Processing and quality of cashmere tops for ultrafine wool worsted blend fabrics

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Keywords Wool fabric, Textile finishing
Abstract This study has focussed on three main areas. First, an evaluation of the physical attributes of cashmere tops available to commercial spinners; second, the influence of processing variables on the efficiency of producing cashmere tops from raw Australian cashmere; and third, the influence of design of cashmere ultrafine wool blends on the fibre curvature of tops. Testing the physical attributes of cashmere tops from traditional and new sources of supply, was followed by statistical analyses based on factors of origin, processor and other determinants. The analyses demonstrated important processor effects and also that cashmere from different origins shows commercially important variations in fibre attributes. It was possible to efficiently produce Australian cashmere tops with Hauteur, tenacity, extension, softness and residual guard hairs quality attributes equivalent to those observed in the best cashmere tops. The blending of cashmere with wool resulted in a reduction of the mean fibre curvature of the blend compared with the unblended wool. The present work demonstrated that the fibre curvature properties of blended low crimp ultrafine wool tops were closer to the properties of pure cashmere tops than were tops made from blended standard high crimp ultrafine wool. The attributes of textiles made from the relatively rare Australian low curvature cashmere could enhance the marketability of both Australian cashmere and low curvature wool.

1.Introduction

Cashmere is a rare exotic animal fibre used to produce soft luxurious apparel. It is expensive to purchase, and needs specialist processing, details of which are kept as tightly guarded secrets. Given the lack of technical information available on the dehairing, worsted processing and quality of cashmere textiles, a series of experiments have been completed (McGregor, 2001). This report is part of that larger study which compared the quality and processing of Australian cashmere into tops and the blending and knitted fabric properties of low fibre curvature and high fibre curvature ultrafine wool when blended with Australian cashmere.

Forte´ Cashmere Company believed that Australian cashmere had the length of Mongolian cashmere (Hopkins, 1987), a source often used for cashmere top making, but provided no data. The Italian processor Nesti (1989) believed that Australia had the potential to produce fine cashmere of 100mm length, capable of producing a top with a Hauteur of 55 mm. Such a product had not been seen, but no evidence was provided to support his view. Within few years, according to Levinge (1993), companies had developed the ability to produce 50mm Chinese top that matched the performance of Australian cashmere. Despite these views, no commercial processing of Australian worsted cashmere yarn has occurred other than the processing of knitwear samples by Dawson International (Smith, 1987, 1992) and sampling trials by Forte´ and their customers (Anonymous, 1991). In 1992, Smith said that the worsted garments made from 17.5mm Australasian cashmere displayed superior handle to garments made from 15mm Chinese woollen spun cashmere. He reported that these garments did not pill, cockle or stretch.

An earlier report provided details of the raw wool top making performance and the quality of the pure wool and cashmere tops that were processed into 30 tex single yarns and knitted into plain jersey fabrics (McGregor and Postle, 2002). It has been demonstrated that Australian dehaired cashmere has greater length after carding, lower fibre curvature and lower resistance to compression than dehaired cashmere from traditional sources (McGregor, 2000a, 2001). These data are the first objective evidence available indicating that Australian dehaired cashmere should perform at a superior level during top making than cashmere from Iran and Mongolia. This paper provides details of:
(1) a survey of the physical attributes of international cashmere tops available to commercial spinners;
(2) the influence of processing variables on quality attributes of Australian cashmere tops; and
(3) the influence of design of cashmere ultrafine wool blends on the fibre curvature of tops.

