WOOL AND ALPACA FIBRE BLENDS

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Alpaca fibre has low crimp and smooth fibre surface. This makes the fibre difficult to process, particularly in sliver/fibre transferring and delivering processes. Blending with wool enhances the alpaca fibre processibility, makes the fibre more easily processed on modern wool processing facilities, and allows the development of new products. To evaluate the effect of wool fibre properties, especially wool crimp, on alpaca/wool blends, two alpaca fibre lots were processed to tops then blended with three commercial wool tops via top gillings. Yarns and knitted fabrics were subsequently engineered with identical machine settings. The performance of alpaca/wool blend slivers, yarns and fabrics has been investigated in this paper.

Blending alpaca fibre with wool improves the cohesion properties of the blend slivers, especially with high-crimp wools. Wool fibre crimp does not affect the evenness of blend yarns, but may affect the yarn hairiness value and tensile properties.

The alpaca/wool fabrics exhibit satisfactory pilling performance. Their dimensional changes are relatively stable after stress relaxation. The fabric made from alpaca/high-crimp-wool blend is softer than that made from alpaca/low-crimp-wool blend.

The world alpaca fibre production is around 5,000 tonnes per annum, of which, the current annual alpaca fibre production in Australia is estimated at 75 tonnes *(1)*. With the limited quantity of Australian alpaca fibre, blending of alpaca fibre with wool is an option to utilise the alpaca fibre in commercial processing. Since alpaca fibres have a very smooth surface and very little crimp, processing pure alpaca fibres has been difficult. The relatively high crimp in fine wool promotes good fibre to fibre cohesion and hence easy processing. Alpaca fibres are also known for its unique softness. Therefore, blending alpaca with wool is expected to enhance the alpaca fibre processibility and impart unique softness to the wool/alpaca blend products.

Mean Fibre Diameter (MFD), staple length, fibre tensile strength, vegetable matter (VM), crimp, and many other wool fibre properties are believed to be important to the performance of the wool fibre processing and end products. Amongst all the important wool fibre properties, fibre crimp is a less significant factor in determining the value of wool fibre commodity. However, wool fibre crimp does affect the fibre processing performance and the properties of its end products.

Wool staple crimp can be expressed by crimp definition and crimp frequency *(2)*. Crimp definition may be simply described as a degree of alignment of the crimp. It relates to how clearly visible the crimp appears, which depends on whether all fibres curve together or not.

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Wools where the fibre crimp is not well aligned are poorly defined. Crimp frequency is defined as the number of crimp wavelengths per centimetre. Crimp frequency and crimp definition, together with greasy colour, tip length, dust and weathering represent the wool style, which is important in determining the processing performance and quality of final wool products.

There is a good relationship between fibre crimp and fibre curvature (°/mm) *(3)*. Fibre crimp, expressed as fibre curvature, can be measured using commercial instruments such as OFDA (IWTO-47-98) and LaserScan (IWTO-12-95) *(3)*. There also appears to be a good relationship between fibre diameter and curvature for both alpaca and wool fibres *(4)* although the relationship for wool is dependent on the source and type of the wool *(3)*. The general trend is that fibre curvature decreases as the MFD increases. However, the curvature of alpaca fibre is much lower than the wool fibre. For fibres in the diameter range of 15-40μm, their curvature ranges are 50-15º/mm for alpaca fibre and 125-58º/mm for wool *(4)*.

Many studies have been devoted to evaluating the effect of staple crimp on processing performance and quality of wool products. Lamb et al *(2)* have demonstrated that, for superfine wools, a lower fibre crimp frequency results in a higher yarn evenness and lower ends-down in spinning. The degree of wool crimp also influences fibre bundle tenacity *(5)*, which is an important indicator of yarn quality. A high degree of wool crimp lead to poorer spinning performance and weaker and less even yarns *(2)*. Fibre curvature has hence become an input parameter in predicting the spinning performance and worsted yarn quality in the YarnSpec^{TM} software package *(6)*.

