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Dehairing Australian alpaca fibres with a cashmere dehairing machine

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Abstract: Many classes of alpaca fibres contain a certain amount of coarse fibres, which are strong and stiff, and cause discomfort to the end users of the alpaca fibre products. It is therefore desirable to separate the coarse fibres from the fine alpaca fibres. This paper reports trial results on alpaca dehairing using a cashmere dehairing machine. The diameters of alpaca fleece, dehaired alpaca fibres and removed alpaca fibres were analysed, and the fibre lengths before and after dehairing have been compared. The results indicate that it is feasible to dehair alpaca fibres using a cashmere dehairing facility. The dehaired alpaca fibres are cleaner, bulkier and softer, with around 1.5 μm reduction in average fibre diameter, but the dehairing process shortens the dehaired fibre length considerably. The dehairing effectiveness of coarse fibre removal using the cashmere dehairing technology has also been discussed in this paper.

Key words: Alpaca, dehairing, fibre diameter, fibre damage, dehairing effectiveness.

INTRODUCTION

Alpaca fibre is a specialty animal fibre. It is sought after for its softness, warmth, lightness, range of natural colour, and good strength. The world alpaca fibre production is around 5,000 tonnes per annum, mostly produced in Peru (approximately 3,500 tonnes) (Wang *et al.*, 2003). Australia currently has the largest alpaca herd outside South America, with approximately 85,000 alpacas (Australian Alpaca Fleece Ltd. Press Release, May 2006). Australia has sound pastures and modern technologies for breeding the best stocks. There is also an increasing demand for alpaca fibres in a niche market. Australia thus has a great potential for a viable alpaca fibre industry, with the national herd numbers growing at about 18% per annum (Australian Alpaca Fleece Ltd. Press Release, May 2006). Each alpaca can produce 6–8 kg greasy fleece every year. It is estimated that by the year 2010 Australian alpaca fibre production could collectively reach up to 1,000 tonnes (greasy) per annum. Despite this, the alpaca fibre industry in Australia is still very small compared to the wool industry.

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There are many applications for alpaca fibres. They are typically blended with Merino wool or other fibres for use in overcoats, scarves, blankets and high-fashion knitwear, mainly because their smooth and silky nature makes alpaca fibres difficult to process alone, compounded by the small quantity of the fibre currently available. To better utilise the fibre, the Australian alpaca fibre industry is currently classing alpaca fibre into several clearly defined micron ranges (5 categories), length groups (5 categories) and colour separation regimes (6 categories) (Wang *et al.*, 2003) as shown in Table 1. Within some colour groups, there are also sub-groups such as brown (BR) and dark brown (DKBR).

Because of the small volume of alpaca fibre production in Australia, each classing line represents a limited quantity of fibre, which is often insufficient to make up a large-scale processing batch on its own. As a result, few fibre processors are able to make use of small quantity of fibre for bulk production. The Strong and Extra Strong lines in particular have been overlooked because of their low value addition to the fibre processors. There is now an increasing trend of using alpaca fibres for pillow and quilt filling (Australian Alpaca Fleece Ltd. Press Release, May 2006), because of their distinctive warmth and softness attributes and the fact that they are natural fibres. In particular, some Medium and Strong alpaca fibres, which have poor spinnability and low commercial value (such as H3, H4 and H5 grades in Table 2), have been extensively used in quilts, doonas and pillows. They are normally blended with wool, cotton or polyester to create the optimal blend for each market and climate from 25% alpaca to 100%

Table 1 **Australian alpaca fibre diameter, length and colour classing lines**

Fibre diameter		Length	Colour
Superfine (SF)	<20 μm	A: 120–150 mm	White (W)
Fine (F)	20–23 μm	B: 80–120 mm	Fawn (F)
Medium (M)	23–26 μm	C: 60–80 mm	Brown [light brown (BR), dark brown (DKBR)]
Strong (S)	26–30 μm	D: <60 mm	Black (BLK)
Extra Strong (XS)	>30 μm	O (overgrown): >150 mm	Rose grey/roan (RG), Grey (G)

Table 2 **Price and hair requirement for A/B length group (80−120 mm) in white/light-fawn colour classed in different micron ranges (AAFL grower raw fleece prices, October 2005)**

