Determination of dehairing, carding, combing and spinning difference from Lama type of fleeces

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Abstract

Mixed fleeces as Llama fleeces, require a special textile process known as dehairing. This process behaves differently according to the Lama type of fleeces dehaired. Dehairing generates structural modifications on textile raw material as it eliminates the longer and straighter (coarser) fibres. This has a marked effect on the following worsted or woolen spinning processes. This work was designed for to test these effects with the objective to report how the type of fleeces affects dehairing, worsted or woolen combing and spinning performances. From a textile behavior point of view, a higher fiber diameter variation was detected in double coated fleeces than in luster fleeces. Luster fleeces have a lower bulk potential than double coated fleeces and a lower comb yield due to the higher dehairing effect. It is also this type that produces less ends protruding from the yarn, which may account in part for their diminished prickle effect.

Key words: Lama fibre, textile trials, bristle, prickle, coarse fibres.

1. Introduction

A characteristic peculiar to the fibre of South American Camelids (SAC) is the presence of a mixed fleece. This is the reason for their textiles processing requiring 'dehairing' to achieve a superior quality product, because this process consists in the removal of the coarser fibers (Russel, 1990). The fibre of the SAC, whether dehaired or non dehaired, is processed through the same conventional textile spinning machinery used for wool (Patthey Salas,1994). In the case of the non dehaired Suri Alpaca type of fleece (Luster), some special adjustments to processing is required (Pepper, 1999). The style or type of fleeces is of fundamental importance in the textile procedures used and in the resulting final product quality (Lupton et al., 1999). Styles of Llamas fleeces are defined according to the interrelationship between the type of wave in the fibre and in the staple as a whole (Stamberg, 1987, Frank et al., 2007), as well as its effect on the the "felting" capacity of the material and, therefore, its volume or ´bulk´ potential (Rainard and Abbot, 1950).

One of the most valued characteristics in animal fibre is the "comfort" effect a textile made from these fibres has on the human skin. The need to dehair Llama fibre to reach the desired level of skin comfort in Llama fibre is well recognized (Villarroel, 1991, Frank et al., 2007). The textile behaviour of a fibre during carding, combing and spinning largely depends of its special characteristics (Monfort, 1960). The objective of this work is to report on the effect of the different types of Lama fleeces on the fibre´s behaviour during dehairing, carding, combing and spinning processes.

2. Materials and methods

2.1. Samples processed: eighteen fleeces were processed, from an experimental Lama flock of similar ages (juveniles at first shearing). The animals were specially shorn for the trial with an electric shears handpiece equipped with narrow pacer combs to facilitate the work. For laboratory processing and later textile processing, each sample was washed and conditioned according to standard procedures (Lamb, 1998).

2.2. Combing, dehairing carding and weaving procedures

Each original sample was divided into four subsamples for its use in the different textile trials. Trial treatments (T) were: *i*) combing without dehairing (CwD), *ii)* combing and dehairing (CD), *iii)* carding without dehairing (CawD, and *iv)* carding and dehairing (CaD).

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Dehairing was done by hand with a variant on the methodology used for Cashmere fibre (Blakeman et al., 1992), using the fingers instead of forceps, and with only five dehairing movements per sample. This method was preferred to the Shirley Trash Separator as this laboratory instrument did not yield repeatable results. Combing was done with a hand-comb (´English comb´) specially made for domestic Camelids fibre and according to the procedures described by McFarland (1993). The carding was done with a pair of cotton type portable carders with a curved board and following the procedures recommended by Raven (1987). Furthermore, to measure the 'bulk' capacity of the different types of fleece, the carding procedures and subsequent evaluation described by Rainard and Abbot (1950) was followed.

Combed samples (both dehaired and not dehaired), were spun on an artisan wheel and two strands twisted according to a standard procedure described by Raven (1987).

2.3. Textile trials evaluation:

The yield, expressed as a percentage, was established as the quantity of fibre remaining after the sample was dehaired and combed. This calculation was done on the basis of the dry weight of the different components adjusted to a 10% regain. All processes were done under standard laboratory conditions (20 ºC; and 65% r.h.).

The evaluation of the 'roving' taken down from the carders was done at both ends and in the middle by measuring the width and height with calipers (0.1 mm accuracy) without exercising pressure on the fibres. For determine the yarn number of each yarn, each strand (without twisting) was measured with a millimeter ruler, weighted under standard laboratory conditions, the title established according to the "numeric" process (Monfort, 1960).

The fibre ends protruding the yarn were counted under a stereoscopic lens (3D) with 12x magnifications. At each severance of the yarn, the frequency of each type of fibre was recorded according to the type of medulla present and its diameter, together with its corresponding coefficient of variation. For these determinations a variant of the procedure for diameter measurements (ITWO 80-3) with a microprojector was used, taking into account suggestions made for Alpaca fibre (Lamb, 1998).

2.4.- Statistical evaluation of the data:

ANOVA F was used and *post hoc* of between-mean comparisons in case of continuous or discrete quantitative variables and when its distribution showed no significant deviation from a normal distribution tested under Lilliefors test, in the assumption of the model used in the later analysis. For the between-mean comparisons Scheffé's test was used under Systat program (Wilkinson,1990).

