Glossary

Commonly used silk terms

Basin waste	A form of silk waste obtained from cocoons which have been only partially reeled because of frequent yarn-breaks.
Bave	The double strand of fibroin bonded together by sericin.
Boiling-off	The process designed to remove the sericin from the bave (also called de-gumming).
Bolting cloth	A fine silk fabric used for filtering purposes (e.g. flour).
Brin	Each of the two silk filaments making up the bave.
Burn-out	A technique used to produce a raised design using acid. Burn-out is always carried out on a fabric made of two fibres, often silk/viscose.
Chiffon	A light, semi-transparent fabric made from a highly twisted single raw silk yarn in the warp and the weft.
Cohesion	The bonding of several raw silk filaments during reeling.
Cooking	The process by which dry cocoons are soaked in hot water prior to reeling, so as to soften (but not remove) the gum or sericin.
Crêpe	A yarn obtained from two or more twisted raw silk yarns (2400–3000 turns/metre). By extension, a fabric made from such yarns.
Crêpe-de-Chine	Fabric made with a raw silk warp and a crêpe weft.
Crêpe georgette	Fabric with a 2S/2Z twisted yarn in both the warp and the weft.
Crêpe satin	A raw silk warp and a crêpe weft, with a satin weave.
Croisure	The crossing of the raw silk yarn over itself during reeling. The croisure ensures the removal of excess water, reduces irregularities in the yarn and improves cohesion.
Denier	The weight in grams of 9000 metres of raw silk yarn.
Dupion	Silk reeled from double cocoons and introduced in the weaving process to give an irregular slub effect.
Faille	Ribbed fabric with a cross-wise rib effect.
Fibroin	The protein substance composing the silk filament.

Floss silk	Short fibres removed from the outside of cocoons before reeling.
Gum	Another name for sericin, which serves to cement the two brins together and protect them.
Habutae	A light fabric made from untwisted or lightly twisted raw silk yarn (also known as habotai or pongee).
Lousiness	A defect of raw silk characterised by white specks which resemble lice but are in fact due to the splitting-up of the silk filament into fibrils.
Mommé	A traditional Japanese unit of measurement, equivalent to roughly 4.48 g/m^2. Silk fabrics are often referred to as 8 mommé (8 mm), 14 mm, etc.
Noils	Short fibres resulting from the silk spinning process.
Organza	Non-degummed silk fabric with a stiff handle.
Organzine	One of the basic twists given to silk yarns, in which two or more single yarns each receive an initial twist of 600–700 tpm before being assembled and twisted in the opposite direction 300–500 tpm.
Pongee	See Habutae.
Reeling	The process of winding the silk yarn from the cocoons.
Renditta	A term used (especially in India) to indicate the quantity of cocoons required to produce 1 kg of raw silk. If it takes 6 kg of cocoons to make 1 kg of raw silk, this is called '6 renditta'.
Schappe	Often used as a synonym for all spun silk, 'schappe' originally meant waste silk which had undergone a fermentation treatment.
Scroop	The characteristic crisp hand and rustling sound of a silk fabric.
Shantung	Although this type of fabric was originally made from wild silk, the term shantung is now often used to describe a fabric including some dupion yarn, with a characteristic slubby effect in the weft, commonly used in bridal wear.
Shot silk	Usually a tabby weave with different colours in the warp and weft, giving a changing colour effect according to the angle of the light.
Spinning	(i) The production of silk filament by the silkworm; (ii) the manufacture of spun silk from short fibres.
Taffeta (or tabby)	Plain-woven fabric using dyed yarns. The organzine warp is often weighted, which gives the fabric a stiff, structured hand.
Tussah (or tassah, or tasar)	Wild silk produced by silkworms of various species, mainly in India and China, which differ from *Bombyx mori* in that they are either totally wild or semi-domesticated and their food is not mulberry leaves but oak leaves.
Waste silk	Collectively, all the short fibres produced before or during reeling, either from unreelable or pierced cocoons or from waste produced during the reeling process.
Weighting	The replacement of the sericin lost during de-gumming (roughly 20–25 % of the weight of the yarn). When this weight-loss is exactly made up for, we speak of 'par weight-

ing' or 'weight-for-weight' but sometimes additional weighting is added over par. The traditional weighting agent was stannic acid (tin salts) but for ecological reasons this is now often replaced by 'chemical grafting', in which a polymer of methyl methacrylate is 'grafted' onto the molecular structure of the silk yarn.

