PROCEEDINGS OF 2006 CHINA INTERNATIONAL WOOL TEXTILE CONFERENCE & IWTO WOOL FORUM

Editors in Chief : Yao Mu
Jiang Shoushan

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ABSTRACT

"2006 China International Wool Textile Conference & IWTO Wool Forum" had received over 315 papers from all over the world. After final censoring, 113 papers were selected and published in the《Proceedings of 2006 China International Wool Textile Conference & IWTO Wool Forum》. It includes seven aspects in the wool textile science & technology field: Fiber Properties and Testing, Spinning and Yarns, Weaving and Fabrics, Dyeing and Dyestuff, Finishing Process and Technology, Special Physics Processing Technology, Trade and Management. Most of the authors of those papers are well established researchers in the field of wool textile. Therefore, the proceedings reflect the most advanced research development and achivement in this field. The publication of the proceedings will be a push to further developments of technology and research breakthrough in the wool textile field.

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The softness of cashmere raw materials and cashmere textiles

B. A. McGregor[1]*, R. Postle[2]

(1. Primary Industries Research Victoria, Department of Primary Industries, Attwood, Victoria, 3049, Australia; 2. Department of Textile Technology, University of New South Wales, Sydney, 2052, Australia)

Abstract: Recent studies evaluating the physical attributes of raw cashmere, dehaired cashmere, cashmere tops and cashmere knitwear are summarised. Commercial lots of cashmere from different Origins showed important variations in fiber attributes including fiber curvature and resistance to compression, fiber diameter and fiber length. Cashmere softness was related to fiber curvature. Cashmere fiber crimp frequency, a fundamental property of cashmere fiber, can be easily measured using the objective fiber curvature measurement. Cashmere fiber curvature is significantly affected by the nutritional management of goats. Cashmere samples tested from new Origins such as Australia were softer and longer than samples tested from traditional Origins of cashmere. Increasing the content of cashmere in a wool/cashmere blended knitted fabric generally resulted in a change in the measured fabric attribute in the direction of pure cashmere fabric. Knitted fabric made from worsted spun cashmere were more compressible (softer) and more resistant to pilling and appearance change than those made from superfine wool despite the cashmere yarns being hairier.

Key words: curvature; crimp; softness; cashmere; wool

0 Introduction

In the textbook on Textile fibers von Bergen[1] states "From time immemorial cashmere has been regarded as one of natural choicest products for its softness affords the wearer an extravagance of comfort and its superb soft texture brings to the garment all that may be desired in real elegance and distinction". This is still the view, as according to Watkins and Buxton[2], the greatest appeal of cashmere is its extreme softness. Softness is frequently equated with 'handle'. fiber fineness and resistance to compression are the most important parameter in the assessment of softness of wool fibers, although resistance to compression is primarily a function of fiber crimp[3-5]. fiber curvature measurement[6] now enables an objective and fast method of measuring a fundamental property of wool fiber, the fiber crimp frequency. Commercial measurement of fiber curvature is obtained with the Optical fiber Diameter Analyser (OFDA) and Laserscan but little is known about cashmere fiber curvature.

Many of the commercial attributes of cashmere that are important in wool processing and in the product attributes of cashmere textiles, particularly softness, have not been measured and therefore are not understood. This paper summarises recent Australian investigations into objectively measured attributes of commercial cashmere textiles, particularly fiber curvature and resistance to compression (soft-

* Corresponding author: Tel: 0061-3-92174364; E-mail: bruce. mcgregor @dpi. vic. gov. au

ness).

1 Raw cashmere

Commercial bales of Australian cashmere have relatively low levels of natural extraneous matter compared with traditional supplies from China. Australian cashmere has an average wool base of 80% and low levels of vegetable matter, wax, suint and soil (Table 1). The relatively low cashmere yield is a result of the goats being shorn of their entire fleece with the resultant fiber containing a high proportion of coarse guard hair that is removed during dehairing.

Table 1 Clean washing yield, mean fiber diameter (MFD), fiber curvature (FC), vegetable matter (VM) and wool base, ash, cashmere yield, wax and suint of commercial bales of Australian cashmere[7].