3. Results

Fleeces samples processed in the trial showed no statistically significant difference ($p>0.05$) to ANOVA. The fiber diameter average of the data population was 24.5 µm.

3.1. Dehairing yield:

The Table 1 shows that the ANOVA F of dehairing yield has a statistically significant differences ($p<0.05$) among type of fleeces (TF), treatment (dehairing and non dehairing) (T) and also in the case of the interaction between TF and T. Between- mean comparisons show that double coated fleeces have a lower yield (40.59 %) than intermediate coated fleece, single coated fleece, hemilustre and luster fleeces (63.21 %, 54.66 %, 58.91 % and 60.83 % respectively). Combing and dehairing (CD) (50.91 %) and carding and dehairing (CaD) (43.34 %) show significant lower yield than combing non dehairing (CwD) (63.16 %) and carding non dehairing (CawD) (65.13 %). The type of fleeces and the textile treatments interaction (TFxT) shown that in double coated fleeces (DC), CD (13.11 %) and CaD (29.24 %) have lower yields than CwD (59.45 %) and CawD (60.55 %), whereas, between other type of fleeces no significant differences were found within T´s.

2.2. Differences in bulk among type of fleeces and among textile treatments:

Table 2 shows the ANOVA F of roving thickness or diameter, obtained as part of bulk evaluation relative to type of fleece (TF), treatments (dehairing and non dehairing) (T), adjusted by number of rovings measured (R), sample repetitions (SR), with roving weight (W) used as co-variable. In this case only the TFxT interaction was tested. Statistically significant between- mean comparisons show that HL and L resulted in a lower roving thickness (12.53 cm and 11.98 cm respectively) than IC, DC and SC (13.19 cm, 13.64 cm and 13.77 cm respectively).

Non dehairing rovings (12.34 cm) were statistically significant narrower than dehairing rovings (13.71 cm). The TFxT interaction shows that the non dehaired rovings are narrower than the dehaired ones in intermediate coated fleeces (IC) (12.11 cm vs 14.26 cm), double coated fleeces (DC) (13.74 cm vs 14.12 cm) and single coated fleeces (SC) (12.34 cm vs 15.21 cm); whereas in hemilustre coated (HL) (12.47 cm vs 12.58 cm) and luster coated (L) (11.58 cm vs 12.38 cm) fleeces, the rovings presented no statistically significant differences ($p<0.05$).

2.3.- Protruding fibre ends counting among yarns obtained from different type of fleeces and different textile treatments:

Table 3 shows the ANOVA F of frequencies of protruding fibre ends within yarns spun from different type of fibre. In the case of frequencies of whole type of fibre (FRT), only the TFxT interaction were statistically significant different ($p<0.05$). Between- mean comparisons show that luster coated fleeces yarns have significantly lower frequencies of FRT in dehaired yarns (22.58 %) than in non dehaired yarns (29.22 %), whereas, with double coated fleeces (DC) the dehaired yarns that had higher frequencies of FRT (30.0 % vs 27.85%); no statistically significant differences were detected between dehaired and non dehaired yarns within intermediate coated (IC) (29.21 % vs 29.20 %), hemilustre coated (HL) (27.08 % vs 27.98 %) and single coated fleeces (SC) (28.03 % vs 28.04 %).

For frequencies of long and strong type of fibre (FRLS), highly statistically significant differences were detected between type of fleeces (TF), textile treatments (T) and within TFxT interactions (see Table 3). The protruding fibre ends of intermediate coated (IC) (14.06 %) and double coated fleeces (DC) (12.12 %) were statistically significant lower than hemilustre coated (HL) (19.63%), luster coated (L) (17.8 %) and single coated (SC) (19.86 %) fleeces. Dehaired samples showed statistically significant lower frequencies (13.36%) of protruding ends than non dehaired samples (20.02 %). The TFxT interaction shows that within intermediate coated fleeces (IC) dehaired yarns have highly statistically significant lower frequencies of protruding ends than non dehaired yarns (4.78 % vs 23.3 %), and similarly, within double coated fleeces (DC) yarns (8.07 % vs 16.15 %). In the case of within hemilustre (HL), luster (L) and single coated fleeces (SC) no statistically significant differences ($p<0.05$) can be detect (18.52 % vs 20.74 %; 15.23 % vs 20.37 % and 20.20 % vs 19.5 2% respectively).

The variable frequencies of long and medium fibre protruding ends (FRLM), ANOVA F results showed a statistically high significance for TF and T, whereas TFxT interactions were no statistically significant ($p>0.05$) (see Table 3). Between-mean comparisons show high statistically significant frequencies for intermediate (IC) and double coated fleeces (DC) (39.41 % and 39.26% respectively); significantly lower frequencies for hemilustre coated (HL) and luster coated fleeces (L) (28.1 % and 30.2 % respectively) and significantly intermediate frequencies in the case of single coated fleeces yarns (32.18 %). Dehaired yarns showed, as well, higher frequencies of FRLM (28.32 %) than non dehaired yarns (19.39 %).