Commonly used mohair terms

Adult hair (Adults)	Mohair shorn from the goat, referred to as the adult goat, generally after the fourth shearing (i.e. the fifth and subsequent shearings).
Amino acids	Any of a group of nitrogenous compounds that form the component molecules of proteins.
Amorphous	Not having a crystalline structure.
Astrakhan (fabric)	A curled-pile fabric which imitates the fleece of a stillborn or very young Astrakhan lamb.
Bulk	The volume occupied by a standardised mass (weight) of randomised clean fibre compressed by a standard force or pressure.
Carbonising	A chemical process, generally using acid, which degrades the vegetable matter in animal fibres to a brittle (carbon) form so that it can be removed by crushing and dedusting.
Character	Refers to the waves or crimps (undulations) that appear in the mohair staple or lock (i.e. waviness or crimp).
Cortex	The inner portion of most animal hair fibres, comprising spindle-shaped cortical cells.
Cotted (Cotts, Cotting)	Matted or felted fibres in the mohair fleece.
Crabbing	A process of setting fabric in a smooth flat state, generally using a hot or boiling aqueous medium.
Cuticle	The protective outer layer that covers the epidermis of the fibre.
Cytoplasm	The protoplasm of a cell excluding the nucleus.
Epidermis	The outer protective layer of cells.
Felting	Matting together (entangling) of fibres during processing or in use.
Fly	Fibres that fly into the atmosphere during processing.
Follicle	That section of the skin which produces a fibre.
Gare	Long hairy-type fibres having a broken (interrupted) medulla and a chalky appearance.
Grease	The waxes secreted by the sebaceous glands in the skin of the animal.
Hauteur	The mean length (length biased) of long-staple fibres in roving, sliver or top form.
Heterotype	Fibres which have a broken (interrupted) medulla.
Hygral expansion	The irreversible change in dimensions of fabrics containing hygroscopic fibres as a result of changes in regain (moisture content).

Initial modulus	The ratio of stress to corresponding strain in fibres (or yarns) below the proportional (Hookean) limit. Related to stiffness.
Kemp	A relatively coarse mohair fibre having a wide medulla (often lattice in type) and a whitish (milky) appearance.
Kid hair (Kids)	Generally the mohair obtained from the first (at six months) and second (at one year) shearing, provided it is no coarser than 30 μm on average.
Lox (or locks)	Medium to heavily stained mohair.
Matrix	The intercellular substance of cells.
Medulla	Central portion (canal) of certain animal fibres consisting of a series of air-filled cavities formed by medullar cells which collapse during the growth period.
Morphology	Branch of biology concerned with the form and structure of organisms.
Noil	Relatively short fibres, as well as neps and small particles of vegetable matter, removed during the combing process.
Regain	Moisture content expressed as a percentage of the dry weight (mass) of the fibre.
Resilience	The ability of the fibre (or fibrous mass) to recover from distortion (compression, bending or elongation).
Sebaceous	Glands in the skin which secrete grease (waxes).
Setting (Set)	Conferring stability (i.e. releasing strain) in a fibre, yarn or fabric, either by heat, moisture or chemical treatment or by a combination of these.
Staple	A well-defined lock (bundle or tuft) of fibres forming a discrete (cohesive) unit in the fleece.
Staple crimp	The crimp (undulations or wave) frequency of a staple.
Staple length	The length of a staple from tip to base.
Style	Generally refers to the twist and spiral formation (i.e. type of ringlets) of the mohair fibres in the staple.
Sudoriferous	Glands in the skin or follicles which secrete sweat (suint).
Suint/Sweat	Excretion from the sweat (sudoriferous) glands of the follicles.
Switch	A tress of false hair or hair piece used to give added length or bulk to a woman's own hair.
Tenacity	Maximum specific stress (i.e. cross-section related strength) developed in a tensile test taken to rupture.
Yolk	The mixture of products secreted by the glands in the skin of the animal.