Wool fibre crimp changes down the fibre processing pipeline *(4, 7)*. A loss of wool fibre crimp occurs due to imposed strains during worsted processing, especially in high speed carding and spinning, and the crimp loss is largely irreversible. Studies *(8)* on the physical properties and processing performance of fine merino lamb's wool have shown that fibre crimp appeared to be as important as fibre diameter in determining the stiffness of fine to superfine merino wool fibres and the softness of the fabric produced from them. Haigh and Robinson *(9)* suggest that the selection of wool crimp frequency depends on particular product applications and low-crimp wools may suit woven fabrics best. On the whole, natural crimp is one of the main factors affecting wool processing performance and final product quality.

Alpaca fibre is softer and has very low crimp and poor crimp definition compared to wool fibre *(4)*. Blending alpaca and wool fibre is a common practice in the alpaca fibre industry. To date, little is known on how wool crimp affects the processing performance of alpaca/wool blends and the quality of the blend products. Knowledge of crimp effects on alpaca/wool blends will help guide textile manufacturers in designing and engineering fabrics with particular handle characteristics and mechanical properties. This study aims to understand how fibre curvature affects the properties of alpaca/wool blends. It reveals the effect of wool fibre curvature on the quality of blend slivers, yarns and fabrics. Comparative studies are conducted to examine the importance of the wool fibre crimp to the alpaca/wool blend yarns and fabrics.

Experimental

Fibre Materials. Table I shows the information on fibre materials used in this investigation. Test samples were collected from the initial form of the fibres or their processed materials.

Table I A list of wool and alpaca samples

Material	Form of fibre	Purpose
Superfine low-crimp (17.8µm, 62.7°/mm), high-crimp (17.9µm, 79.0°/mm) and superwashed (21µm, 56.8°/mm) wool tops	Commercial tops	Alpaca/wool blends
Fine (21.4µm, 37.6°/mm) and strong (31.7µm, 30.7°/mm) alpaca fibre lots	Greasy alpaca	Topmaking and alpaca/wool blends

Alpaca and Wool Topmaking. Two lots of alpaca fibres, fine (21.4µm) and strong (31.7µm), were scoured using a six-bowl wool scouring machine. The scoured alpaca fibres were processed to top using a modern worsted wool processing line at a low production speed.

Top Blending, Yarn Engineering and Fabric Knitting. To examine the effect of wool fibre on the performance of alpaca/wool blend, the blending was started from tops. Three types of blends at two blend ratios, 30% fine alpaca and 70% superfine low-crimp wool blend, 30% fine alpaca and 70% superfine high-crimp wool blend, and 50% strong alpaca and 50% superwash wool blend, were examined. The blended slivers were converted into rovings, and then spun to 20.2 tex yarns. The single yarns were folded and the two-fold yarns were knitted into fabrics. The low-crimp-wool blend and high-crimp-wool blend went through exactly the same processing routes, machines and machine settings from top blending to fabric knitting.

Measurements. Fibre length was measured using a SDL 218 - Fibre Diagram Machine. An Optical Fibre Diameter Analyser (OFDA100) was used to measure the fibre diameter and curvature. Yarn tensile properties were measured using an Uster Tensorapid 3 instrument at a gauge length of 50 cm and a jaw separation speed of 500 mm/min, 2000mm/min or 5000mm/min. This was to examine the effect of the testing speed on the tensile properties of blend yarns. An Uster 4 tester was used to measure the yarn evenness and hairiness values at a test speed of 200 m/min for 2.5 minutes. Fabric pilling tests were conducted on an ICI pillbox.

Fabric handle was subjectively evaluated by a panel of 20 assessors, half of which were experienced with softness assessment, and the rest of which were inexperienced assessors. Each assessor reported which one was softer between the fabrics of alpaca/high-crimp-wool blend and alpaca/low-crimp-wool blend.