The ANOVA F of variable frequencies of long and fine fibre protruding ends (FRLF), showed highly statistically significant differences for TF, T and TFxT (see Table 3). Between- mean comparisons detect significantly higher frequencies within intermediate coated (IC) and double coated fleeces (DC) (39.41 % and 39.26 % respectively); lower frequencies for hemilustre (HL) and luster coated fleeces (L) (28.10 % and 30.2 % respectively) and for single coated the results are significantly intermediate for frequencies of FRLF (32.18 %). Also dehaired yarns showed higher frequencies of FRLF (37.56 %) than non dehaired yarns (30.09 %). The TFxT interactions shows that within intermediate coated (IC) dehaired yarn has higher frequencies of FRLF than non dehaired yarn (52.58 % vs 26.23 %), and double coated fleeces (DC) show a similar behaviour (D: 43.27 % vs wD: 35.25 %); within hemilustre, luster and single coated there are no statistically significant differences between dehaired and non dehairing yarn (29.39 % vs 26.8 %; 31.05 % vs 29.31 % and 31.53 % vs 32.82 % respectively).

The ANOVA F of variable frequencies of short and strong fibre protruding ends (FRSS), showed a highly statistically significant differences for T and TFxT, whereas significantly differences among type of fleeces (TF) were no detected (see Table 3). Between-mean comparisons showed lower FRSS for dehaired yarn (5.28 %) than for non dehaired ones (7.52 %). The TFxT interaction shows that within intermediate coated (IC) dehaired yarn has lower FRSS (1.66 %) than non dehaired yarn (9.30 %), similarly within double coated fleeces (DC) dehaired yarns show substantially lower FRSS than non dehaired (4.17 % vs 7.79 %). In the case of hemilustre (HL), luster (L) and single coated (SC) fleeces, no statistically significant differences were detected (6.30 % vs 6.75 %; 5.93 % vs 7.18 % and 8.33 % vs 6.58 % respectively).

The ANOVA F of variable frequencies of short and medium fibre protruding ends (FRSM), show statistically significant differences for TF and TFxT, whereas, among textile treatments (T) shows that no significantly results are detected (see Table 3). Between-mean comparisons show that double coated (DC) and single coated (SC) fleeces have lower FRSM (9.62 % and 8.52 % respectively) than intermediate coated (IC), hemilustre (HL) and luster coated (L) fleeces (12.43 %, 11.00 % and 10.52 % respectively). Dehaired double coated (DC) fleeces had higher FRSM than non dehaired (10.69 % vs 8.56 %), and among intermediate coated (IC), hemilustre (HL), luster (L) and single coated (SC) fleeces there were no statistically significant differences (12.13 % vs 12.74 %; 10.44 % vs 10.44 %; 8.22 % vs 8.22 % and 7.51 % vs 9.54 % respectively).

The ANOVA F of the variable frequencies of short and fine fibre protruding ends (FRSF), showed statistically significant differences for T, whereas, among type of fleeces (TF) and TFxT interactions, no significant results were detected (see Table 3). Between-mean comparisons show that the dehaired yarn have a lower FRSF (5.68 %) than the non dehaired yarn (11.64 %).

2.4. Different type of fibre detected within yarns in relation to different type of fleeces and textile treatments:

Table 4 shows frequencies, mean fibre diameter and mean fibre diameter coefficient of variations results for different type of fibre (identified by type of medulla), evaluated within the yarns obtained from the different type of fleeces and textile treatments process.

2.4.1. Non medulated:

2.4.1.1.- Frequencies of non medulated type of fibre (FRNMF):

Table 4 ANOVA F shows FRNMF statistically significant differences among type of fleeces (TF) within whole staple, within yarns and among textile treatments (T), whereas, interaction TFxT within yarns was not statistically significant. Intermediate coated fleeces (IC) show higher frequencies (62.27 %) than hemilustre (HL) (31.43 %) and luster coated (L) (34.45 %) ones, and also within yarn and within whole staple. All this type of fleeces results is statistically significant higher than those of double coated (DC) and single coated (SC) fleeces (26.09 % and 25.02 %) within yarn. DC and SC show higher frequencies within whole staple (34.06 % and 43.39 % respectively). Dehaired yarns show statistically significant higher FRNMF than non dehaired yarns (38.11 % *vs* 33.61 %).