Grade	Fibre diameter	Price ($/kg)	Hair content requirement
H1	SF (<20 μm)	25	Min guard hair
H2	F (20–23 μm)	10	Min guard hair
H3	M (23–26 μm)	5	No excessive guard hair
H4	S (26–30 μm)	4	Some guard hair
H5	XS (>30 μm)	1.8	Some guard hair

alpaca fibre. However, strong and stiff fibres in these classed lines can cause discomfort to the end users because such fibres often poke through quilts and pillow covers. Therefore, removing coarse fibres and foreign matters from the alpaca filling material is desirable for such applications. In addition, raw alpaca fibre needs to be opened properly before it can be used as filling materials.

Apart from the vegetable matter and dirt that adversely affect the direct application of scoured alpaca fibres, coarse fibres in next-to-skin products often cause prickle and affect the handle and comfort properties (Kennis, 1992; Naylor *et al.*, 1997). As alpaca fibres come from different regions and are harvested during different seasons, the fibre characteristics within a classed line often vary. Therefore, opening and blending fibres homogeneously will be beneficial to the fibre products. Especially, during woollen processing, using proper opened alpaca fibres can make alpaca fibre blending easier and produce better-quality yarns. The dehairing process will help fibre opening and blending. In addition, guard hair content affects alpaca fibre price, as shown in Table 2. Finer fibres are valued highly, and removal of coarse fibre would lead to micron reduction in the dehaired fibre. Hence, value could also be added to the alpaca clips through reclassing the dehaired fibres.

This paper explores the technical feasibility of dehairing alpaca fibres using a prototype cashmere dehairing machine [Singh, 2003; Singh *et al.*, 2005]. The diameters of scoured alpaca fleece, dehaired alpaca fibres and removed alpaca fibres were measured by an optical-based fibre diameter analyser (OFDA), and the results were analysed to reveal the effectiveness of alpaca fibre dehairing. Fibre length was also measured to assess the fibre damage due to dehairing. Finally, the effectiveness of alpaca fibre dehairing and the benefit of possible reclassing of dehaired fibres have been discussed.

EXPERIMENTAL

A modular type of dehairing machine, which was built for cashmere dehairing, was used for both cashmere and alpaca fibre dehairing in this study. As shown in Figure 1, this machine consists of six dehairing units, each comprising a pair of feed rollers, a combing roller and a transfer roller. Details of the machine have been described elsewhere (Singh, 2003; Singh *et al.*, 2005). The output rate for dehairing cashmere was 2–2.3 kg/h, but it has been substantially increased to about 6 kg/h for alpaca fibre dehairing. As the value adding for alpaca fibre dehairing is much less than cashmere dehairing, the production rate for alpaca fibre dehairing has to increase in order to make the practice of alpaca fibre dehairing commercially viable. The output rate of alpaca dehairing was increased with the combination of elevated roller speeds (all roller speeds were increased by 25% compared to cashmere dehairing) and throughput. Both combing rollers to knives and combing rollers to transfer rollers were set to 0.38 mm for alpaca and cashmere dehairing. The feed rollers to combing rollers were set to 0.23 and 0.50 mm for cashmere and alpaca dehairing, respectively. The wider setting for alpaca fibre dehairing was to reduce combing roller droppings and increase the output weight.

Commercially scoured Australian alpaca fibres (a Medium-classed alpaca fibre lot, a Strong-classed alpaca fibre lot and an Extra Strong–classed alpaca fibre lot) were used for the dehairing trials. They are typical materials used for quilts and doonas. Droppings from the first two

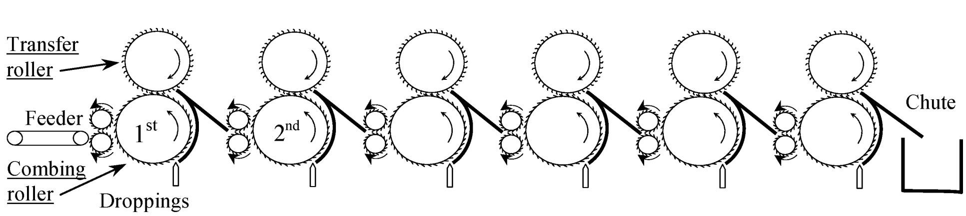

Figure 1 Schematic diagram of the modular-type dehairing machine used for alpaca fibre dehairing.