The breaking strength of slivers was measured using a Lloyd material testing instrument at a gauge length of 50 cm and a jaw separation speed of 500 mm/min. The sliver cohesion force was expressed by the sliver breaking length in Equation 1.

$$\text{Breaking length (m)} = \frac{\text{Sliver breaking strength (g)}}{\text{Sliver linear density (g/m)}} \qquad (1)$$

Each sliver breaking length presented in the Results and Discussions section represents its mean and 95% confidence level.

All measurements were conducted in a testing laboratory where the temperature was controlled by a central conditioner at 20±2°C and relative humidity was maintained at 65±2%.

Results and Discussion

Effect of Fibre Curvature on Sliver Cohesion Force. It can be seen from Figure 1 that, for the fine alpaca fibre, the carded sliver is weaker (having a shorter breaking length) than its top. This is because gillings improved the fibre alignment, which led to more fibre-to-fibre frictional force along slivers. Strong alpaca fibre top has even shorter sliver breaking length than fine alpaca slivers, including carded sliver, due to the lack of fibre crimp in strong alpaca fibre. It was observed that the carded alpaca slivers were too weak to collect with the normal roller drafting and coiler arrangement on the CA7 card. A portable sliver coiler was used to collect the card sliver off the carding machine.

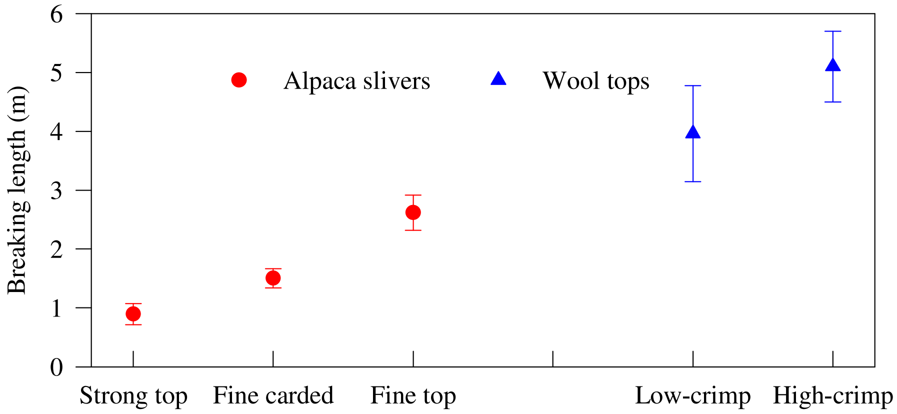

Figure 1 Breaking length of different slivers

Figure 1 also shows that the breaking length of alpaca tops is significantly shorter than that of wool tops. This is simply because alpaca staple has less crimp but a bulkier and fluffier structure compared to wool fibre. In addition, the coefficient of friction of alpaca fibre is smaller than that of wool fibre *(Wang et al 2005, Fibres and Polymers, in press)*, resulting in reduced inter-fibre cohesion of alpaca slivers, hence a low sliver breaking length. Comparing the low and high crimp tops in Figure 1, the trend is obvious: the low-crimp fibre top has a shorter breaking length than the high-crimp fibre top. Therefore, for a better sliver cohesion, high-crimp fibre should have an advantage.

Cohesion force of slivers of alpaca/wool blends tends to decrease as the blending passages increase, as shown in Figure 2. This may be due to a further reduction of fibre curvature through gillings and the alpaca fibre's smooth surface, which separates wool fibres of rough surfaces and creates a media between wool fibres to reduce the inter-fibre frictional force. Therefore, evenly blended slivers should have a minimum sliver breaking length. Comparing Figure 2 with Figure 1, it can also be seen that the blended slivers have a longer breaking length than the alpaca tops, but a shorter breaking length than wool tops. Blending wool with alpaca fibre therefore improves the alpaca fibre processibility.

It is worth mentioning that the fibre length of alpaca/high-crimp-wool blend is shorter than that of the alpaca/low-crimp-wool blend (as shown in Table II), but the alpaca/high-crimp-wool blend sliver has a higher breaking length (Figure 2). This suggests that fibre curvature plays a key role in determining sliver cohesion force.