2.4.1.2. Diameter of non medulated fibres (DNMF):

Table 4 ANOVA F shows that the DNMF has highly statistically significant differences among type of fleeces (TF), within whole staples and yarns, and the interaction TFxT within yarn were also significant. Within yarns, intermediate coated (IC) show statistically lower DFMF (17.57 µm) than double coated (DC), hemilustre, luster and single coated (SC) fleeces (18. 88 µm; 19.19 µm; 19.87 µm and 18.23 µm respectively), whereas, within the whole staple all DFMF were lower than within yarns. Also, within yarns no statistically significant difference can be detect among IC, DC and SC fleeces (17.30 µm vs 18.02 µm vs 17.70 µm), however, HL and L had statistically significant higher DNMF (18.95 µm and 18.44 µm respectively) than CI, DC and SC type of fleeces. Dehaired and non dehaired yarns from double coated fleeces had statistically significant differences (19.23 µm vs 18.54 µm), as it also was the case for lustre (20.48 µm vs 19.26 µm), however, no statistically significant difference between dehaired and non dehaired yarns was detected for IC, HL and SC fleeces (17.38 µm vs 17.76 µm; 18.98 µm vs 19.40 µm and 18.04 µm vs 18.42 µm).

2.4.1.3. Coefficient of variation of non medulated fibres diameter (CVNMF):

Table 4 ANOVA F shows a CVNMF with highly statistically significant differences among type of fleeces (TF), for within the whole staple and yarns. Among textile treatments were also statistically significant. Interaction of TFxT within yarn was highly statistically significant as well. Within yarns, double coated (DC) (13.24 %) and hemilustre (HL) (13.14 %) fleeces show a statistically significant lower variation than intermediate coated (IC) (15.66 %), luster (L) (15.17 %) and single coated (SC) (14.88 %), whereas, within whole staple HL (11.94 %), L (13.01%) and SC (11.82 %) ones showed a lower variation than DC (27.30 %). At the same time, DC fleeces were statistically significant higher than IC (16.46 %) and both types are statistically significant higher than HL, L and SC ones. Dehaired yarn show lower variation than non dehaired (13.91 % vs 14.94 %).

Within the TFxT interaction IC, DC and L fleeces show lower variation within dehaired yarns than in non dehaired yarns (13,92 % vs 17,41 %; 12,19 % vs 14,30 % and 14,33 % vs 16,01 % respectively); HL show inverse significantly results (14.05 % vs 12.23 %) between dehaired and non dehaired, and finally within SC statistically no significant differences was detected (15.03 % vs 14.74 %) between both textile treatments.

2.4.2.- Interrupted medulla:

2.4.2.1.- Frequencies of interrupted medulated fibres (FRIF):

Table 4 ANOVA F shows for FRIF highly significant differences among type of fleeces (TF) into the whole staple and yarns. Among textile treatments there is no statistically significant, and into interaction TFxT within yarn was statistically significant. Within yarns, double coated (DC) show a higher frequency of FRIF than single coated (SC) ones (21.80 % vs 15.06 %), whereas, intermediate coated (IC), hemilustre (HL) and luster (L) display significantly lower frequencies (8.84 %; 12.87 % and 12.58 % respectively). This coincident with the FRIF frequencies within the whole staple, but L fleeces display higher FRIF (13.57 %) than SC (11.53 %) ones, and SC fleeces show a significantly higher FRIF than HL (8.82 %) and IC (5.63 %) within the whole staple. Within IC showed statistically significant lower FRIF for dehaired than non dehaired (6.9 % vs 10.69 %) fibres, and also in the case of HL fleeces (11.37 % vs 14.38 %). Although, in DC fleeces the FRIF was statistically significant higher in the case of dehaired than non dehaired yarns (23.61 % vs 20.0 %), with luster and single coated fleeces having no significantly differences were detected (12.8 % vs 12.3 % and 15.92 % vs 14.21 % respectively).

2.4.2.2.- Diameter of interrupted medulated fibres (DIF):

Table 4 ANOVA F shows DIF highly significantly differences among type of fleeces (TF), in the case of the whole staple and within yarns. Among textile treatments and interaction TFxT within yarn were no statistically significant. Within yarns, double coated (DC) had a significantly lower diameter (22.60 µm); single coated (SC) significantly intermediate (24.41 µm); intermediate coated (IC) (26.51 µm), hemilustre (HL) (25.94 µm) and luster (L) (26.58 µm) were significantly higher DIF than the former, with no statistically significant difference detected among them by between-mean comparisons. On the other hand, within the whole staple, DC fleeces had a significantly lower DIF (21.20 µm) than SC (24.95 µm) while, this last had a significantly lower DIF than HL and L (27.40 µm and 26.47 µm respectively).

2.4.2.3.-Coefficient of variation of interrupted medulated fibres diameter (CVIF):

Table 4 ANOVA F shows CVIF have highly statistically significant differences among type of fleeces (TF), within the whole staple and yarns. Among textile treatments showed statistically significant differences, and the interaction TFxT within yarns showed also a significantly differences. Within yarn, double coated (DC) fleeces showed a higher statistically significant CVIF (17.70 %) than luster (L) (14.83 %). Intermediate (IC) and double coated (DC), hemilustre (HL) and single coated (SC) fleeces show significantly lower CVIF (13.38 %; 12.26 % and 13.52 % respectively) relative to the former, but no significantly difference among them. Whereas, in the whole staple, IC and DC fleeces (13.53 % and 13.09 %) were statistically significant higher than L and SC fleeces (12.25 % and 12.26 % respectively). At the same time this last were significantly lower than HL (11.23 %). Within dehaired yarns CVIF (13.91 %) were significantly lower than non dehaired yarns (14.77 %). The TFxT interaction shows significantly difference between dehaired (D) and non dehaired (wD) in the case of IC (17.35 % vs 18.05 %) and in the case of L fleeces (13.26 % vs 16.15 %), whereas, there were no statistically significant differences between D and wD in DC (13.13 % vs 13.65 %), HL (12.30 % vs 12.23 %) and SC fleeces (13.50 % vs 13.54 %).