combing rollers that contained individualised coarse alpaca fibres were taken out as removed fibre (including dirt and vegetable matters). When some lumps of unopened clusters of alpaca fibre were found in the droppings under the first and second combing rollers, they were picked out and put back to the feeding unit for further dehairing. Fibre samples were randomly collected from the fibre feeding unit (Scoured/Raw fibre), droppings under the first and second combing rollers (Removed fibre) and dehaired fibre collection chute (Dehaired fibre) of the dehairing machine for analysis. For comparison, scoured goat's wool was also used for dehairing.

The fibre diameter and curvature were measured using the OFDA instrument according to the IWTO-47-98 testing standard—measurement of the mean and distribution of fibre diameter of wool using an optical fibre diameter analyser. Raw and dehaired fibre length tests of Medium and Strong fibre lots were done by the hand draw method. Each fibre length result represented the average of five length tests. All fibre samples were conditioned in the standard testing laboratory (temperature of 20 ± 2°C and relative humidity of 65 ± 5%) for at least 24 hours before testing, then measured under the same standard conditions.

Single fibre tensile data were obtained using a Single Fibre Analyser (SIFAN, BSC Electronics, Perth, Australia), which first measured the diameter profile for calculating the diameter of a single fibre, and then produced a tensile curve of the fibre for determining the fibre initial modulus from the load versus strain curve. Single fibres were randomly sampled from scoured alpaca and raw cashmere fibres for tensile testing. As the gauge length for single fibre tests was set at 40 mm, any fibre shorter than 55 mm was discarded. Although the fibre selection was biased toward longer fibres, especially for cashmere fibres, testing results (fibre initial modulus data) would still be useful for comparing the fibre stiffness among alpaca fibres, cashmere fibres, and hairs. Each fibre diameter profile was measured at an interval of approximately 6 μm along the fibre length. The tensile tests were performed at a speed of 500 mm/min.

RESULTS AND DISCUSSION

Cashmere dehairing

The cashmere dehairing process can effectively separate guard hair from cashmere. The mean fibre diameter (MFD) of guard hair is approximately 5 times of the thickness of cashmere fibres (down), and the difference in fibre thickness between cashmere and guard hair is clearly visible to the naked eyes, as shown in Figure 2. Since guard hair is much stiffer than fine cashmere fibres, the scoured goat fleece can be easily separated into hair and fine cashmere through the dehairing process. Hair content tests revealed that the dehaired fibre, cashmere, contains less than 0.5% of guard hair by weight.

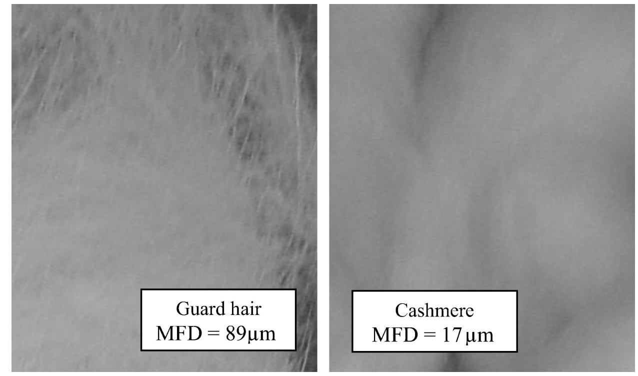

Figure 2 Visual difference between guard hair and cashmere fibres.

Alpaca fibre dehairing

Three alpaca dehairing trials were conducted using Medium, Strong and Extra Strong alpaca fibre lots, respectively. The ratios of removed fibre weight (including other impurities) to the input fibre weight were approximately 6%–9% for each fibre lot. It was observed that the cashmere dehairing machine was suitable for alpaca fibre dehairing, and there were no processing problems with dehairing the three alpaca fibre lots. The dropped fibre weight under each combing roller did not significantly affect the dehairing performance either. If the dropped fibre ratio was high, the lump of unopened dropped fibre needed to be dehaired again, which lowered dehairing efficiency.