2.Methods

2.1 Survey of attributes of international cashmere tops available to commercial spinners
Samples of commercial cashmere tops (n ¼ 25) were provided by manufacturers in Europe, Iran, China and Australia and were collected by the author. Fibre classed as Cashgora by cashmere marketing agencies and processed into tops was included. Mean fibre diameter (MFD) and diameter distribution (coefficient of variation, CV(D) and per cent .30mm), fibre curvature (FC, 8/mm), medullated fibre incidence (per cent w/w) and diameter (white samples only) were determined by mini coring dehaired cashmere samples or guillotining tops. Following aqueous scouring, two subsamples were measured twice (8,000 counts for each measurement) using the OFDA100 (IWTO, 1995, 1996). Fibre length was measured by Almeter (IWTO, 1985). Resistance to compression was determined according to AS 3535 (1988). Not all samples were tested for Hauteur. Samples of top were measured for bundle tenacity and bundle extension using the Sirolan-Tensor (Yang et al., 1996). The strain rate was set at 20 mm/min and the gauge length at 3.2 mm.
Attributes were modelled as a function of origin and processor using multiple regression with factors (Genstat, 2000). There was no evidence of interaction between the origin and processor. Residual standard deviation of regressions (RSD) and correlation coefficients are provided. The initial geographical origins could be sensibly grouped into broader regions without losing any explanatory power of the model. The final origins were: West Asia (Iran, Turkey, Afghanistan), Eastern Asia (China including inner Mongolia, but excluding Xinjiang Autonomous Region), Central Asia (Western Mongolia, Xinjiang Autonomous Region of China), New (only one top from New Origins was available) and Cashgora. For fibre curvature, Iran was a separate origin. Some data were presented as box plots, showing the median, upper and lower quartiles with outliers, plotted in country or origin groups.

2.2 Influence of processing variables on quality attributes of Australian cashmere tops
Cashmere was purchased to specification from the Australian Cashmere Marketing Corporation. It was sampled by core testing and shipped to Cashmere Processors Ltd, Auckland, New Zealand, who had been dehairing cashmere for 10 years. Following dehairing, the bulk of the cashmere was carded, gilled thrice with a draft of 4-5 and shipped to the University of New South Wales. Combing trials were undertaken on a PB25L worsted combing machine designed for fine and short wools of 21mm and finer (N. Schlumberger et Cie, Guebwiller, Haut-Rhin, France) by adjusting the distance from nipper to drawing-off rollers with the setting altered from the minimum of 23-42.5 mm. For the experiment described in Section 3, the setting was set at 25 mm. To maintain combed sliver cohesion, it was necessary to apply twist at a rate of 4 tpm. Following finisher gilling, Almeter samples were given 36 turns of twist within 10 min, and were tied and stored. Tops were tested for a range of physical attributes using the methods described earlier. Fibre length on second grade cashmere and noils was measured using a modified length after carding procedure (LAC) and tops by Almeter (IWTO, 1985).

2.3 Influence of design of cashmere ultrafine wool blends on the fibre curvature of tops
This study was undertaken as a replicated experiment. This experiment had nine treatments. The design was: Blend/(WT * BR) £ 3 replicates. Blend was analysed as: Control (CM), specified as 100 per cent Australian cashmere; Blends, blends of cashmere with wool and the pure wool treatments. WT, wool type had two levels: SW, standard high crimp ultrafine wool tops; LCW, soft handling low crimp ultrafine wool tops. BR, referred to blend ratio and had four levels specified as: 75, 50, 25 and 0 referring to the percentage of cashmere in the blend. In the graphical representation of results, BR 100 refers to the control, CM. Raw wool was tested as described for cashmere. Wool was processed into tops and following combing, but before gilling, was allocated at random into three replicates and treatments. Following three blending gillings and two finisher gillings tops were sampled. Data are given for selected measurements.