2.4.3.- Fragmented medulla:

2.4.3.1.- Frequency of fragmented medulated fibres (FRFF):

Table 4 ANOVA F shows FRFF highly statistically significant differences among type of fleeces (TF), within the whole staple and yarns, but not among textile treatments and in the interaction TFxT within yarns. Within yarns, hemilustre (HL) fleeces had statistically significantly higher FRFF (28.34 %), double coated (DC) ones had statistically significantly intermediate FRFF (24.19 %), and intermediate coated (IC) (18.18 %), luster (L) (21.07 %), and single coated fleeces (SC) (21.40 %) had a statistically significant lower FRFF with no statistically significant difference detected among them.

Within the whole staple, DC, HL and SC fleeces show no statistically significant differences among them (18.18 %; 21.07 % and 21.39 % respectively) but they have a higher statistically significance than L fleeces (23.51 %), and both have a higher statistically significant FRFF than IC fleeces (14.46 %).

2.4.3.2.-Diameter of fragmented medulated fibres (DFF):

Table 4 ANOVA F shows a DFF highly significantly differences among type of fleeces (TF), within the whole staple and yarns, there were no significantly differences among textile treatments, and the interaction TFxT within yarns gave statistically significant differences. Within yarns, double coated (DC) (20.39 µm) and single coated (SC) (20.88 µm) show lower DFF than intermediate coated (IC) (21.91 µm), hemilustre (HL) (22.81 µm) and luster (L) (23.36 µm) fleeces; however they had no statistically significant difference among them. The TFxT interaction shows that dehaired IC has a lower DFF than non dehaired (20.87 µm vs 22.95 µm), and in the case of L an inverse situation is seen -dehaired L is higher than non dehaired L (23.88 µm vs 22.85 µm)-, and finally among DC, HL and SC were no statistically significant difference and among them (20.67 µm vs 20.14 µm; 22.63 µm vs 22.98 µm and 20.80 µm vs 20.97 µm respectively).

2.4.3.3.- Coefficient of variation of fragmented medulated fibres diameter (CVFF):

Table 4 ANOVA F shows for CVFF highly statistically significant differences among type of fleeces (TF), within the whole staple and yarns, however, among textile treatments (T) and into interaction TFxT within yarn the differences were not statistically significant. Within yarn, intermediate coated (IC) and luster (L) fleeces (15.06 % and 14.91 % respectively) show a statistically significant higher CVFF than double coated (DC) (12.95 %), hemilustre (HL) (12.02 %) and single coated (SC) (12.92 %) ones. Within the whole staple, IC (21.10 %) fleeces shows a significantly higher variation than SC (13.52 %) fleeces, which, at the same time, shows a significantly higher one than HL and L fleeces (11.90 % and 11.94 % respectively). Both type of fleeces were statistically significant higher than DC fleeces (+10.89 %).

2.4.4.- Continuous medulla:

2.4.4.1.- Frequency of continued medulated fibres (FRCF):

Table 4 ANOVA F shows FRCF highly statistically significant differences among type of fleeces (TF), within the whole staple and yarns. Among textile treatments (T) and the interaction TFxT within yarns showed no statistically significant differences. Within yarns, intermediate coated (IC) fleeces show lower FRCF (7.49 %), while double coated (DC) (21.66 %) and hemilustre (HL) (21.69 %) ones show a significantly intermediate FRCF, and luster (L) and single coated (SC) fleeces show a significantly higher frequencies (27.28 % and 29.88 % respectively). Within the whole staples, DC (19.05 %) and L (21.03 %) show statistically significant higher frequencies than IC (13.80 %), HL (11.56 %) and SC (15.85 %) fleeces.

2.4.4.2.-Diameter of continued medulated fibres (DCF):

Table 4 ANOVA F shows DCF highly significant differences among type of fleeces (TF), within the whole staple and yarns, while among textile treatments there are no significantly differences, while the interaction TFxT within yarns showed significantly differences. Within yarns, double coated (DC) fleeces (29.53 µm) had a statistically significant lower DCF than within intermediate coated (IC) (31.12 µm), luster (L) (31.82 µm) and single coated (SC) (31.06 µm) ones, while hemilustre (HL) shows a significantly higher DCF (33.19 µm). A similar situation can be seen within the whole staple: DC had lower diameter (28.57 µm) than IC (33.80 µm) and HL (34.20 µm), and L and SC were statistically significant lower DCF (30.12 µm and 30.73 µm respectively). In the case of DC type of fleece, dehairing process decrease DCF (28.18 µm vs 30.89 µm for dehaired and non dehaired respectively). Within IC (31.17 µm vs 31.07 µm), HL (33.26 µm vs 33.12 µm), L (32.28 µm vs 31.35 µm) and SC (30.83 µm vs 31.30 µm) no statistically significant difference were detected by between-mean comparisons.