Appendix 11

Luxury flame retardant fabrics for aircraft applications

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Abstract

The increasing markets for executive jets and boats are mirrored by the demand for luxury fabrics used in their interior furnishings. Recent changes in US Federal (and other national) Aviation Authority (FAA) regulations, which now demand high level of fire resistance, have created a paradoxical situation where formerly acceptable fabrics fail the new specification and fabrics which do pass fail to have the desired level of aesthetic quality. Consequently, there is a need for fibres and fabrics that can combine the highest levels of technical performance with aesthetic character. Surprisingly, cost is often not a constraining factor in selection of fibre type and fabric structure; the challenge lies in finding the combination of excellent aesthetic and fire performance properties.

Textiles used inside commercial and now executive aircraft have to pass the stringent flammability requirements defined by the FAA specification FAR 25.853 Part IV Appendix F and, by international agreement, all national aviation authorities subscribe to these regulations. At the present time only a few fabrics having the desired aesthetic quality, notably those developed by Dalton Lucerne, UK, which comprise exotic animal hair fibres such as mohair, alpaca and cashmere, have achieved the high levels of fire performance demanded. The particular success of these fabrics lies in their ability to pass the heat release requirements using the Ohio State University (OSU) calorimeter.

This paper will describe the challenges faced by the designers of such fabrics and the means by which passing the FAA specification FAR 25.853 Part IV Appendix F has been achieved to date.

Introduction

Aeronautics is a world-class industry within Europe which in 1996 produced a trade balance of E 8bn. Corporate and private customers represent 53.7 % of the entire aviation market in units and Allied Signal (avionics manufacturer) forecasts that business aircraft sales will reach 6800 units valued at £89 billion in the period 1999–2009 (1998 estimates 6500 units worth $78 billion).[1] European completion centres are increasingly being used to furnish American private jets, because American centres have severe production backlogs. Fabric spend per aircraft can be £20–30 K.

Textiles used inside commercial aircraft have to pass the stringent flammability requirements defined by the Federal Aviation Authority and, by international agreement, all national aviation authorities subscribe to these regulations. Fabrics developed during the last 12 years or so require the use of extremely fire resistant fibres such as the aromatic polyamides, including Nomex (Dupont) and Kermel (Rhodia, formerly Rhône Poulenc) used alone or in blends with flame retardant wool. The balance between fire performance and aesthetics is acceptable for commercial use including first-class areas. Recently, the US Federal Aviation Administration (FAA) (and hence international) fire science performance tests relating to seating materials have been extended to all textiles present in interiors of private and commercial aircraft designed to carry more than 19 persons. This has created a demand for high performance in a market where luxury and aesthetics predominate and where cost is of minor importance. These regulations now include both the smaller executive jets and larger jets customised to carry only a few passengers. The fabrics used by commercial airlines even in first-class accommodation are of too low an aesthetic quality to suit this select but expanding market.

In order to exploit this new market, Dalton Lucerne Rare Fibres, UK, have developed a range of exotic animal hair fibre weft yarns, woven on polyester or silk warps, for use in luxury jets, and these pass the fire performance demands set by the FAA specification, FAR 25.853 Part IV Appendix F.[2] Recently Dalton Lucerne have been named in the UK as a Millennium Product Company because of the novelty and innovative character of their current fabric range. This paper discusses the burning behaviour of this range of fabrics in terms of heat release (using the Ohio State University calorimeter[3]) and the smoke and toxic gas emissions using the 'National Bureau of Standards (now NIST) Smoke Test'.[4]

