeding 30 microns (objectionable fibres) 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. Dehairing, as a mechanical way, 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 implies a true paradigm shift with regard to the classic textile processing of Alpaca and Lama fibers (from worsted to woolen system). This would enhance the fiber softness to touch, together with other important features that would render the fiber price more competitive.

**Corresponding author: E-mail: frank.agro@ucc.edu.ar, frank-agro@ucc.edu.ar;*

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1. 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. The textile scientist, on the other hand, needs to understand the contribution of fiber attributes to such quality assessment [3].

Quality can be defined from a final consumer perspective by '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 [3]. The concept of hand encompasses several attributes: Comfort on the skin (itching), stiffness, bulkiness, smoothness and softness [4]. 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 [5]. The fibers of domestic Camelids is seriously compromised, from a commercial standpoint, by this feature [6].

Several studies have shown that itching sensation comes from the coarser fibers of the right tail of the distribution of fiber diameter (´coarse edge´) [7,8]. [9] 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/llamas, 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 minireview is to analyze the physical characteristics that determine the comfort of fabrics made with Camelids fibers, discuss the effect on its value and evaluate an possible approaches on possible mechanical modification by dehairing.

2. 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 and the effect on the behavior of the fiber during textile processing [13].

Fig. 1 illustrates the diameter distribution in the different fiber types and the composition of the 'coarse edge' (the vertical 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 [15]. Overall fibre diameter distribution non depicted as normal [16].

Taking the distribution of all fibers do not respond to a normal distribution, but the different fiber types identified by the type of medulla, they do respond to a normal distribution (see Fig. 1A).

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].

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

It has been confirmed that the difference of Alpaca fiber in 'hand' with respect to wool is 12 µm less. This means that 27 µm Alpaca is as soft as 15 µm wool [22]. A more recent research work takes this value to 8.5 microns [23], which is equivalent to 18.5 micron wool.

3. DEFINITION AND SOLUTION OF PRICKLE EFFECT OR ITCHING

[9] states that the itching effect is directly correlated to Euler's theory of the bending or 'buckling' of a beam or wire, according to which