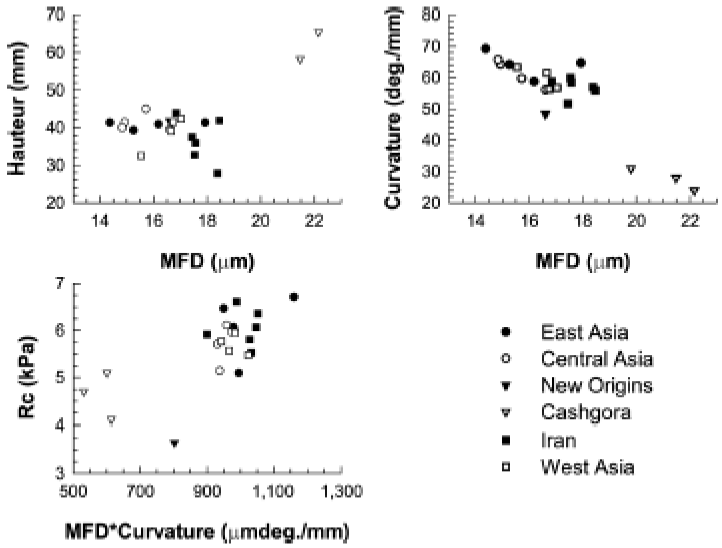
3. Results

3.1 Survey of attributes of international cashmere tops available to commercial spinners
Data from all origins have been pooled and summarised in Table I.
3.1.1 MFD. The MFD of cashmere tops ranged from 15.2 to 19.3um (Table I, Figure 1). Modelling indicated that origin was significant (P <0:001), but processor was not significant (P>0:25) and the model accounted for only 50 per cent of the variation (r= 0:71; RSD = 1:05). This suggests that once cashmere is combed, it is less influenced by the effects of processor that affect the attributes of dehaired cashmere.
3.1.2 Fibre curvature. No significant regression could be modelled. Origin was only significant at P = 0:06: Fibre curvature of tops was strongly related to MFD (Figure 1) with curvature declining 5.48/mm for each 1um increase in MFD. The linear regression constants for the relationship between FC and MFD were: FC = 150:9 2 5:4(0:80)MFD: RSD = 6:7; r = 0:81; P<0:001.

Table I.
Mean, SD and range of pooled data for attributes of international cashmere tops and a comparison with the attributes of the experimental Australian cashmere top

Top attribute	Mean	SD	Maximum	Minimum	Present experiment
MFD, μm	17.3	1.2	19.3	15.2	16.6
CV(D), per cent	21.3	1.2	23.8	19.8	20.6
Per cent of fibres $>30\,\mu$m	0.6	0.4	1.6	0.1	0.2
Fibre curvature, °/mm	59.2	5.0	68.5	48.9	48.4
Resistance to compression, kPa	6.1	1.2	8.3	3.7	3.7
Incidence of medullated fibre, per cent w/w	0.4	0.5	1.5	0.1	0.1
Mean medullated fibre diameter, μm	34.3	9.1	51.7	26.8	33.9
Hauteur, mm	39.4	4.5	45	28	42
CV(H), per cent	42.6	7.0	57.4	31.8	45.0
Hauteur, per cent of fibres <25 mm	21.3	11.5	51.1	6.9	20.1
Hauteur longest 5 per cent, mm	70.5	6.2	82	59	76
Barbe, mm	46.7	4.5	54	37	50
CV(B), per cent	37.8	5.0	47.8	31.2	12.0
Ratio Hauteur: MFD, mm/μm	2.37	0.38	2.96	1.52	2.49
Bundle tenacity, cN/tex	10.3	1.0	12.0	8.3	11.2
Bundle extension, per cent	38.8	6.3	50.0	19.5	50.0

Figure 1. Various fibre attributes of cashmere tops from different origins



3.1.3 Resistance to compression. The fitted model included only origin and processor (RSD = 0:52; r =0:87). Resistance to compression of tops was poorly related to fibre curvature or the product of fibre curvature and MFD (Figure 1) with the spread of data points being reduced with the variate MFD·FC.
3.1.4 Hauteur. Hauteur ranged from 28 to 45mm (Table I, Figure 1). The regression for top hauteur (RSD = 3:46; r = 0:90) included only origin ($P < 0:001$) and processor ($P = 0:044$) with origin alone accounting for 74 per cent of the variation. This model predicted that the longest tops came from New Origins with the tops from East Asia 7mm shorter and that from Western Asia 11mm shorter.
3.1.5 Bundle tenacity and extension. The ranges in bundle tenacity and bundle extension are shown in Figure 2. Prediction modelling for bundle tenacity revealed that origin and processor were only significant at P = 0:1 and they were excluded from the final model. Only Hauteur was significant (Figure 3). The linear regression constants for the relationship between tenacity (cN/tex) and Hauteur (mm) were: tenacity = 5.5 + 0.12 (0:04)Hauteur: RSD = 0:86; r = 0:55; P <0:01.