Burning behaviour of exotic animal hair-containing fabrics

The use of wool and its flame retarded variants is well-established in the commercial aircraft field since the latter used alone or both forms blended with inherently fire-resistant aramid and similar fibres will enable heat release peak and average values to be below the required 65/65 $kW\,m^{-2}$ upper limits.[2] This is a consequence of the excellent low flammability of wool even when not flame retardant treated as shown by a relatively high LOI value of about 25 and a low flame temperature of about 680 °C. Its similarly high ignition temperature of 570–600 °C is a consequence of its higher moisture regain (8–16 % depending upon relative humidity), high nitrogen (15–16 %) and sulphur (3–4 %) contents and low hydrogen (6–7 %) content by weight.[5]

Table A11.1 Principal amino acid contents and elemental constitutions of wool and mohair fibres[6]

Property	Wool	Mohair
Elemental analyses:		
Sulphur, % w/w	3.3–3.6	2.9–3.6
Nitrogen, % w/w	16.6	16.6
S-containing amino acids:		
Cystine, % w/w	10.4–11.8	10.4

The very similar, but aesthetically superior mohair fibres, while being produced from Angora goats, might be expected to have similar flammability properties. The mohair fibre is typified by its high lustre, which coupled with its fineness and handle, provides fabrics having exceptional visual and physical aesthetics. The inherent flammability of all animal hair fibres is considered to be in part determined by their high nitrogen and sulphur contents as suggested above. Table 1 gives comparable selected amino acid and elemental contents for both wool and mohair.[6]

Mohair has slightly lower cystine and hence lower sulphur contents than wool fibres and the reported limiting oxygen value for the former is 24[6] compared with the value of 25 for wool. These values reflect a reasonable and similar level of inherent flame retardancy. To date, however, mainly because of its cost, mohair has not found its way into aircraft fabrics although previous attempts to flame retard it have been as effective as for wool.[6]

Alpaca fibres are produced from species of llama, principally the llama, guanaco and vicuña. Fibres from the vicuña are the finest, and because they have very smooth exterior surfaces they are similar to the mohair fibre in terms of aesthetic properties. Little, if any, data on the flammabilities of these fibres exist, however.

Heat release properties of animal hair-containing fabrics using the OSU calorimeter

The results presented in this paper are those form a series of exotic animal hair-containing fabrics tested usually as a fabric-faced aramid fibre-based honeycomb-structured board, representative of aircraft panelling composites.

Mohair fibre, yarn and fabrics

Mohair fibres from angora goats (see Fig. A11.1) were spun into 20s (worsted count) worsted yarns and woven on cotton, silk or polyester warps to yield plain or patterned (having a fleur-de-lis motif) fabrics having nominal area densities of about 150 $g\,m^{-2}$ (6 $oz\,yd^{-2}$). These fabrics were finished by standard commercial methods to remove warp size and adventitious impurities prior to further treatment (see below). A similar fabric with an alpaca weft and silk warp was also woven. Examples of these finished fabrics are shown in Fig. A11.2 to illustrate their level of aesthetic quality.

A11.1 An adult, full pedigree, Texan Angora goat.

A11.2 Typical luxury mohair fabrics for aircraft interiors.

Table A11.2 Fabric samples and derived composites and associated treatments

Sample	Back-coat	Adhesive	Board	Al foil	FR1/board	FR1/fabric face
Mohair (61%)–silk (39% as warp): plain weave						
MS1	✓					
MS2	✓					✓
MS3	✓	✓	S-SSCP*			✓
MS4	✓	✓	S-SSCP*		✓	✓
MS5	✓	✓	Airbus			✓
Mohair (61%)–silk (39% as warp): fleur-de-lis motif						
MSF1	✓					
MSF2	✓					✓
MSF3	✓	✓	S-SSCP*			
Mohair–polyester (warp)						
MP1	✓					✓
MP2	✓	✓	S-SSCP*			✓
MP3	✓	✓	S-SSCP*		✓	✓
MP4	✓	✓	S-SSCP*	✓	✓	✓
Mohair–cotton (warp)						
MC1	✓					✓
Alpaca (60%)–silk (40% as warp)						
AS1	✓					✓
AS2	✓	✓	S-SSCP*			✓

Note: *this denotes the board type produced by Schneller, Inc.