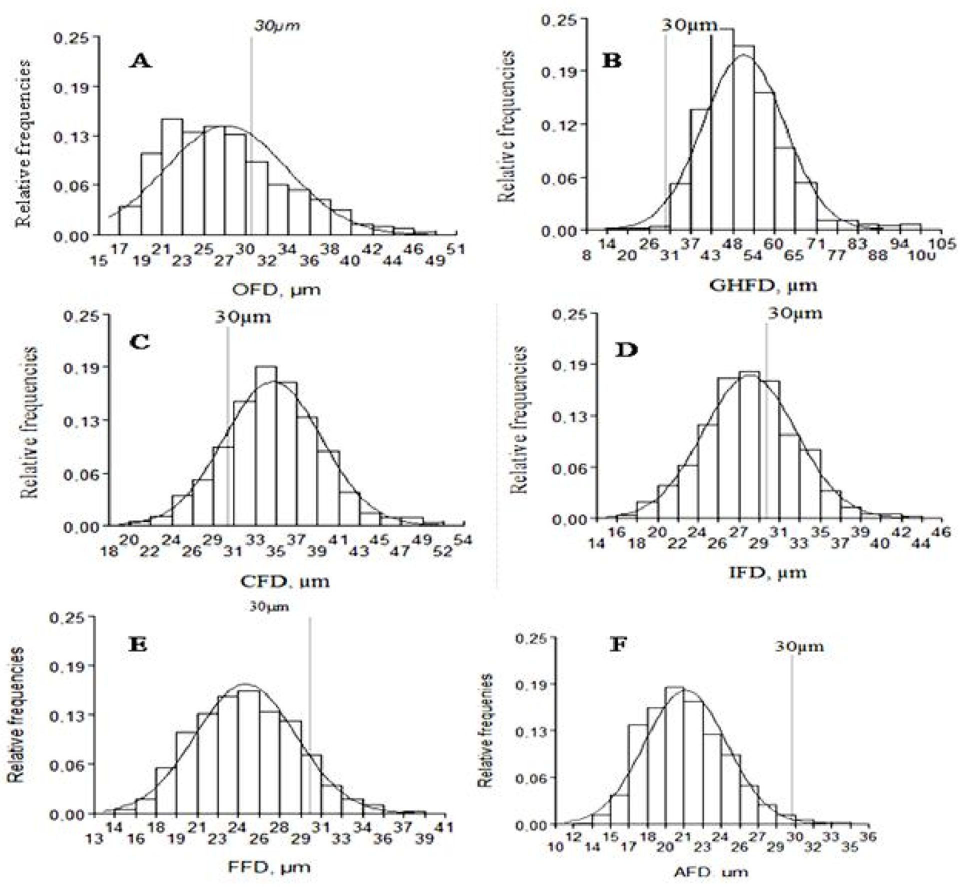


Fig. 1. Histogram with normal distribution of fibre diameter from different type of fibre defined by type of medulla. A: overall fibre diameter (OFD), B: Guard hair fibre diameter (GHFD), C: Continuous fibre diameter (CFD), D: Interrupted fibre diameter (IFD), E: Fragmented fibre diameter (FFD), F: Amedulated fibre diameter (ADF).

Sources: Frank, 2012 (no pub.) [14]

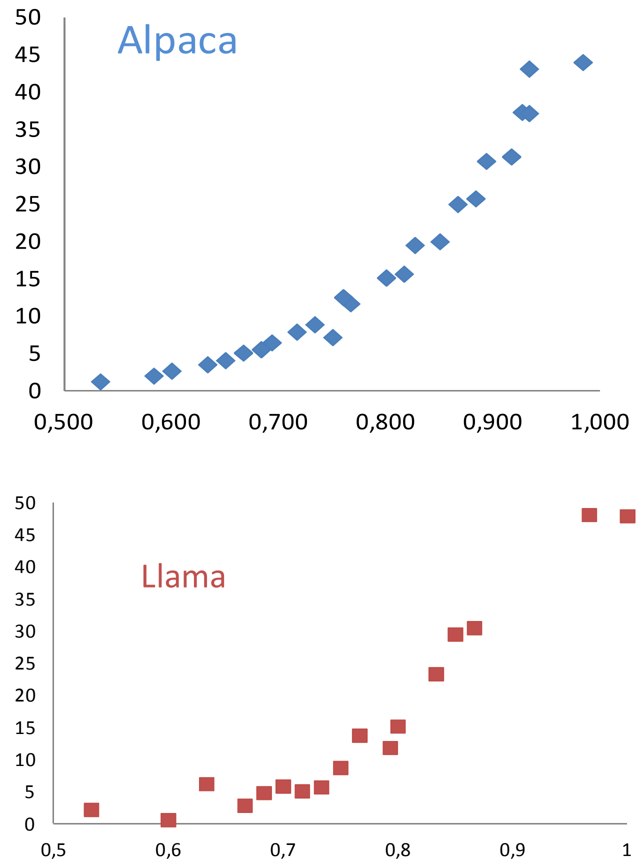


Fig. 2. Potential relationship between prickle factor (Pcf) on fibre diameter/30 µm (DMF/30) in Alpaca and Llama fibre

Source: Frank et al. [21]

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, being independent of the type of fiber used (natural or artificial). 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 [24] (see Fig. 3).

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. When Pcr=75 mgf, the results of fibre diameter calculations for different individual fibre lengths and Young's modulus values of alpaca fibres [25] are listed in Table 1.

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 [4]. The average diameter of the protruding fibers is 2 - 3 µm larger than that of the yarn [8,14].

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

	Buckling	**Bending**
Length of evoked fibre	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 fibre diameter (µm)	28.3	29.97

Source:: Frank, 2012 (No pub.) [14]

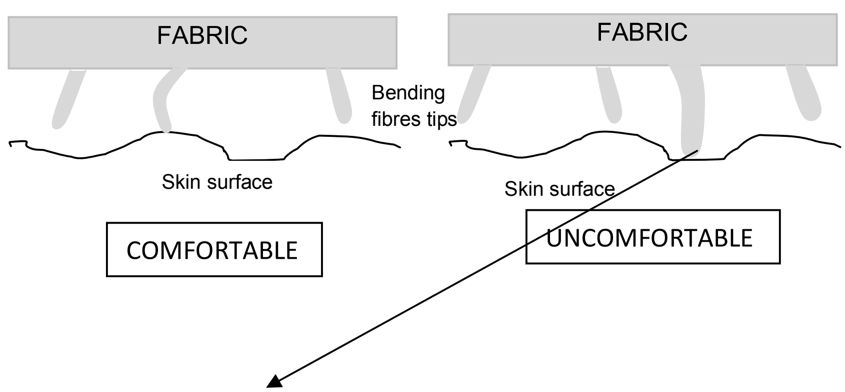
If the problem of the pruriginous effect lies in the coarse edge of the diameter distribution, two possible solutions are identified: decreasing the mean diameter (leftward shift of the normal curve with corresponding coarse-edge shift) or the range of distribution of fiber diameters (move leftwards the coarse edge leaving the mean unchanged) [26]. The latter could be achieved by dehairing or genetic selection. There is anecdotal information for the former and experimental data for the latter [15]. However, it seems that fineness alone would not correct the itching effect [21].