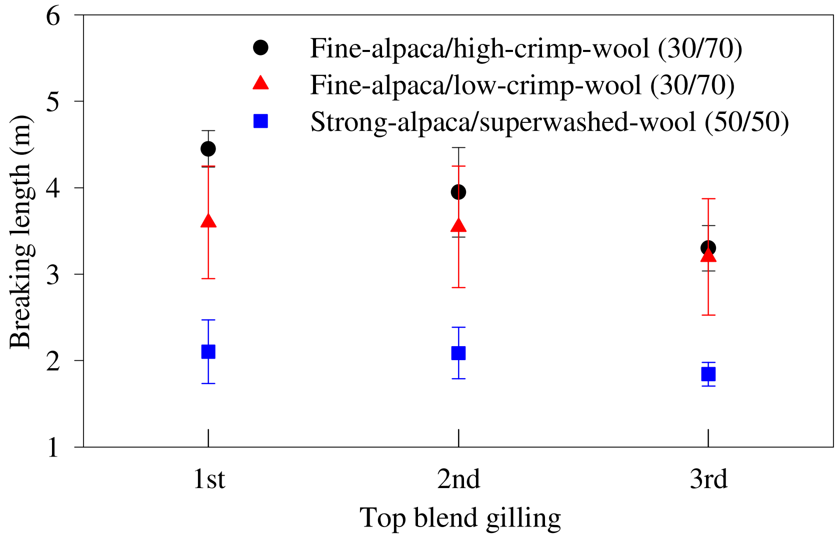

Figure 2 Breaking length of slivers of alpaca/wool blends at different blending passages

Table II Length properties of 3rd blend gilled slivers of fine alpaca and wool tops

Sliver	Hauteur (mm)	CVH (%)	% fibre < 30 mm
Alpaca/low-crimp-wool	67.5	44.0	11.3
Alpaca/high-crimp-wool	55.5	45.7	14.9

Yarn Properties. Figures 3A and 3B show that there is no significant difference (at 5% significance level) in yarn count and yarn evenness between alpaca/low-crimp-wool blend and alpaca/high-crimp-wool blend yarns. The high-crimp-wool blend yarn has a higher hairiness (H) value than the low-crimp-wool blend (Figure 3C). Yarn hairiness is an indirect measure of the number and cumulative length of all fibres protruding from the yarn surface. Yarns produced from short length fibres are more hairy than those from long fibres. The difference in hairiness between the two yarns may be directly caused by the differences in fibre length and short fibre content, as the fibre in low-crimp-wool blend is longer than the fibre in high-crimp-wool blend, and the short fibre content in low-crimp-wool blend is less than that in high-crimp-wool blend (Table II). Fibre curvature may also contribute to the differences. However, it is unclear at this stage what degree of difference the fibre curvature makes.