3.2 Influence of processing variables on quality attributes of Australian cashmere tops
The amount of cashmere recovered after dehairing was similar to that predicted by the core testing undertaken by the Australian Wool Testing Authority. The visual inspection of the coarse hair removed during dehairing indicated that all the cashmere was removed during dehairing. Of the cashmere dehaired, 8.4 per cent was of inferior length grades of which nearly 5 per cent was discarded as short fibre machine droppings (Table II). The reported scouring yield of 94.9 per cent, was less than expected, as the mean washing yield of the purchased bales and grower lots (when adjusted for the weight of the lots) was 96.6 per cent.

Figure 2. Box plots of bundle tenacity and bundle extension of cashmere tops from different origins (IR, Iran; WA, West Asia; CH, China; CA, Central Asia)

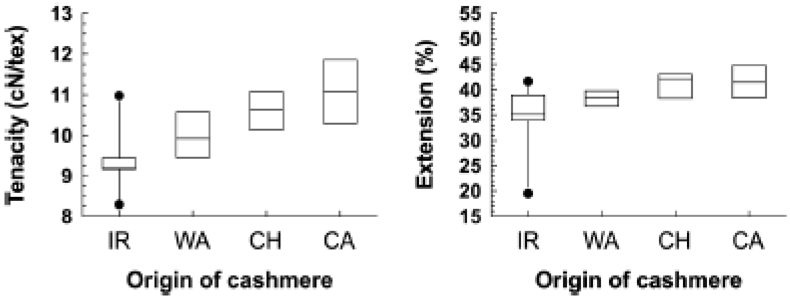


Figure 3. The relationship between bundle tenacity and Hauteur of cashmere tops (pooled data from all origins)

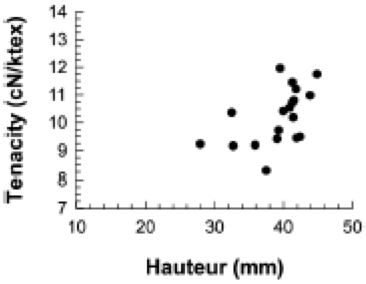


Table II. Reconciliation of cashmere fibre weight during purchase, sampling and processing

Processing step	Weight (kg)	Proportion dehaired cashmere per cent
Total weight of hair-in raw cashmere less samples (AWTA tests)	372.9[a]	–
Weight of cashmere down less samples (AWTA tests)	125.3[a]	–
Weight of dehaired cashmere at end of dehairing[b]		
Cashmere (in sliver form)	116.6	91.6
Second grade cashmere	4.7	3.7
Short fibre machine droppings	6.0	4.7
Total (not adjusted for moisture)	127.3	100.0

Notes: [a]Values adjusted for moisture content; and [b]values provided by dehairer and not adjusted for moisture.

Results of the comb setting adjustment trial are shown in Figure 4 and the regression constants are given in Table III. Increasing the comb setting significantly increased the Hauteur of the combed cashmere and the production of noil. Following cashmere combing at the setting of 25 mm, the mean + SD noil yield was 16.0 +0.3 per cent (n = 81). Details of top and noil fibre attributes are shown in Table IV.

The properties of the experimental top are compared to the international tops in Table I.

Figure 4. The relationship between the comb setting, fibre length of the combed sliver and noil production for the experimental Australian cashmere