Sample preparation

Normally, fabrics used as decoration for wall panels will be tested as fabric-faced composites on standard aramid honeycomb board such as is specified by an aircraft manufacturer (e.g. Airbus Industrie) or a board manufacturer (Schneller Inc, Ohio, USA). In order that fabrics could adhere to these boards, they were treated with a proprietary back-coating formulation based on an antimony/bromine-containing resin. The proprietary adhesive was applied to the back-coated face enabling it to adhere to the board. In some cases, a thin (0.025 mm) aluminium foil was sandwiched between the back-coated face and the board. Once the final composite had been produced, it could be tested with and without the application of an amount of a proprietary ammonium salt-based semi-durable flame retardant equivalent to 1–2% by weight phosphorus on fabric. A limited selection of fabrics (mohair weft-cotton warp plain and fleur-de-lis) were exposed as free fabrics in the absence and in the presence of the flame retardant FR1 and tested with warp and weft yarns vertically within the OSU calorimeter. Table A11.2 lists the fabric samples used, the derived composites and both component and composite treatments used to produce final samples for testing.

Sample heat release results following exposure to OSU testing[2,3]

Experience has shown that in order for a fabric/board composite to achieve a pass with peak release rate $<65\,kW\,m^{-2}$ and a 2 minute average heat release rate $<65\,kW m^{-2} min^{-1}$ under OSU conditions (i.e. heat flux = $35\,kW\,m^{-2}$), the choice of adhesive and back-coating are critical and that a final spray treatment of a flame retardant was necessary. The samples in Table A11.2 have been selected and constructed to indicate the importance of elements of these selection criteria and Table A11.3 presents the heat release results for these. OSU results for composites, according to the standard procedure,[2] were undertaken at the testing facility at Avro International Aerospace, Woodford, UK; fabric results were obtained on the facility at Hexcel Composites Ltd, Duxford, UK.

Peak heat release (PHR) and time to PHR: The influence of the differing warp types is shown by comparing sample PHR values for MS2 (silk warp), MP1 (polyester warp) and MC1 (cotton warp) where the last with a highest value of $88\,kW\,m^{-2}$ suggests the influence of the highly flammable cotton present. The alpaca–silk combination (AS1) has a similar value which may indicate a poorer inherent flame resistance of this fibre compared to mohair. The effect on PHR of adding the flame retardant to a back-coated-free fabric is minimal and is shown by comparing the mohair–silk fabrics MS1 and MS2; a slight increase occurs, however, for the fleur-de-lis versions (MSF1 and MSF2) with the value rising from 55 to 61 $kW\,m^{-2}$. Once a fabric adheres to an aramid board as shown in the results for MS3, there is a rise in PHR. This is supported by comparing samples of free (MP1) and mounted (MP2) mohair–polyester fabrics where PHR rises from 58 to $67\,kW\,m^{-2}$; this is probably a consequence of the adhesive present, although slight reductions in mounted fabrics occur for mohair–silk fleur-de-lis and alpaca–silk fabrics.

If the board is pretreated with flame retardant, then some of the lowest PHR values are seen for a given composite (e.g. MS4 and MP3). Exchanging a Schneller S-SSCP board for an Airbus analogue (compare MS4 and MS % results) seems to decrease favourably PHR values.

The time to PHR is far less sensitive to the composite variables with only the adherence of the fabric to the support board producing a consistent increase in time. Similarly, replacement of the relatively thin S-SSCP board (3 mm) with the thicker Airbus board (7 mm) increases the time from 21 s (MS4) to 39 s (MS5). It would seem, therefore, that the increased sample thickness, mass and hence heat capacity may be a determining factor here.

Two-minute average heat release (AHR): Average heat release (AHR) values over the first two minutes exposure period reflect the total fuel content of samples and so free fabric values (MS1, MS2, MSF1, MP1 and AS1) are considerably less than those for fabric/board composites. The conversion to a composite raises AHR values close to the limit of $65\,kW\,m^{-2} min^{-1}$ and this is not affected by the presence or absence of flame retardant addition to the board. Lowest values, which often determine whether a composite passes or fails, are shown for samples which have the Airbus (thicker) board (MS5) or insertion of aluminium foil (MP4).