2.4.4.3.- Coefficient of variation of continuous medulated fibres diameters (CVCF):

Table 4 ANOVA F shows CVCF highly significant differences among type of fleeces (TF) for the whole staple and yarns. Among textile treatments (T) showed significant differences and also the interaction TFxT among yarns. Within yarns, double coated (DC) fleeces (21.76 %) had a significantly higher CVCF than intermediate coated (IC) (17.76 %), hemilustre (HL) (17.90 %), luster (L) (15.40 %) and single coated (SC) (15.60 %) ones, while within the whole staple, DC was even statistically significant higher (25.82 %), and IC (13.83 %), HL (14.17 %) and SC (14.95 %) fleeces were significantly lower in CVCF with no statistically difference among them, however L had a significantly lower CVCF (10.83 %) at the between-mean comparisons. The dehairing process reduced significantly the CVCF from 19.55 % to 15.78 %. In the TFxT interaction, the dehairing process reduced significantly the CVCF in DC (15.81 % vs 27.72 %), in HL (14.81 % vs 20.99 %) fleeces, whereas in IC (17.32 % vs 18.00 %), L (15.42 % vs 15.38 %) and SC (15.54 % vs 15.65 %) ones, no statistically significant effects were detected by between-mean comparisons.

2.4.5.- Lattice medulla:

2.4.5.1.- Frequency of lattice medulated fibres (FRFL):

Table 4 ANOVA F shows FRFL highly statistically significant differences among type of fleeces (TF), in the whole staple and within yarns, but not among textile treatments. The interaction TFxT within yarn showed statistically significant differences. Within yarns, double coated (DC) show significantly lower FRFL (1.29 %) than intermediate coated (IC) (2.93 %), hemilustre (HL) (5.34 %), luster (L) (4.16 %) and single coated (SC) (8.94 %) fleeces, whereas in the whole staple, IC (1.12 %), DC (0.39 %) and L (1.7 %) fleeces no statistically significant differences were detected among them. HL and SC were statistically significant higher in FRFL (2.69 % and 3.21 % respectively). The TFxT interaction of the dehairing process reduces FRFL in IC (0.67 % vs 5.21 %), DC (0.69 % vs 1.91 %), and HL (2.74 % vs 7.95 %) fleeces, whereas with L (4.57 % vs 3.75 %) and SC (10.12 % vs 7.76 %) fleeces, no statistically significant differences were detected by between-mean comparisons.

2.4.5.2.- Diameter of lattice medulated fibres (DLF):

Table 4 ANOVA F shows a highly significant DLF differences among type of fleeces (TF), within the whole staple and yarns. Among textile treatments (T) showed statistically significant differences as well as the interactions TFxT within yarn. Within yarns, intermediate coated (IC) (46.71 µm) and double coated (DC) (50.93 µm) fleeces had statistically significant higher DLF than hemilustre (L) (39.96 µm), luster (L) (39.65 µm) and single coated (SC) (44.85 µm) ones. A similar behaviour can be seen in the whole staple: IC and DC (57.50 µm and 48.00 µm respectively) were statistically significant higher in DLF than HL (45.57 µm), L (44.00 µm) and SC (46.75 µm). Dehaired yarns show significant lower DFL (41.13 µm) than non dehaired yarns (47.72 µm). In the TFxT interaction, the dehaired yarns had a lower diameter in IC (45.16 µm vs 48.26 µm), DC (41.80 µm vs 60.07 µm) and HL (33.61 µm vs 46.32 µm) fleeces, while in the L (40.25 µm vs 39.06) and SC (44.83 µm vs 44.87 µm) fleeces no statistically significant difference can be detected by between-mean comparisons.

2.4.5.3.- Coefficient of variation of lattice medulated fibres diameter (CVLF):

Table 4 ANOVA F shows CVLF highly significant differences among type of fleeces (TF) in the whole staple and within yarns. Among textile treatments (T) and the interaction TFxT within yarn there were no statistically significant differences. Within yarns, double coated (DC) fleeces show higher CVLF (11.31 %) than intermediate coated (IC) (4.64 %), hemilustre (HL) (7.36 %), luster (L) (8.96 %) and single coated (SC) (9.71 %) ones , while in the whole staple, IC shows higher CVLF (18.05 %) than DC (9.60 %), L (9.10 %) and SC (9.51 %) fleeces. This later type of fleeces was statistically significant higher in CVLF than HL (4.96 %) one.