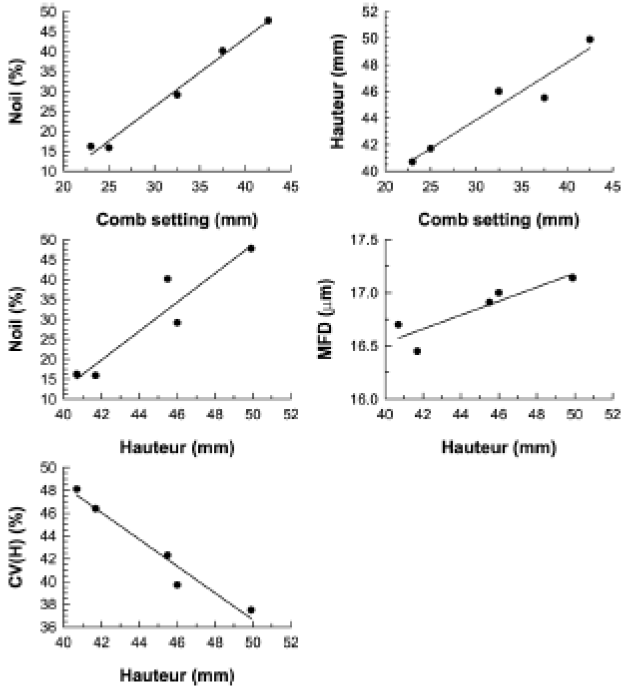


Table III. Regression and correlation coefficients for the relationships between the setting on the comb, properties of the combed cashmere sliver and the quantity of noil

Response variate	Regression constant	Dependent variate	Regression coefficient (se)	*r*	RSD	*P*
Hauteur	30.9	Comb setting	0.43 (0.07)	0.95	1.17	0.01
Noil	−25.3	Comb setting	1.72 (0.11)	0.99	1.81	0.001
MFD	13.9	Hauteur	0.07 (0.02)	0.85	0.14	0.05
Noil	−132.4	Hauteur	3.6 (0.8)	0.92	5.61	0.02
CV(H)	95.5	Hauteur	−1.18 (0.15)	0.97	1.10	0.005

3.3 Influence of design of cashmere ultrafine wool blends on the fibre curvature of tops
The fibre curvature of the blended tops was affected by Blend, WT and BR (all P<0:001; Figure 5). Fibre curvature of the pure tops before aqueous scouring were: CM 31.2, LCW 61.2, SW 96.38%mm; sed 1.13; P< 0:001 and after aqueous scouring were: CM 48.9, LCW 74.7, SW 108.58%mm; sedCM-WT 1.4, sedWT 0.9; P<0:001: Increasing blend ratio reduced fibre curvature and CV(H) (Figure 5).

4. Discussion

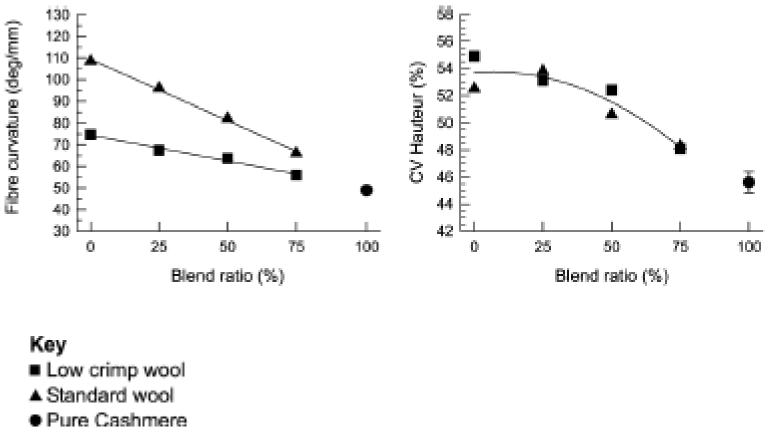
4.1 The effect of processor on cashmere top attribute
Typically cashmere woven goods for fine men's suiting consist of blends with super 120s, 130s, 140s or 150s wool. Sometimes such fabrics consist of 100 per cent cashmere, but usually they contain only 10 or 20 per cent cashmere. Cashmere is added to improve the fabric handle and marketability. For such classic fabrics, fine worsted yarns are usually used. Knowledge of the attributes of cashmere tops would aid yarn design, but information on cashmere tops is difficult to attain in the public domain.

Table IV. The relative amount, fibre length and other attributes of Australian cashmere following dehairing and combing

Description	Proportion (per cent)	Length (mm)	Barbe (mm)	MFD (μm)	Med (per cent w/w)	Tenacity (cN/tex)
Short machine droppings	4.7	–	–	–	–	–
Second grade cashmere	3.7	23.4	35.8	17.3	0.3	10.2
Machine waste and losses	5.0	–	–	–	–	–
Noil	16.0	13.5	17.3	15.0	0.1	7.0
Fibre in tops < 25 mm	9.0	In top	In top	–	–	In top
Fibre in tops > 25 mm	61.6	41.8	50.2	16.0	0.1	11.2

Note: Med, incidence of medullated fibres.