Table A11.3 OSU heat release results according to FAA specifications[2]

Sample	Mass, g	Thickness, mm	Peak heat release rate, kW m^{-2}	2 minute average HRR, kW m^{-2} min^{-1}	Time to PHR, s	Pass/fail
Mohair (61 %)–silk (39 % as warp): plain weave						
MS1 (ave. of warp and weft)	5	0.5	34	18	13	Pass
MS2	5	0.5	38	16	11	Pass
MS3	—	—	86	55	23	Fail
MS4	32	4.2	75	55	21	Fail
MS5	58.5	8.7	58	41	39	Pass
Mohair (61 %)–silk (39 % as warp): fleur-de-lis motif						
MSF1	5	0.5	55	27	14	Pass
MSF2	5	0.5	61	93	14	Fail
MSF3	—	—	58	52	23	Pass
Mohair–polyester (warp)						
MP1	6	0.25	58	35	17	Pass
MP2	32	3	67	65	20	Fail
MP3	32	4	61	63	18	Pass
MP4	34	3	64	46	19	Pass
Mohair–cotton (warp)						
MC1	10	0.5	88	46	23	Fail
Alpaca (60 %)–silk (40 % as warp)						
AS1	8	0.5	85	38	19	Fail
AS2	34	5	77	60	25	Fail
Schneller S-SSCP	26	3	55	41	—	Pass
Airbus board	—	7.2	21	17	—	Pass

In summary, the most robust passes cannot easily be predicted in terms of whether additional flame retardant to the supporting board should be present or not. However, the inclusion of aluminium foil (MP4) and use of a thicker board (MS5) does seem to produce consistently lower PHR and average HR values.

Smoke and toxic gas analyses

The smoke and toxic gas emission levels are listed in Table A11.4 for a selection of the samples in Table A11.3. Results were undertaken for flaming and non-flaming conditions. It would appear that all samples except one (MP3) tested under both

Table A11.4 Smoke and toxic gas emissions of selected samples

Sample	Smoke: DS within 4 min	HCN, ppm	CO, ppm	NO_x, ppm	SO_2, ppm	HCl, ppm	HF, ppm	HBr, ppm	Pass/ fail
Test criteria	<200	<150	<350	<100	<100	<150	<100	—	Pass
Mohair (61 %)–silk (39 % as warp): plain weave									
MS1 (ave. of warp and weft); flaming	94	10	100	—	3	8	—	10	Pass
MS1 (ave. of warp and weft); non-flaming	54	10	10	—	5	8	—	5	Pass
Mohair–polyester (warp)									
MP3 Flaming	210	5	10	3	5	56	7	23	Fail
MP3 Non-flaming	117	5	10	4	4	38	5	9	Pass
Mohair–cotton (warp)									
MC1 (ave. warp and weft); flaming	153	20	175	—	10	15	2	15	Pass
MC1 (ave. warp and weft); non-flaming	70	5	50	—	13	15	3	5	Pass
Alpaca (60 %)–silk (40 % as warp)									
AS1 (ave. warp and weft direction); flaming	141	20	125	—	11	14	1	18	Pass
AS1 (ave. warp and weft direction); non-flaming	73	18	13	—	14	10	1	6	Pass

Notes: DS is the optical density of smoke after 4 minutes exposure to the incident heat flux.

conditions have produced passes under the FAA and related regulations.[2] The upper limits for each emitted species are listed also in Table A11.3. Furthermore, the emission values for flaming conditions are in all cases greater than respective non-flaming conditions. This reflects upon the effectiveness of the inherent flame retardance of the component fibres and the flame retardant finishes present.

Single-layered fabric samples show some variations which might be both warp (mohair versus alpaca) and weft (silk versus cotton) related. For example the presence of the cotton weft in MC1 fabrics increases the smoke and CO emissions relative to the silk weft in MS1 fabrics under both flaming and non-flaming conditions. Alpaca as a weft (AS1) also appears to have slightly increased smoke and CO generation compared to mohair weft in MS1 when both contain silk warps. The effect of polyester warp in MS3 samples is masked by the adhesion of this sample to the S-SSCP board.