3.- DISCUSSION

This work was designed for test the fleece type effects on dehairing, worsted and/or woolen combing, and spinning performances. The laboratory methodology utilized is only valid under the laboratory conditions in which it was carried out to observe statistically significant variations between the textile process and the type of fleeces. Significantly variations are observed when one considers takes into account the type of fleeces as the principal effect as well as when the interaction among the types of fleece are considered together with the type of procedures. Between-mean comparisons show that the double coated fleece type has considerably less yield after being dehaired. The same is noted when the yarn yield is considered in both types of textile process (treatments). This coincides with results observed with Cashmere fibre (Couchman, 1989) and is similar to results with Guanaco fibre dehairing (Moseley, 1985). This coincidence lends validity to the procedures employed here, even if they are not a standard procedure. The difference in yield is statistically significant when one considers pure Cashmere (like IC or DC) relative to Angora goats (like L) or Angora crosses (like HL), which coincide with the values obtained here. In a different procedure (comparing two different machines), slightly better yields (percentage of "down" fibre obtained) are obtained with Angora and Angora crosses (Couchman and Holt, 1990).

Results of trials undertaken to determine the capacity to produce bulk that each of the samples has and is about the measurement of the average width of the 'roving' or 'cigar' formed on taking down the processed fibre from the hand carder. Between-mean comparisons shows that Lustre and Hemi lustre types produce less volume (bulk) because of the total or partial lack of crimped fibres (Rainard and Abbott, 1950), which also coincides with observations made with Suri Alpaca (Safley, 1997). The interaction between types of fleece and treatments shows that both dehaired and not dehaired materials, the straight fleece types (L y HL) result in a less thick "cigar", while the non-lustre types (CI, DC y SC) result in a greater bulk. When comparing them there are statistically significant differences in favour of the dehaired samples. This phenomenon could also be explained by the presence or absence of waves or curls (´crimps´) in the fibres, since the fibres that the dehairing removes are usually straighter as well as thicker and longer (´coarser´).

The ends of loose fibres, which protruding from the yarn and as a result from the fabric, therefore determining the ´prickle´ effect (in the words of textiles commerce). This phenomenon is sometimes erroneously interpreted as an itch product of a skin allergic reaction (Naylor and Phillips, 1995). To quantify this effect the number of ends protruding from the yarn obtained by the worsted combing procedure was counted in this work. Here it is notable the difference in the fibre ends in relationship to the type of fleeces used. The fibre ends when using lustre (HL, L) fleeces are the less frequent at between-mean comparisons. Surprisingly, the dehairing treatment does not significantly reduce the number of protruding fibre ends as a main effect, even if the interaction between type of fleece and type of loose fibre ends is statistically significant. Most notable in the interactions is the lower amount of fibre ends in the dehaired lustre, while, at the same time, the statistically significance is unclear for the rest of the interactions.

The classification of loose fibre ends in their subjective length and thickness shows that the prickle effect is a consequence of the pressure exerted by the fibres on the nerve-endings that release the stimulus (Garnsworth et al., 1988). This pressure has to do with the bulge of the fibre considered as a solid cylinder that has a certain Young module (or elasticity) (E), a certain diameter (d) and juts out with a certain length of the protruding fibres (l). All these variables interrelate in what is known as Euler theory: Ed^4/l^2 (Naylor and Phillips, 1995). According to this theory, the shorter and thicker the fibre ends are, the greater the prickle effect, though it is the shorter and thicker fibers the ones that are significantly the rarest (CG), and the finer fiber generally being much more common. This is more notable when comparing the means of double coated fleeces. The effect of dehairing on the frequency of certain fibres seems clear in the treatments when considering the types of end fibres. At the same time, the interaction between type of ends and type of fleece is complete and statistically significant. This not very logical interaction seems to be related to the fact that the combing process alters the frequency of the original fibres and that the low-tension lab spinning does not break the fibre as does an industrial spinning. As a result long loose ends are more abundant than short ones in this work.

The frequencies of the various fibres that appear in the yarn, taking into account the different medulla as the indicators of those different types of fibres are demonstrated here. The frequencies of the fibres and/or thicker medulla are notably changed relative to the relationship of the frequencies of those same fibres in the original samples. However, the dehairing procedure does not achieve statistically significant differences as a main effect on the thick medulla, but does so in the interaction with type of fleeces. When fine and very fine fibres (without a medulla) are observed, it is very infrequently as a result of combing process, where the finer and shorter fibres are eliminated as a sub product or 'blouse' (von Bergen, 1969). This is quite clear in the case of double coated fleece as they as the ones that provide the least fine and very fine fibres to the yarn. Apparently this is not modified by dehairing (see interaction between treatments and type of fleeces).

It is presents as well the average diameters and the coefficients of variation of the diameters of the fibres measured from the yarns obtained by the combing process after being independently previously dehaired and non dehaired. There are differences in types of fibre of all the types of fleece yarns that coincide with what is happens in the the whole staple. Something very similar occurs with the coefficient of diameter variation as well as with the fibre diameter. The use of the medulla is meaningful since it is related to the capacity to differentiate types of fibre as has been determined in Frank et al. (2007). In spite of the accepted precise relationship between the diameters of the fibre with the type of medulla (Villarroel León, 1991), one notes that the interrelationship between type of medulla and type of fleece is statistically significant. One very important type of medulla from a textile point of view, such as the thick medulla (´lattice´), presents variable diameters relative to the type of fleece to which the fibre belongs.