Results in Table 3 show that the dehairing process does remove some coarse fibres, leading to the dehaired fibres being 1.4, 1.6 and 1.5 μm finer on average than the undehaired Medium, Strong and Extra Strong alpaca fibre lots, respectively. For all fibre lots examined, compared to the raw fibre and removed fibre, the dehaired fibre had a smaller coefficient of variation of fibre diameter (CV_D), a smaller percentage of fibres greater than 30 μm (%AE30) and a higher average fibre curvature (AvCur). These changes are important for fibre applications as filling materials.

It can also be seen in Table 3 that the removed fibres are much coarser than their respective raw fibres and dehaired fibres. The removed fibres also have a very high percentage of fibres with a diameter greater than 30 μm, and contain fibres of very low crimp.

Table 3 **OFDA results for alpaca fibre dehairing**

Fibre Lot	Sample	MFD (μm)	CV_D (%)	%AE30	AvCur (°/mm)
Medium	Raw fibre	23.3	28.8	12.2	36.7
	Removed fibre	48.5	34.4	83.2	17.8
	Dehaired fibre	22.0	26.3	7.5	40.3
Strong	Raw fibre	26.6	27.9	27.5	34.9
	Removed fibre	29.3	33.5	41.7	34.2
	Dehaired fibre	25.0	25.6	20.9	38.0
Extra Strong	Raw fibre	31.7	35.0	44.7	25.6
	Removed fibre	43.7	33.2	80.1	18.8
	Dehaired fibre	30.2	33.5	42.1	29.5

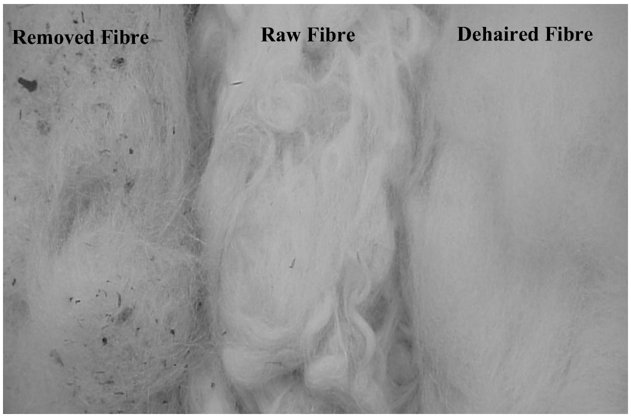

Figure 3 Visual appearance of fibres before and after dehairing (Extra Strong alpaca fibre lot).

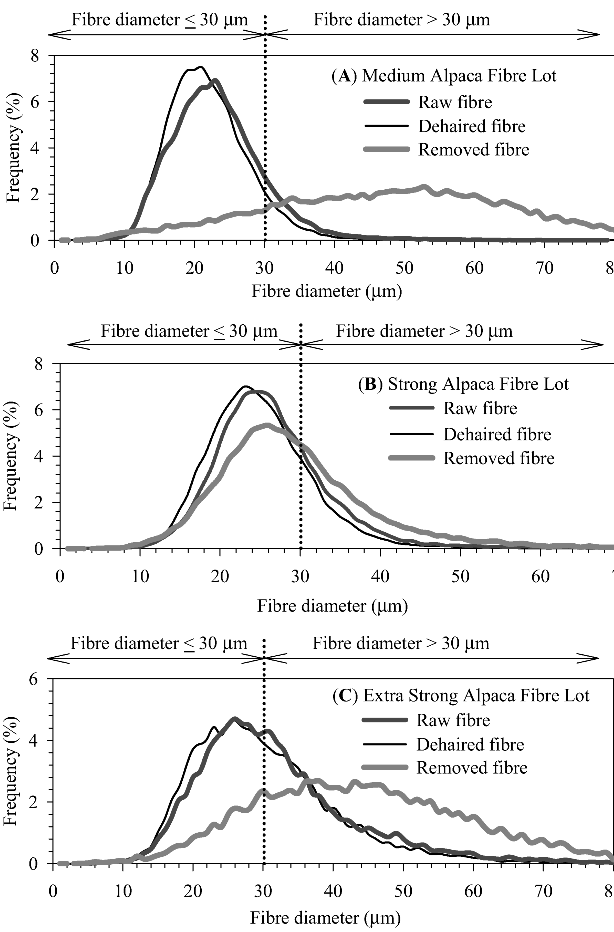

Figure 4 Fibre diameter distributions of raw, dehaired and removed alpaca fibres.