Hand-dehairing has demonstrated its feasibility [27], although the process is only efficient with double coated and intermediate coated fleece [28]. However, a recent work has shown that the *per person* and *per hour* yield is 9.9±1.1 g/person/h, which renders it economically unviable [29].

Dehairing or separation of different fibre types by mechanical means is the alternative to be analyzed [30]. The results of South American Camelids fiber dehairing as compared to cashmere (a more studied fiber) are listed in Tables 2 [31]. 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.

Mechanical reduction, via the dehairing of objectionable fibers is dramatic in all species of fibers. But, the reduction of fiber length by the effect of breakage, it is also important, being its greatest disadvantage (see Table 2).

The Table 3 presents the variables that best explain the differences between dehaired and non dehaired samples (FFP/w, FGP/p and FMedGr), while the correlation of variables between fibre tip and prickle score is more important in significant samples. This coincides in the results obtained in other studies where the protruding fibers show the itch effect [10]. The variables that indicate frequency differences of coarse fibers (objectionable) are best indicate itching effect, both in the yarn and in the protruding ends. These determinations were made using the perception of the hand and fingers [10].



$$Pcr = \frac{\pi^3 E D^4}{31.36 L^2}$$

where Pcr is the Euler buckling load

E is the Young's modulus of the material
D is the diameter of the fibre
L is the length of the buckling column

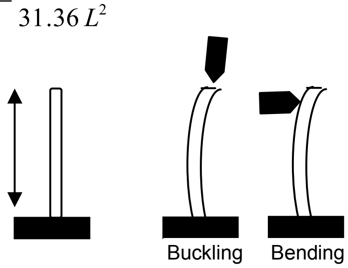


Fig. 3. Simplified scheme of fibre prickle effect on skin of a fabric

Sources: redraw from Naylor [9]; Ramsay et al. [24]

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. [31]

Table 3. Correlation between differences in fibre variables and Friedman Rank Score taking protruding fibre tip and fibre in the whole yarn, and significant and non significant dehaired vs non dehaired samples

Variables	Dehaired vs Non Dehaired (p>0.05)†					Sig.	Dehaired vs Non Dehaired (p>0.05)†						
	Yarn	Sig	Tip	Sig.	Y-T		Yarn	Sig	Tip	Sig	Y-T	Sig	Variable description
Bulk	-0.29+	*	-	-	-	-	-0.70	***	-	-	-	-	Bulk (cm³/g)
WFD	0.45	***	0.22	ns	0.58^	***	0.27	ns	0.50	**	0.54	**	Weighted fibre diameter (µm)
CVWFD	0.01	ns	-0.24	ns	0.61	***	0.20	ns	-0.4	ns	0.12	ns	WFD coefficient of variation (%)
F>30µm	0.52	***	0.10	ns	0.51	***	0.44	*	0.53	**	0.14	ns	>30 µm frequency (%)
FFP	-0.47	***	-0.21	ns	0.49	***	-0.62	***	-0.60	***	0.43		Fine fibre percentage (w/w, %)
CFP	0.47	***	0.21	ns	0.49	***	0.62	***	0.60	***	0.43		Coarse fibre percentage (w/w,%)
FFD	0.35	**	0.12	ns	0.59	***	0.21	ns	0.38	ns	0.71	***	Fine fibre diameter (µm)
CFD	0.07	ns	-0.19	ns	0.42	***	0.26	ns	0.00	ns	0.14	ns	Coarse fibre diameter (µm)
AFF	-0.04	ns	0.66	***	0.66	***	-0.11	ns	0.52	**	0.52	**	Amedulated fibre frequency (%)
FFF	-0.54	***	0.04	ns	0.27	ns	0.30	ns	0.06	ns	0.15	ns	Fragmented medulla fibre frequency (%)
IFF	0.06	ns	0.02	ns	0.27	ns	-0.48	*	-0.18	ns	0.11	ns	Interumped medulla fibre frequency (%)
CFF	0.32	*	0.77	***	0.77	***	0.12	ns	0.11	ns	0.52	**	Continuous medulla fibre frequency (%)
LFF	-0.04	ns	-0.08	ns	-0.28	*	0.81	***	0.61	***	0.27	ns	Lattice medulla fibre frequency (%)
AFD	0.28	*	0.16	ns	0.31	*	0.07	ns	0.39	ns	0.58	***	Amedulated fibre diameter (µm)
FFD	0.22	ns	0.19	ns	0.69	***	0.50	**	0.41	*	0.31	ns	Fragmented medulla fibre diameter (µm)
IFD	0.25	ns	0.16	ns	0.60	***	0.42	*	0.42	*	0.27	ns	Interumped medulla fibre diameter (µm)
CoFD	0.44	***	0.24	ns	0.52	***	0.65	***	0.71	***	0.66	***	Continuous medulla fibre diameter (µm)
LFD	0.23	ns	-0.12	ns	0.59	***	0.11	ns	-0.17	ns	0.12	ns	Lattice medulla fibre diameter (µm)