Therefore, between-mean comparisons showed that the greater diameters of the fibre with a large medulla as well are present in double coated type of fleeces. Something similar (though not so noticeable) happens with the rest of the types of medulla, while unmedulated fibres do not present different diameters between themselves. Again the process of dehairing influences the diameter of the resulting fibre by an important interaction with the type of fleeces. There is a remarkable difference in diameters between the dehaired and not dehaired of the double coated type of fleeces. One can note this difference in the fibres that have not yet been processed. It must remember that these differences are achieved by estimating a weighted average diameter provided by the frequency of the types of fibre used, and that they are not determined by an arithmetical average; but as a result of belonging a population to a data population with multi-modal distribution (Sokal and Rholf, 1981).

4. *CONCLUSIONS*

From the point of view of textile behaviour, there are substantial differences among the type of fleeces. Lustre types have less capacity to form 'bulk' than non-lustre types, and generally, responds less to dehairing, in the sense of reducing through this procedure the amount of coarse fibre present, while in double coat fleeces the coarse fibre reduction is notably greater. As a result the double type of fleeces has a lower yield than the other types of fleeces. It is the luster type of fleeces the ones that results in less ends protruding from the yarn, which may account in part for their diminished prickle effect.

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Tables and Figures:

Table 1: ANOVA F dehairing yield of processed samples

Source	df	F
Type of Fleeces(TF)	4	10,661***
Treatment(T)	3	12,226***
FT x T	12	2,066*
Error	51	

*p<0.05; **p<0.01; ***p<0.001

Table 2: ANOVA F roving diameter measured as bulk evaluation

Source	df	F
Type of Fleeces (TF)	4	5,460***
Treatment(T)	1	24,226***
Nº of rovings (R)	2	,263
Sample repetition(SR)	2	7,140***
Roving weights(W)	1	8,257**
FT x T	4	3,726**
Error	303	

*p<0.05; **p<0.01; ***p<0.001

Table 3: ANOVA F frequencies of protruding fibre ends from different type of fibre within yarns

Source	df	FRT	FRLS	FRLM	FRLF	FRSS	FRSM	FRSF
Type of Fleeces (TF)	4	1.42	10.41***	5.57***	11.67***	1.12	2.97*	2.21
Treatment(T)	1	0.83	27.67***	50.58***	21.84***	8.47**	2.07	33.32***
FT x T	4	2.81*	6.06***	1.55	6.74***	4.56**	2.53*	0.83
Error	299							

References:

FRT: Frec. whole fibre types; FRLS: Frec. long and strong protruding fibres; FRLM: Frec. long and medium protruding fibres; FRLF: Frec. long and fine protruding fibres; FRSS: Frec. short and strong protruding fibres; FRSM: Frec. short and medium protruding fibres; FRSF: Frec. short and fine protruding fibres. ; *p<0.05; **p<0.01; ***p<0.001

Table 4: ANOVA F frequency, diameter and diameter coefficient of variation of different fibre types (by medulla) in whole staple and within yarn

Source	df	FRNMF	DNMF	CVNMF	FRIF	DIF	CVIF	FRFF	DFF	CVFF	FRCF	DCF	CVCF	FRLF	DLF	CVLF
Whole staple																
Type of Fleece (TF)	4	18.13***	10.35***	15.98***	33.31***	142.56***	8.58***	17.09***	30.65***	70.57***	11.00***	75.31***	65.18***	28.10***	30.03***	11.22***
Within yarn																
Type of Fleece (TF)	4	24.22***	13.98***	5.86**	25.32***	37.52***	16.92***	12.44***	35.99***	14.81***	13.68***	16.86***	3.68**	14.30***	5.07***	2.92**
Treatment (T)	1	4.01*	0.42	4.26*	0.03	1.10	4.80*	2.13	0.64	2.01	0.01	1.05	5.19*	2.44	7.32**	0.02
TF x T	4	1.43	3.2**	4.48***	2.70*	0.90	3.38**	1.26	3.48**	1.11	1.57	4.05**	3.55**	3.67**	4.48***	1.80
Error	299															

References:

FRNMF: Frec. non medulated fibres; DNMF: diameter of non medulated fibres; CVNMF: coef. of variation of non medulated fibres diameter; FRIF: Frec. interrupted medulated fibres; DIF: diameter of interrupted medulated fibres; CVIF: coef. of variation of interrupted medulated fibres diameter; FRFF: Frec. fragmented medulated fibres; DFF: diameter of fragmented medulated fibres; CVFF: coef. of variation of fragmented medulated fibres diameter; FRCF: Fred. continued medulated fibres; DCF: diameter of continued medulated fibres; CVCF: coef. of variation of continued medulated fibres diameter; FRLF: Fred. lattice medulated fibres; DLF: diameter of lattice medulated fibres; CVLF: coef. of variation of lattice medulated fibres diameter; *p<0.05; **p<0.01; ***p<0.001.