Trait	Washing yield/%	MFD /μm	FC /(°) · mm^{-1}	VM /%	Wool base /%	Ash /%	Cashmere yield(w/w)/%	Wax /%	Suint /%
Mean	96.4	17.0	51	0.8	80.4	1.9	33.3	3.0	4.2
s. d.	0.8	0.8	4	0.4	0.9	0.3	1.8	0.7	0.6

Generally, raw cashmere does not show staple crimp but cashmere fibers are crimped[8-9]. McGregor[8-9] has used raw cashmere samples collected from animals in China, Iran and Australia to demonstrate that raw cashmere fiber crimp can be estimated by fiber curvature measurements. Over 60% of the variation in cashmere fiber curvature was explained by the origin of the cashmere, cashmere fiber crimp frequency and cashmere mean fiber diameter. Based on the samples measured, Iranian cashmere had 7.5 (°)/mm higher fiber curvature than Chinese cashmere which had 4.6(°)/mm, higher fiber curvature than Australian cashmere ($P<0.001$). Increasing cashmere fiber crimp rate by 1 crimp/cm increased fiber curvature 4.1(°)/mm ($P<0.001$). This rate of increase was in addition to effects of origin and mean fiber diameter. Over the normal range of cashmere mean fiber diameter (13 to 18 μm), the rate of fiber curvature was reduced by 10.6(°)/mm.

Samples of Chinese Liaoning cashmere do show staple crimp[10]. In these samples, increasing staple crimp frequency by 1 crimp per cm was correlated with an increase in fiber curvature of 6.5(°)/mm ($r^2=0.61$)[11]. In raw Chinese Liaoning cashmere, there was a significant difference between each age and sex group in fiber curvature (bucks 52, does 65, kid bucks 78(°)/mm, $P<0.001$).

In Australian goats, cashmere fiber curvature was dependent on nutrition. In a controlled nutrition experiment, using goats individually pen fed for seven months, goats fed to lose weight grew less cashmere that was finer with significantly increased fiber curvature compared with goats fed to gain weight (Table 2).

Table 2 The effect of nutrition treatment on live weight change, cashmere production, cashmere mean fiber diameter (MFD), cashmere fiber length and cashmere fiber curvature (FC)[11-12].

Nutrition treatment	Live weight change * /g · d^{-1}	Cashmere weight/g	MFD /μm	Cashmere fiber length/mm	FC /(°) · mm^{-1}
Live weight loss	−28	146	16.67	87.7	61.3
Live weight maintain	+2	192	16.93	99.9	53.2
Live weight gain	+38	221	17.69	102.2	47.5
$sed_{loss-other}$; P-value		28.1; 0.05	0.38; 0.05	8.5; NS	4.7; 0.05
sed_{other}; P-value		19.9; NS	0.27; 0.05	6.0; NS	3.3; NS

* Fleece-free live weight change during cashmere growth period from mid December to mid April.

2 Dehaired cashmere

Samples of commercial dehaired cashmere (Table 3) from China (including Inner Mongolia and Xinjiang Autonomous Region), Iran, Turkey, Afghanistan, Australia, New Zealand, and the USA were tested and statistical analyses completed based on factors of Origin, processor and other determinants (McGregor 2001). Origin of cashmere and processor effects significantly affected cashmere mean fiber diameter, fiber curvature and resistance to compression. Chinese cashmere samples were finer than those from other Origins and cashmere from Australia was finer than that from Iran (Figure 1). There were significant differences in fiber curvature and resistance to compression between Origin. After adjustment for Processor effect, cashmere from New Origins had lower fiber curvature than that from Iran, East and Western Asia (Figure 1).

Table 3 Median and range of attributes of dehaired cashmere (n = 101)[8]

Top attribute	Median	s. d.	Maximum	Minimum
Mean fiber diameter(MFD)/μm	16.4	1.4	19.3	13.5
CV fiber diameter/%	21.7	1.6	29.0	19.8
fibers > 30 μm/%	0.5	0.5	2.1	0.1
fiber curvature/(°) · mm^{-1}	60.0	9.3	79.7	40.1
Resistance to compression/kPa	5.6	0.6	7.7	4.5
Incidence of medullated fiber(w/w)/%	0.43	2.38	8.8	0.0
Mean medullated fiber diameter/μm	34.8	12.3	62.9	23.6
LAC/mm	22.8	7.8	36	15
CV(LAC)/%	67.0	5.7	75.6	52.1
K25H/%	63.1	11.3	86.7	38.0
L5H/mm	53.6	10.6	77	32
Barbe/mm	33.6	7.1	50	19
Ratio LAC : MFD/mm · μm^{-1}	1.41	0.30	2.21	0.93
Bundle tenacity/cN · tex^{-1}	9.9	0.9	12.0	8.2
Bundle extension/%	40.8	4.5	50.0	31.3
Lightness	61.1	3.6	65.4	44.8
Yellowness	−0.3	1.8	3.7	−4.3