†: Comparison of pairs by Wilcoxon, between dehaired samples and not dehaired fibre samples, +: Spearman correlation of the score of Friedman and variable within the fibre tips and within the fabric, ^: Spearman correlation of the score of Friedman and variable Y-T: difference between the fibre tips and within the fabric
Sources: redrawn from Frank et al. [10]

After an Alpaca fiber dehairing assay conducted in Australia, it was concluded that only a relatively small amount of coarse fibers can 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 [25]. A recent trial with top dehairing alpaca from Peru has yielded better results. On a trial results on alpaca dehairing using an AM2 technology dehairing machine was recently performed. The diameters of alpaca fleece, dehaired alpaca fibres and removed alpaca fibres were analyzed, and the fibre lengths were compared before and after dehairing. In this dehairing assay, the following input was included: Alpaca tape top: 22.4 microns average of diameter; 23.5% CV of fibre diameter; Objectionable fiber w/w: 6.8%; Nº/weight: 0.32; Fiber of> 30 µm: 6.6%. Average fiber length (down + guard hair: Baer diagram): 111.8 mm. One dehairing Product/Down (VI) was obtained: average fineness 21.9µm; 24% CV of fineness; Objectionable fiber w / w: 2.2%; Nº/weight: 0.16; Fiber of > 30 µm: 3.6% Average fiber length (Barbe): 76.6±2.3 mm (reduction: 22%); Hauteur: 72.1±13.2 mm (reduction: 10%). Yield at end dehairing was 83.5%. It was concluded that the product can be processed by the worsted system [32].

4. CONCLUSIONS AND RECOMMENDATIONS

The distribution of diameters of Llamas/Alpacas fibers shows a marked positive skewness.

Comfort of Llamas/Alpacas fibres is strongly affected by the presence of objectionable fibers (<30 m).

Dehairing can be a viable solution if they can alleviate the adverse effect of fiber breakage and corresponding shortening.

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

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCIES

1. Watkins P, Buxton A. Luxury fibres-rare materials for higher added value. The Economist Intelligence Unit Special Report No. 2633. Business International, London; 1992.
2. von Bergen W. Wool Handbook, Interscience Publishers, New York. 1969;2(1):380.
3. Naylor GRS, Phillips DG. Fabric-evoked prickle in worsted spun single jersey fabrics. Part III: Wear Trial Studies of absolute fabric acceptability. Textile Res. J. 1997;67:413-416.
4. De Boos AG, Naylor GR, Slota IJ, Stanton J. The effect of the diameter characteristics of the fibre ends on the skin comfort and handle of knitted wool fabrics. Wool Tech. Sheep Breed. 2002;50:110-120.
5. Frank EN, Hick MVH, Adot O. Descriptive differential attributes of Llama fleece types and its textile consequence. 2-Consequences from dehairing processes. The Journal of the Textile Institute. 2010; 102(1):41-49.
6. Vallely P. Premium fibre: Taking alpacas to the next level ´being at the crossroads´ is a cliché used far too often. Alpacas Aus. 2010; 60:44-45.
7. Garnsworthy RK, Gully RL, Kandiah RP, Kenins P, Mayfield RJ, Westerman RA. Understanding the causes of prickle and itch from skin contact of fabrics. CSIRO Division of Wool Technology Report G4; 1988.
8. Naylor GRS. The relationship between the Fibre Diameter distributions of wool top, fibre ends and yarn surface fibres. Wool

Tech. Sheep Breed. 1992a;40:40-43.