Figure 5. The fibre curvature and CV Hauteur of the blended cashmere and wool tops showing affect of blend ratio and wool type. The effective standard error is plotted as an error bar with pure cashmere



This analysis reports significant effects of processor and origin on the Hauteur of cashmere tops. Effects of processor on cashmere length are very important as the length of cashmere affects the price of cashmere (McGregor, 2000b) as well as spinning speed and yarn linear density. It is clearly in the interests of those aiming to produce fine cashmere yarns to determine which processors can maximise the length after carding of dehaired cashmere and/or the Hauteur and from which origins suitable cashmere may be attained. The fibre curvature of tops appeared to be less than that of dehaired cashmere (McGregor, 2000a), probably reflecting the removal of noil (McGregor, 2001). However, in this analysis the effect of processor includes: both difference in processing between dehairer processors and effect of subsequent processing, i.e. differences between cashmere top makers; and the differences due to fibre processed as a result of selection or purchase decisions. This analysis is not able to differentiate between these causes, where appropriate. For example, it has been demonstrated that dehairer processor affected the yellowness and lightness of commercial lots of cashmere (McGregor, 2000a). This may suggest that processing treatments such as scouring and drying conditions or the actual origin of cashmere purchased may affect the measured colour. The effect of top maker processor on Hauteur of cashmere tops may be due to the differences in machinery, machinery operation, processing operations etc. and/or the quality of dehaired cashmere processed.

4.1.2 Bundle tenacity

There are no reported data on the bundle strength of the cashmere top. Modelling by Yang et al. (1996) showed that a 10 per cent decrease in bundle tenacity roughly doubled the spinning ends-down and was equivalent to a decrease in Hauteur of 9 mm. On this basis, they concluded that bundle tenacity was potentially the third most important property in wool tops after MFD and

Hauteur. Higher tenacity fibres result in less fibre breakage and the potential use of the worsted spinning system. Worsted spun yarns are used to produce a wider range of more durable woven fabrics than is available from woollen spun short cashmere.

In the present study, the tenacity of the experimental Australian cashmere was at the high end of the results from the survey (Table I). The tenacity of cashmere tops in the survey was dependent on Hauteur, a finding reported for wool by the developers of the instrument (Yang et al., 1996). The mean value reported here for the bundle tenacity of cashmere tops appears to be about 5 per cent less than those reported for 18-25mm wool tops that had a mean Hauteur of 69mm (range 50-96 mm, Yang et al., 1996). If adjustment is made for the difference in Hauteur (30 mm) using the regression constant for top Hauteur (0.1206 cN/tex/mm), then cashmere tops would have a bundle tenacity of 25 per cent greater than that reported for wool tops. The bundle extension of these cashmere tops was similar to those reported for wool (Yang et al., 1996).

4.2 Cashmere processing

The dehairer was able to separate all the cashmere identified in the AWTA core tests. The recovery of all the cashmere was that no cashmere was lost in the separated coarse hair. The visual inspection of the coarse hair confirmed this result. In the reconciliation of the fibre some of the weights have not been corrected for moisture content, as samples were not available and so care needs to be exercised in interpreting these values. Of the cashmere dehaired, 8.4 per cent was of inferior length grades of which nearly 5 per cent was discarded as short fibre machine droppings. The cashmere of suitable length for further worsted processing was 91 per cent of the cashmere weight obtained by dehairing. The second grade cashmere droppings had a length after carding (LAC) of 23mm and are potentially suitable for certain woollen spinning applications, such as blending with wool or cotton in high twist yarns. The LAC of the dehaired cashmere was 28.8mm compared with the mean maximum raw fibre length of 75.3mm (McGregor, 2001). This indicates that the dehairing and carding processes resulted in a decrease in length by approximately 61 per cent. It is highly likely that the fibre length of the dehaired cashmere was reduced during carding, as is experienced during the carding of wool. In order to maintain the length of the dehaired cashmere fibre it is advisable for the Australian cashmere industry to investigate more suitable carding processes, including appropriate lubricants, for the long cashmere produced in Australia. It is likely that longer dehaired cashmere could be produced by keeping separate the longer cashmere produced during the first dehairing pass. This was deliberately not done in this experiment.