Apart from fibre micron reduction and curvature enhancement, other benefits from dehairing include the removal of vegetable matter and dirt as shown in Figure 3 (left), and opening and mixing of the fibres as shown in Figure 3 (right). The dehaired fibres are not only finer but also cleaner, bulkier and softer than the raw fibres. In addition, the dehaired fibre has been thoroughly opened and homogeneously blended.

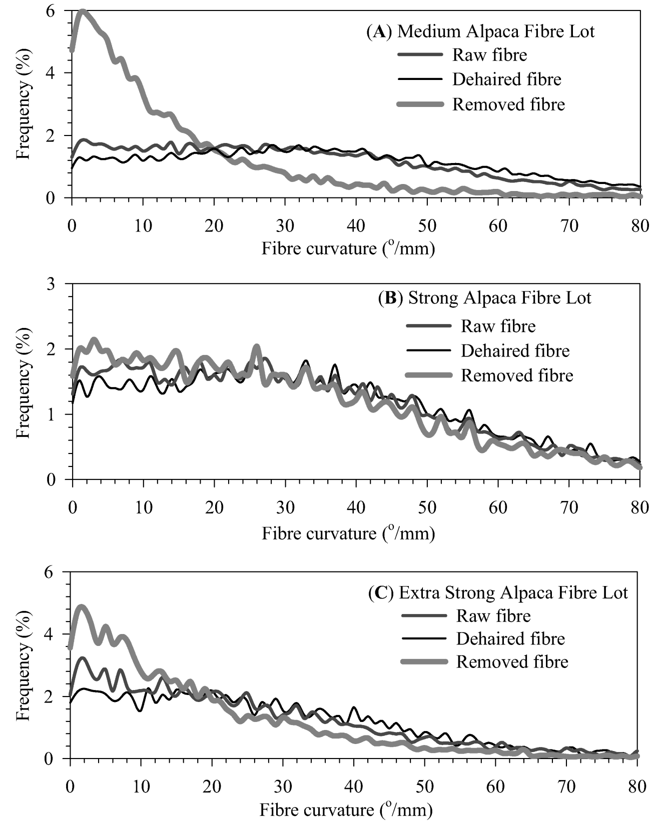

Figure 5 Fibre curvature distributions of Medium, Strong and Extra Strong alpaca fibre lots.

Alpaca fibre diameter and curvature distributions before and after dehairing

Figure 4 shows the diameter distributions of fibres at different positions in the dehairing machine. From the diameter distribution curves and comparison of raw and dehaired fibre curves, it can be seen that only a small portion of coarse fibres (i.e. fibre diameter > 30 μm) in the raw fibres have been removed during the dehairing process, and considerable amount of coarse fibres still remain in the dehaired fibres (Fig. 4). This indicates that the effectiveness of fibre separation in alpaca dehairing is much lower than in cashmere dehairing.

Fibre curvature distribution curves for the three fibre lots in Figure 5 show that a majority of removed fibres have very low fibre curvature values, indicating that these fibres are likely to be stiff and could poke through a quilt cover when they are used as a filling material.

Reasons behind difference in alpaca and cashmere dehairing effectiveness

From the results in Table 3 and Figures 4 and 5, it is obvious that alpaca fibre dehairing is not as efficient as cashmere dehairing in removing coarse fibres. Three major factors may contribute to this. First, the diameter difference between hair and fine fibre is smaller for alpaca fleece than cashmere goat fleece (Fig. 6). Second, the difference in fibre stiffness, as reflected by the initial modulus

Figure 6 Microscopic images of fibre snippets from goat fleece (Left) and alpaca staples (Right).