9. Naylor GRS. The role of coarse fibres in fabric prickle using blended acrylic fibres of different diameters. Wool Tech. Sheep Breed. 1992b;40:14-18.
10. Frank EN, Hick MVH, Castillo MF, Prieto A, Adot OG. Fibre-based components determining handle/skin comfort in fabrics made from dehaired and non dehaired llama fibre. International Journal of Applied Science and Technology. 2014;4(3): 51-66.
11. Naebe M, McGregor BA, Swan P, Tester D. Associations between the Physiological. Basis of fabric-evoked prickle, fiber and yarn characteristics and the wool comfortmeter value. Textile Research Journal. 2014;85:1122-1130.
12. Süpüren Mengüç G, Özdil N, Hes L. Prickle and handle properties of fabrics produced from specialty animal fibers. Textile Research Journal. 2015;85(6):561-670.
13. Mayo O, Crook B, Lax J, Swan A, Hancock TW. The determination of Fibre Diameter Distribution. Wool Tech. Sheep Breed. 1994; 42:231-236.
14. Frank EN. Datos en fibra de Llama no publicados, equipo SUPPRAD, Córdoba, Argentina. (No Pub.). Spanish; 2012.
15. Frank EN, Hick MHV, Molina MG, Prieto A, Castillo MF. Correlaciones genéticas, fenotípicas y heredabilidades de los componentes del diámetro de la fibra en llamas. Revista Argentina de Producción Animal Spanish. 2008;28(1): 123-124.
16. Gilmour AR, Atkins KD. Modelling the FFDA fibre diameter histogram of fleece wool as a mixture distribution. Aust. J. Agric. Res. 1992;43:1177-1788.
17. Smuts S, Hunter L. Medulation in Mohair. Part II: Geometrics and the relationship between various measures of Medulation. SAWTRI Tech. Report Nº 508; 1987.
18. Balasingam A. 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. 2005;32.
19. Frank EN, Hick MVH, Adot OG. Descriptive differential attributes of type of fleeces in Llama fiber and its textile consequence. 1-Descriptive aspects. The Journal of the Textile Institute. 2007;98:251-259.
20. Davison IM. Fleece factors. Alpacas Aust. 2010;12-14.
21. Frank EN, Adot OG, Hick MVH, Prieto A, Castillo MF. Relación entre el diámetro de la fibra y el factor de picazón en alpaca y llama. En: VI Congreso Mundial Camélidos, Arica, Chile. Libro de Resúmenes VI Cong. Mundial de Cam.: Spanish. 2012;195.
22. Wang X, Wang L, Liu X. The Quality and Processing Performance of Alpaca Fibres. RIRDC Publication Nº 03/128. 2003;66-76.
23. Hillbrick LK. Fibre properties affecting the softness of wool and other keratins. Doctor of Philosophy Thesis, Deakin University, Australia; 2012.
24. Ramsay DJ, Fox DB, Naylor GRS. An instrument for assessing fabric prickle propensity. Text. Res. J. 2012;82:513-520.
25. Wang L, Singh A, Wang X. Dehairing Australian alpaca fibres with a cashmere dehairing machine. Journal of the Textile Institute. 2008;99(6):539-544.
26. Naylor GRS, Phillips DG. Veitch CJ. 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. 1995;43:69-82.
27. Cochi N. Determinación del rendimiento y calidad de la fibra descerdada de llamas (*Lama glama*). Tesis de Ingeniero Agrónomo. Universidad Mayor de San Andrés. La Paz. Bolivia. Spanish; 1999.
28. Frank EN. Descripción y análisis de segregación de fenotipos de color y tipos de vellón en Llamas argentinas. Tesis Doctoral Universidad de Buenos Aires. Spanish. 2001;280.
29. Quispe EC, Chipa L, Pinares R. Análisis económico y de la producción del descerdado manual de la fibra de llamas (*Lama glama*) Chaku. Arch. Zootec. Spanish. 2015;64(246):191-198.

30. Batten G. Goat Cashmere. Producing the finest fibre from New Zealand goats. New Zealand Cashmere Association. 2003; 68.
31. Frank EN, Hick MVH, Prieto A, Castillo MF. Efectos del descerdado sobre la calidad de la fibra obtenida de camélidos sudamericanos y cabra criolla patagónica. Revista Argentina de Producción Animal. Spanish. 2009;29(1):134-135.
32. Frank EN, Seghetti Frondizi DG, Hick MVH, Castillo MF, Burgos A, Cruz A. Dehairing of alpaca fibres top with AM2 dehairing technology. In: 7th European Symposium on South American Camelids and 3rd European Meeting on Fibre Animals, Assisi, Italy; 2017.

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