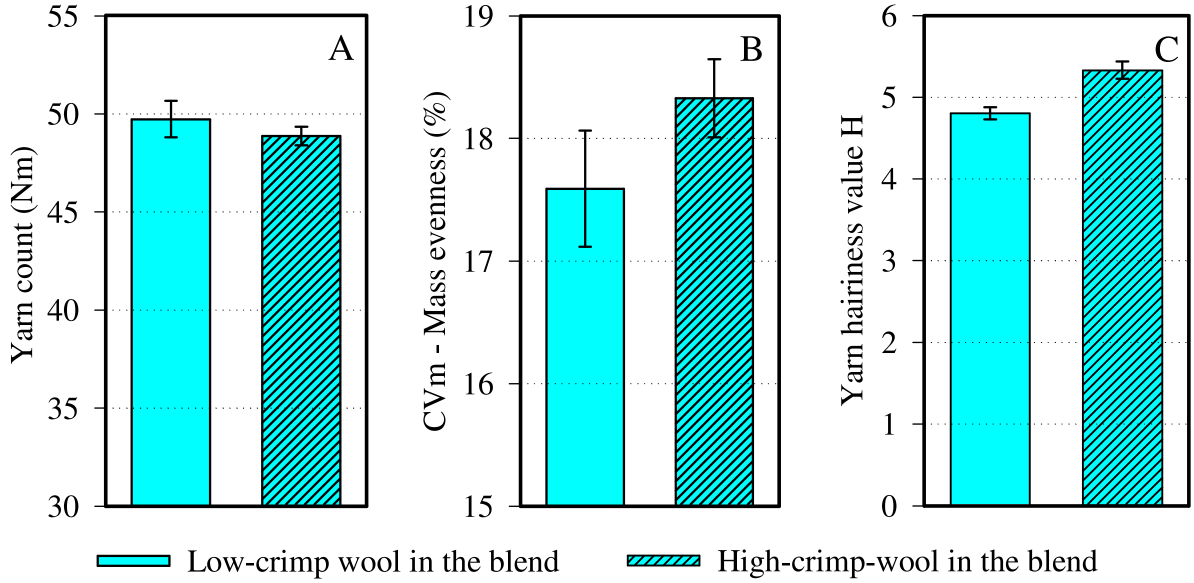

Figure 3 **Differences in yarn counts, evenness and hairiness between alpaca/low-crimp-wool and alpaca/high-crimp-wool blend yarns**

Both elongation and tenacity of the alpaca/low-crimp-wool blend yarn are higher (on average, approximately 14% and 4%, respectively) than those of the alpaca/high-crimp-wool blend yarn, as shown in Figure 4. This may be because of the difference in wool fibres used in the blends, especially fibre length and short fibre content. The tenacity of both yarns increases as the test speed increases. However, the effect of testing speed, especially a high speed, on yarn elongation is not as significant as on yarn tenacity.

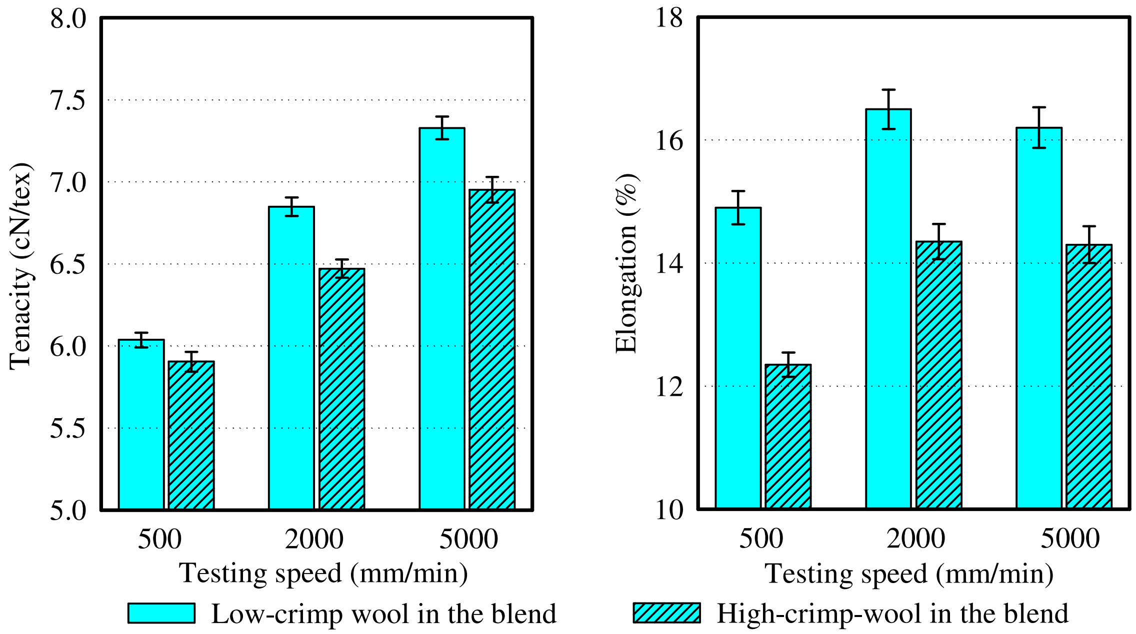

Figure 4 **Effect of tensile testing speed on the tensile properties of alpaca/wool blend yarns**