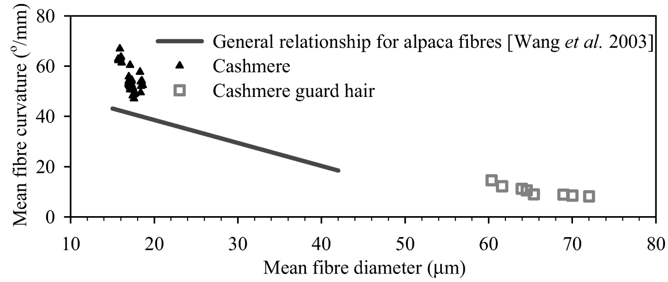

Figure 8 Relationship between fibre diameter and fibre curvature.

values measured using the SIFAN instrument (Fig. 7), is relatively small for alpaca fibres. Finally, the difference in fibre curvature is much smaller for alpaca fibres than for the guard hair and fine cashmere (Fig. 8). The very low curvature value for the cashmere guard hair facilities its removal in the dehairing process, because of the much reduced fibre-to-fibre cohesion and entanglement.

Alpaca fibre length results before and after dehairing

Results in Table 4 show that the dehaired alpaca fibre length is around 12 mm shorter than their scoured counterparts for both Medium- and Strong-classed lines. For instance, 50% of the fibres are longer than (known as the average length in cashmere industry) 68 mm and 55 mm for scoured and dehaired Medium alpaca, respectively. In other words, the average length of Medium alpaca fibre was shortened 13 mm during dehairing. Meanwhile, the average length of cashmere fibre is shortened by only 4 mm during dehairing. This suggests that the alpaca fibre dehairing process has significantly damaged the alpaca fibre. This may be because the dehairing output rate used for alpaca fibres (6 kg/h) was about 2 times higher than that for cashmere (2–2.3 kg/h). As alpaca fibre dehairing requires high-volume production compared to cashmere, it appears that alpaca fibre length damage could be a significant factor affecting other applications of the dehaired alpaca fibres instead of filling materials.

Australian shorn cashmere from farmed cashmere goats consists of 60%–70% coarse guard hairs, which is much higher than raw cashmere materials harvested from traditional cashmere producing countries, such as China. The dehairing machine used in this paper was purposely built for dehairing Australian goats' fleece, which contains significantly low Actual Clean Wool Content (ACWC). Further research on different dehairing machines/technologies and machine settings may be needed.

Table 4 **Fibre length results**

Class	Fibre	The longest fibre (mm)	5% of the fibres > (mm)	50% of the fibres > (mm)	95% of the fibres > (mm)
Medium	Scoured	120	78	68	30
	Dehaired	109	65	55	25
Strong	Scoured	131	77	65	27
	Dehaired	117	68	53	18
Cashmere	Scoured	114	96	48	21
	Dehaired	105	91	45	19

Reclassification of dehaired alpaca fibres

The diameters of the three alpaca fibre lots were intentionally selected to demonstrate the possible benefit from reclassing the dehaired fibres. There is a wide fibre diameter distribution range for dehaired alpaca fibres (Fig. 4), and the coarse fibres contribute to the MFD of the dehaired products. The difference in mean fibre diameters between dehaired and undehaired alpaca fibres is only around 1.5 μm (Table 3). The dehaired fibre diameter results in Table 3 suggest that after dehairing, the Medium and Strong alpaca fibre lots can be reclassified as a fine alpaca fibre line and a Medium alpaca fibre line, respectively, but the dehaired Extra Strong alpaca fibre lot remains in

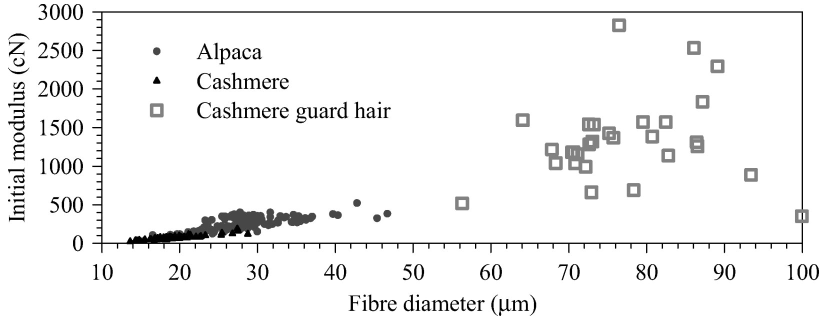

Figure 7 Stiffness of alpaca, cashmere and guard hair (initial modulus was calculated from the load–strain curve).