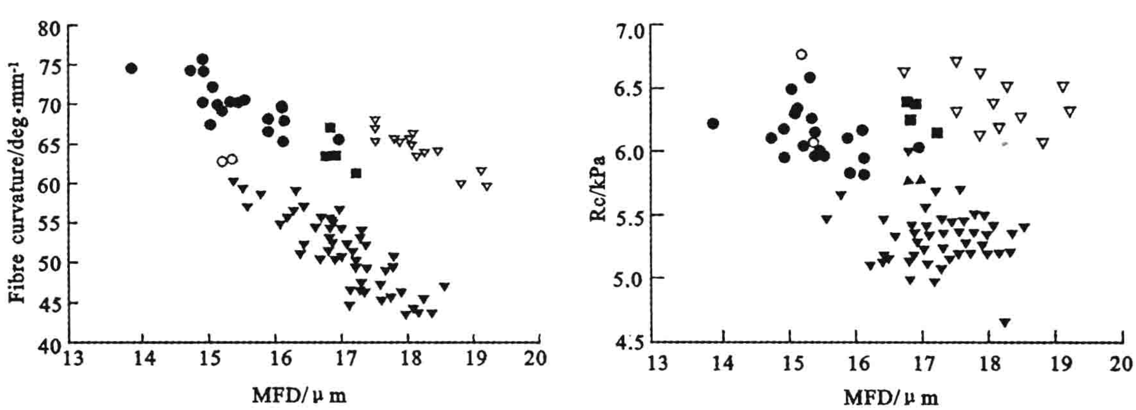

Fig. 1 The fiber curvature, resistance to compression (Rc) and mean fiber diameter (MFD) attributes of commercial lots of dehaired cashmere by Origin of fiber after adjustment for Processor effect (adapted from[8]).

●—China; ▽—Iran; ■—West Asia; ●—Central Asia; ●—Australian and other new origins

The fitted regression for resistance to compression (softness) was:

Dehaired cashmere resistance to compression = Constant + Origin ($P<0.001$) + Processor ($P<0.001$) − MFD ($P=0.02$; RSD = 0.24; $r=0.94$).

This analysis differentiated the cashmere produced in different regions of the world on the basis of the cashmere fiber attributes (Figure 1). By plotting any two of mean fiber diameter, fiber curvature and resistance to compression, cashmere from different producing regions segregate into distinct groupings. The plot of resistance to compression against fiber curvature (Figure 1) suggests that a general relationship exists for cashmere where increasing fiber curvature is correlated ($r=0.85$) with increasing resistance to compression.

If lower resistance to compression is related to softness of handle, then this study has identified that cashmere from New Origins of production is likely to have softer handle than cashmere from traditional Origins as it has significantly lower fiber curvature. The predominant form of crimping and the low rate of fiber crimping would explain the low resistance to compression of cashmere and the differences in resistance to compression of cashmere from different origins[9].

Using different samples McGregor[11] showed that in raw and dehaired Australian and Chinese Liaoning cashmere, increasing mean fiber diameter and cashmere fiber length were associated with decreasing fiber curvature, for each 3 μm increase in mean fiber diameter, fiber curvature declined 10 to 41 degrees/mm; for each 10 mm increase in cashmere fiber length, fiber curvature declined 3 to 13 degrees/mm. In Australian and Liaoning cashmere, the direction of response in fiber curvature to changes in mean fiber diameter and fiber length was similar.