Fabric Weight and Handle. The low-crimp-wool blend fabric and high-crimp-wool blend fabric went through exactly the same processing routes and machines. Both yarns were satisfactory for knitting. The weights are 139.6g/m^2 and 139.9g/m^2 for low-crimp-wool blend fabric and high-crimp-wool blend fabric respectively. The slight weight difference should be a result of the difference in yarn counts (Figure 3A).

Handle of the knitted fabrics of alpaca/wool blends was assessed subjectively by a panel. All assessors agreed that the knitted fabric made from 30% fine alpaca and 70% high-crimp-wool blend has a softer handle than the knitted fabric made from 30% fine alpaca and 70% low-crimp-wool blend, although the difference in handle between the fabrics is small. After two standard washes, the fabric handle was assessed again. The preferred softer fabric is still the same high-crimp-wool blend.

The yarn initial modulus, as shown in Figure 5 agrees well with the subjective assessment of fabric handle. The initial modulus of high-crimp-wool blend yarn is lower than that of low-crimp-wool blend yarn, indicating that high-crimp-wool blend yarn is softer than the low-crimp-wool blend yarn.

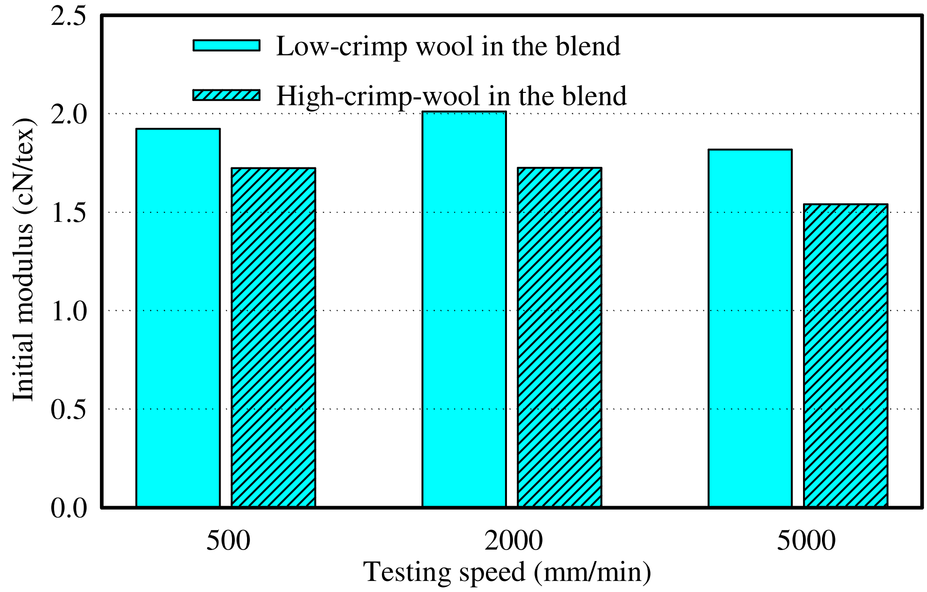

Figure 5 Initial moduli of alpaca/wool blend yarns at different tensile testing speeds

Fabric Pilling. The pilling assessments indicate that there is no significant difference in pilling performance on both alpaca/low-crimp-wool and alpaca/high-crimp-wool blend fabrics. They are both rated 4 with a slightly fuzzy surface. The alpaca/low-crimp-wool fabric seems to be slightly less fuzzy than alpaca/high-crimp-wool fabric. This is because the alpaca/low-crimp-wool yarn is less hairy than the alpaca/high-crimp-wool yarn.