Table 5 **Estimation of total value of dehaired and dropped products**

Lot	Medium	Strong	Extra Strong
%AE30	12.2	27.5	44.7
D_{Coarse} (μm)	36	37	41
D_{Fine} (μm)	21.6	23.5	23.9
W_{AE30} (%)	28	48	70
Estimated value after dehairing ($/kg)	7.47	3.34	2.66

the same classing line. Therefore, if the raw fibre micron is properly selected, that is, dehairing fibre lots close to the micron borderline so that only a small improvement in fineness could reclass the fibre lots, it is possible to reclass the micron line of dehaired alpaca fibres. However, because of the length change, the dehaired alpaca fibre may be reclassed to a lower length group.

To further examine the fibre reclassing issue, it is assumed that the alpaca dehairing process is perfect, and the feed fibres can be ideally separated into coarse and fine fibre at a certain micron level (say 30 μm). When the coarse fibres (fibres with diameter greater than 30 μm) were completely removed through the dehairing process, the coarse fibre would take 12.3%, 27.5% and 44.7% of the fibre counts for Medium, Strong and Extra Strong lots, respectively (%AE30 in Table 3). According to the raw fibre diameter distribution plots in Figure 4, the MFD of the coarse fibre end (>30 μm) was approximately 36, 37 and 41 μm, respectively, for the three lots. These coarse fibres should be classed as an Extra Strong fibre line, and have less commercial value because their guard hair contents are very high. Assuming that all fibres less than or equal to 30 μm became dehaired fibre, the MFD of the dehaired fibre would be around 21.6, 23.5 and 23.9 μm, respectively, for the three fibre lots examined. The perfectly dehaired Medium fibre would be classed as a Fine fibre line, and the dehaired Strong and Extra Strong alpaca fibre lots would be classed as a Medium fibre line. The percentage of coarse fibre weight to the fibre lot, W_{AE30} (%), may be estimated using

$$W_{\text{AE30}} = \frac{\text{Coarse fibre weight}}{\text{Coarse and fine fibre weight}} = \frac{D_{\text{Coarse}}^2 \times \%\text{AE30}}{D_{\text{Coarse}}^2 \times \%\text{AE30} + D_{\text{Fine}}^2 \times (100 - \%\text{AE30})},$$

where D_{Coarse} and D_{Fine} are the mean fibre diameters of coarse and fine fibres, respectively, after the perfect dehairing; %AE30 is the percentage of fibres greater than 30 μm before dehairing.

Assuming that there is a 3% weight loss (sinkage) during dehairing, the length damage due to dehairing would not affect the fibre reclassing and the Extra Strong fibre is worth $1.8/kg, the maximum value of 1 kg of fibre after dehairing can be estimated as shown in Table 5.

As can be seen from the estimation based on an ideal scenario, there is not a great increase in the profit margin from alpaca fibre reclassing, not to mention the added cost of dehairing itself and the fact that perfect alpaca fibre dehairing cannot be achieved. Therefore, making a profit solely through reclassing the dehaired alpaca fibre to a finer line is a challenging proposition at present. The real benefit lies in the enhanced quality of the final alpaca product. For the purposes of removing foreign matter, some very coarse fibres and fibre opening, dehairing alpaca fibres is quite feasible. The local specialty fibre industry in Australia has been exploring this benefit with encouraging results.

CONCLUSIONS

This paper has examined the feasibility of dehairing Australian alpaca fleece with a cashmere dehairing machine. The dehaired alpaca fibres are cleaner, bulkier, softer and better suited as filling materials. There is a relatively small reduction in the average fibre diameter after alpaca fibre dehairing, and this could lead to reclassification of dehaired alpaca fibres to a finer line. The alpaca fibre dehairing is not as effective as cashmere dehairing because of the small differentials of fibre diameter, stiffness and crimp between fine and coarse alpaca fibres. As a result, only a relatively small amount of coarse fibres could be removed in the dehairing process. In addition, dehairing shortened the alpaca fibre length considerably. Thus, alpaca fibre dehairing is unlikely to be a viable practice if the aim is solely to reduce the average fibre diameter and reclassify the dehaired fibre to a finer line. The true benefit should be the enhanced quality of the final alpaca products such as quilts and doonas.

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