The length after carding (LAC) of dehaired cashmere was affected by Origin[8]. The data shows that dehaired cashmere from New Origins had LAC's up to 20% longer than that from traditional Origins. The data also suggests that increasing mean fiber diameter was correlated with increasing LAC of dehaired cashmere. The fitted model line indicated that LAC increased 1.62 mm per 1 μm increase in mean fiber diameter, $r=0.87$. It is clear why most cashmere is processed on the woollen system as the short LAC of dehaired cashmere is unsuitable for worsted processing. This data indicates that dehaired cashmere from New Origins is longer and finer than cashmere from the Origins traditionally used for worsted processing. The regression for dehaired cashmere LAC was:

$$\text{Dehaired LAC}=\text{Constant} + \text{Origin}\times\text{Processor}\ (P<0.001) + \text{MFD}\ (P=0.002)+ \text{MFD}\times\text{Processor}\ (P=0.017)\quad (\text{RSD}=2.47;\ r=0.86;\ n=49).$$

The variation of lightness and yellowness of white cashmere (pooled data for dehaired cashmere and tops, $n = 66$) was large and of commercial significance for dyers[8]. Origin alone accounted for > 50% of the variation. Both lightness ($r = 0.86$) and yellowness ($r = 0.93$) regressions included Year and Processor effects (all $P<0.001$), but the years for the oldest samples were not significant, indicating that for these samples, the length of storage did not affect colour.

3 Cashmere tops

The range in attributes of commercial cashmere top attributes has been described by McGregor and Postle[13]. Modelling of top attributes was less precise than that of dehaired cashmere as the number of tops and processors was reduced ($n = 21$). Cashmere top data from all origins have been pooled and summarised in Table 4. Applying the fitted model for dehaired cashmere mean fiber diameter indicated that Origin was significant ($P<0.001$) but Processor was not significant ($P > 0.25$) and the model accounted for only 50% 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 dehaired cashmere.

fiber curvature of tops was strongly related to mean fiber diameter (MFD) with curvature declining 5.4 degrees/μm for each 1 μm increase in MFD. The fiber curvature of tops appeared to be less than that of dehaired cashmere. The linear regression constants for the relationship between FC and MFD were:

$$\text{FC} = 150.9 - 5.4\ (0.80)\text{MFD}\quad (\text{RSD} = 6.7;\ r= 0.81;\ P<0.001).$$

For top resistance to compression, the fitted model included only Origin and Processor (RSD= 0.52; $r = 0.87$). Resistance to compression was poorly related to fiber curvature or the product of fiber curvature and MFD with the spread of data points being reduced with the variate MFD × FC.

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% of the variation. This model predicted that the longest tops came from New Origins with the tops from East Asia 7 mm shorter and that from Western Asia 11 mm shorter.

Table 4 Median, s. d. and range of pooled data for attributes of cashmere tops (adapted from McGregor and Postle[13])

Top attribute	Median	s. d.	Maximum	Minimum
Mean fiber diameter(MFD)/μm	17.5	1.2	19.3	15.2
CV fiber diameter/%	21.2	1.2	23.8	19.8
fibers>30μm/%	0.6	0.4	1.6	0.1
fiber curvature/(°) · mm^{-1}	58.0	5.5	68.6	48.9
Resistance to compression/kPa	5.9	1.3	8.3	3.6
Incidence of medullated fiber* (w/w)/%	0.3	0.4	1.5	0.1
Mean medullated fiber diameter* /μm	29.8	9.2	51.7	23.5
Hauteur/mm	41.1	4.9	50	28
CV(H)/%	41.2	6.9	57.4	31.8
K25H/%	16.8	11.6	51.1	6.9
L5H/mm	69.7	6.6	82	59
Barbe/mm	46.7	4.9	57	37
CV(B)/%	36.7	5.0	47.8	31.2
Ratio Hauteur : MFD/mm · μm^{-1}	2.37	0.36	2.91	1.52
Bundle tenacity/cN · tex^{-1}	10.4	1.0	12.0	8.3
Bundle extension/%	39.1	6.6	50.0	19.5

* white fiber only.

As worsted processor's have traditionally used longer cashmere from Iran and Mongolia, this analysis indicates that longer and potentially softer cashmere can be sourced from New Origins of production.

The impact of changes in comb setting on other top properties including tenacity and noil production has been explored and described elsewhere[13].

4 Cashmere yarns and knitwear

An evaluation of the impact of blending cashmere with high or low crimping superfine wool on the attributes of textiles has been completed[8,14]. Both blend ratio and wool type affected the attributes of tops, roving, worsted spun yarn and plain knitted fabric. The differences in raw wool attributes of low crimp superfine wool, compared with standard high crimp superfine wool, were translated into different yarn and knitted fabric physical properties.