Fabric Shrinkage. The dimensional stability results of knitted fabrics in Figure 6 show that after the stress relaxation (first one or two normal washes), their dimensional changes are basically stable. There is a trend that the low-crimp-wool blend tends to shrink less.

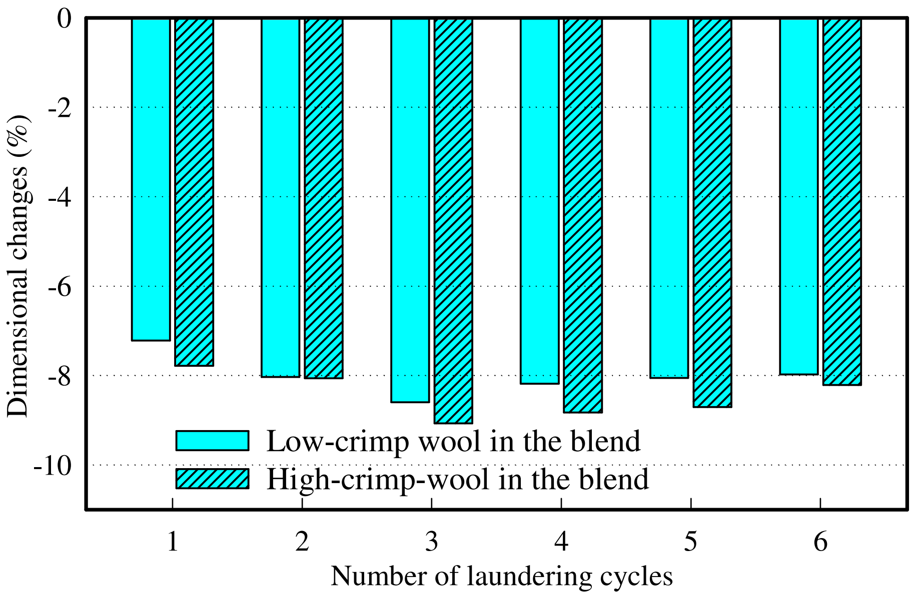

Figure 6 **Dimensional changes of alpaca/wool fabrics**

Conclusion

The low crimp and smooth surface of alpaca fibre make the alpaca fibre difficult to process, particularly in sliver/fibre transferring and delivering. This paper studied the effect of fibre curvature of wool and alpaca fibres on sliver cohesion forces and the performance of alpaca/wool blend yarns and fabrics. Fibre curvature in the alpaca/wool blend is higher than that in alpaca component. Blending alpaca fibre with wool improves the cohesion properties of the blend sliver, especially with high-crimp wools. For a high ratio of alpaca component in the blend, high-crimp wool may be used to improve sliver cohesion.

There is no significant difference in yarn count and yarn evenness between alpaca/low-crimp-wool blend and alpaca/high-crimp-wool blend yarns when they were processed the same way. However, the high-crimp-wool blend yarn has a higher hairiness value (H) than the low-crimp-wool blend possibly due to the differences in fibre length.

The alpaca/wool fabrics exhibit similar pilling performance. Their pill ratings are satisfactory for apparel fabrics. Dimensional changes are basically stable after the stress relaxation of blend fabrics. There is no significant difference in the level of dimension changes between the fabrics of low-crimp-wool and high-crimp-wool blends except that the alpaca/low-crimp-wool fabric tends to shrink less than the fabric made from alpaca/high-crimp-wool blend. The fabric made from alpaca/high-crimp-wool blend is softer than that made from alpaca/low-crimp-wool blend. This may be explained by the test results that the initial modulus of alpaca/high-crimp-wool blend yarn is lower than that of alpaca/low-crimp-wool blend yarns.

It is recommended that the selection of wool fibre curvature for alpaca/wool blend should depend on the blend ratio and end-uses. Generally, wool fibre crimp is not critical to the quality of the blends. However, for alpaca and superfine wool blends, high-crimp-wool may be preferred if the ratio of alpaca fibre component is high.

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