4.2.1 Combing. The regression coefficients obtained in the comb setting test indicated that for every 5mm increase in the settings, the following changes occurred in the resulting combed sliver: Hauteur increased by 2.1 mm, CV(H) declined by 2.4 per cent, noil increased by 8.6 per cent and MFD increased by 0.13mm (Table III). The results also indicate that it is possible to obtain a Hauteur of 50 mm, but that noil losses will approximate to 50 per cent. This may be commercially acceptable as Nesti (1989) reported that some outer Mongolian and Iranian cashmere is combed, but the loss of noils was reported to be as high as 35-38 per cent, a loss that would dramatically increase the cost of the yarn. Even after this level of noil removal, Nesti reported that the average length of the top was 33-38mm and was therefore unfit for spinning finer counts than metric 40s (,25 tex). Improved rectilinear combs can produce tops from 17mm cashmere that have a Hauteur of 44.5 mm, a CV(H) of 45.7 per cent while keeping waste at 8.5 per cent (Certo, 2001). The level of medullated fibre in the Australian cashmere top was at the lower end of that reported for sampled tops and the diameter of the medullated fibres was averaged for the sampled tops (Table I).

When the comb setting of 25mm was used, the 42mm Hauteur of the cashmere top was 55 per cent of the mean maximum raw cashmere length. The length properties of these cashmere tops place them at the middle to upper level of world cashmere tops (Table I).

The ratio of the Hauteur of the experimental cashmere to the MFD of the top, was 2.49 mm/mm compared with the mean values obtained for international cashmere tops of 2.37 mm/mm and Certo's (2001) recent report on a modern combing machine of 2.62 mm/mm. The improvements in lubrication may explain the increase in the ratio of Hauteur/MFD of wool reported over the past 15 years. In fine wool tops processed by Kurdo et al. (1986) this ratio averaged to 2.82 mm/mm and with commercial fine wool tops examined by McGregor (2001) the mean (^SD) ratio of Hauteur/MFD was 3.41 (0.22) mm/mm (range 3.13-3.69 mm/mm). Use of this mean and upper range ratio indicates that the potential Hauteur for Australian 16.6mm cashmere is 56-61 mm.

4.3 Influence of design of cashmere ultrafine wool blends on the fibre curvature of tops
Fibre curvature of raw wool affects the measured softness (compressibility or yielding to pressure) and stiffness of raw wool (Madeley et al., 1998; Swan, 1994; van Wyk, 1946). There has been a debate over the use of low curvature soft handling ultrafine wool, but low curvature ultrafine wool is relatively scarce. Only 5 per cent of 18-18.5mm wool lots can be expected to have a resistance to compression ,7.3 kPa (Whiteley et al., 1986). In a commercial flock bred for 16-18mm low staple crimp frequency wool only 12 per cent of the wool tested had a fibre curvature of ,808/mm (McGregor and Toland, 2002).

The present work demonstrates that when raw wools of differing fibre curvature were blended with cashmere of a much lower fibre curvature, there was a significant decline in fibre curvature of the blended tops. The implications of this are that the subsequent textiles should have a lower resistance to compression and are potentially softer. The present work demonstrated that the fibre curvature properties of blended low crimp ultrafine wool tops were closer to the fibre curvature properties of pure cashmere tops than were tops made from blended standard high crimp ultrafine wool.

5. Conclusions

Cashmere tops show commercially important variations in fibre attributes. Origin of cashmere and processor were the major determinant of cashmere top Hauteur. Cashmere from Australia can be efficiently processed to produce tops of long Hauteur, high tenacity and low fibre curvature compared with traditional cashmere and Australian cashmere is likely to have a softer handle. Differences in raw wool and raw cashmere fibre curvature attributes were translated into different blended fibre top properties. The fibre curvature properties of blended low crimp ultrafine wool tops were closer to the fibre curvature properties of pure cashmere tops than were tops made from blended standard high crimp ultrafine wool. The attributes of textiles made from the Australian low curvature cashmere could enhance the marketability of both Australian cashmere and low curvature ultrafine wool.

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