For worsted blend yarns made from wool and cashmere of similar diameter, yarn hairiness increased with a decrease in the fiber curvature of the top[15]. This also corresponded with an increase in the cashmere content or low crimp wool content in the yarn. This is likely due to the presence of increased proportion of the shorter cashmere fibers in the surface regions of the yarn, leading to increased yarn hairiness. The hair-length distributions of the conventional worsted wool, cashmere, and wool/cashmere yarns all followed a single negative exponential law[15].

The blending of cashmere with wool resulted in a reduction of the mean fiber curvature of the blend compared with the unblended wool, with a resultant change in physical properties of the textile materials. The work demonstrated[8,14] that most plain knitted fabric attributes were crimp dependent including the fabric mechanical properties of compression, bending rigidity, shear rigidity and tensile strain, and also the fabric attributes of thickness, width (and indirectly mass per unit area), air permeability, resistance to pilling and appearance change, hygral expansion and relaxation shrinkage. Examples are provided (Table 5).

This work demonstrated that the physical properties of pure low crimp superfine wool knitted fabrics were closer to the properties of pure cashmere knitted fabrics than knitted fabrics made from pure standard superfine wool. Increasing the content of cashmere in a wool blended knitted fabric generally resulted in a change in the measured fabric attribute in the direction of pure cashmere fabric. The degree of crimp dependence detected in the present work was much greater than previously reported.

Table 5 Examples of the differences in knitted fabric mechanical properties and other physical attributes of fabrics knitted to a tightness factor of 15.5 tex$^{1/2}$/cm from low crimp wool (LCW) or standard high crimp wool (SW) including fabrics made from their intimate blends with cashmere (CM). The standard error of difference for comparing different wool types (WT) with cashmere or between LCW and SW and the *P*-value are shown.

Attribute	CM	LCW	SW	$sed_{CM\text{-}WT}$	sed_{WT}	$P\text{-value}_{WT}$
Fabric thickness T_m/mm	2.62	2.79	2.92	0.065	0.042	<0.01
Compressibility/%	62.9	58.8	56.9	1.24	0.83	<0.05
Resistance to pilling and appearance change*	3.8	3.8	2.7	0.2	0.15	<0.01

* Higher score is better. Maximum visual score = 5.0 when no change is detected.

During this work, it was found that differences existed between the standard ICI Pill Box Method and the Random Tumble Method in both the significance and magnitude of resistance to pilling and appearance change and the amount of fabric mass loss of worsted spun cashmere and cashmere superfine wool blend knit fabrics[16]. The ICI Pill Box Method differentiated to a greater extent, the effects of wool type and blend ratio of cashmere and wool compared with the Random Tumble Method. Generally, the addition of cashmere or low crimp superfine wool resulted in fabrics being more resistance to pilling and appearance change compared with fabrics made from high crimp superfine wool. This was associated with increased fabric mass loss when assessed by the ICI Pill Box Method but not with the Random Tumble Method. These conclusions can be compared with those of Li and Zhou[17] who evaluated pilling of woollen spun pure Chinese cashmere knitwear. Li and Zhou[17] concluded that the ICI Pill Box Method was preferred over the Random Tumble and Martindale abrasion tests which were regarded as being too severe, the opposite of the findings with worsted spun cashmere yarns.

5 Conclusion

There are important differences between the properties of raw cashmere from different origins. Of significance are the differences in cashmere fiber curvature, fiber length and resistance to compression (softness). It has been demonstrated that cashmere fiber crimp frequency, a fundamental property of cashmere fiber, is now easy to measure by using the objective fiber curvature measurement. Cashmere fiber curvature is significantly affected by the nutritional management of cashmere goats.

Commercial lots of cashmere (dehaired and tops) from different origins of production and processors show important variations in softness (resistance to compression), fiber diameter, fiber curvature and other attributes. It is possible to differentiate cashmere from different Origins on the basis of fiber diameter, fiber curvature and resistance to compression. Cashmere samples tested from new Origins such as Australia were softer and longer than samples tested from traditional Origins of cashmere.

Knitted fabric made from worsted spun cashmere were more compressible (softer) and more resistance to pilling and appearance change than those made from superfine wool despite the yarns being hairier. Increasing the content of cashmere in a wool/cashmere blended knitted fabric resulted in a change in the measured fabric attribute in the direction of pure cashmere fabric.

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