All samples showed measurable amounts of sulphur dioxide from the mohair or alpaca fibres present (see Table A11.1) as well as hydrogen chloride and hydrogen bromide, probably from the flame retardant back-coating applied to each fabric. Again, flaming values are greater than respective non-flaming values and this probably is a consequence of the antimony–halogen flame retardant formulations acting specifically in the flame and so generating higher concentrations during flaming combustion conditions.

Conclusions

It is evident from these results that fabrics and fabric panel composites in which the weft yarns are mohair and alpaca can be fabricated in a manner which enables the strict fire and emission performance requirements of FAA specification JAR 25.853, Part IV, Appendix F to be met. Not only are the fabrics of extremely high visual and physical character and hence luxurious aesthetics, but also fabric weights are considerably less than currently available fabrics used in aircraft interiors.

Based on the current degree of success, it is intended to develop a range of fabric designs and structures which will guarantee FAA specification passes. This will entail studying the effect of fabric composite design variables on heat release properties in the first instance followed by the creation of a multi-dimensional model which will enable fabric fire performance to be predicted at the design stage.

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Appendix 1

International trade rules for raw silk and other products of silk (ratified by the Directing Board, 7 November, 1997 at Bangkok)

Introduction

Task setting and conduct of proceedings

At the Brighton Congress 1995, the proposal of the Swiss National Delegate, Mr P Zwicky, to set up a sub-committee under the chairmanship of Mr P Giger, President of Section III, aimed at adapting the International Trade Rules for Raw Silk to actual requirements, found unanimous approval.

A first review of the existing Rules – dating back to 1978 – showed that the Rules now as before served its purpose still reasonably well with some parts in need of amendment though. By and large it involved a textual up-dating concerning the inclusion of new means of communication as well as some changes of specifications which took into account the changed practices in the trade. Therefore, the task at hand being judged rather one of small adjustments than one of a monumental revision, it was felt practical that the initial study group be a limited one consisting of a few persons with active experience in the trade. The sub-committee's study group was composed of:

Mr P Giger (chairman), Mr B Trudel,
Mr G Gamma, Mr H Frei and Mr P Genoud.

Notwithstanding the expertise of this group in technical and trading matters, it was felt necessary also to have reviewed the work by other competent professionals before presenting such a paper to our National Delegates. This commission is most grateful to have been able to draw valuable legal, linguistic and practical advice from Mr S Wesley of the law offices of Bignon & Lebray in Lyon and Mr R Currie, Secretary General of ISA also situated in Lyon. The contributions of these gentlemen greatly added to clarity when formulating the current revision of the existing rules.

With the approval of the Executive Committee of ISA the study group submitted a first version of the International Trade Rules for Raw Silk in May 1997 to the National Delegates for examination by or on behalf of their members. A number of Delegates responded, and this study group is grateful for the valuable suggestions they made. As for the rest who sent us no response we hope it is right to assume that their silence signals tacit agreement to the suggestions made. We herewith present to you the International Trade Rules for Raw Silk (1997) as adopted by the Directing Board of ISA at its Congress meeting on 7 November 1997 at Bangkok.

Scope of application of the International Trade Rules for Raw Silk

It is understood that Sellers, intending to sell raw silk or Buyers, intending to buy raw silk under the conditions of these International Trade Rules must advise the other party of the fact. If the Seller and Buyer agree to make their contract subject to these international trade rules, ISA recommends that this be stipulated in writing with the clause 'contract subject to ISA International Trade Rules for Raw Silk' or with any similar clause, so as to form an integral part of the contract.

In the event of different or additional conditions being stipulated in writing between the contracting parties when the contract is concluded, such conditions shall also form an integral part of the contract. These International Trade Rules are also intended to apply when a difference of opinion or dispute arises between parties to a contract on a matter on which a contract itself is silent or imprecise.

The provisions of these International Trade Rules may also apply to transactions between contracting parties in the same country but it is not intended that they shall apply in preference to any national or transnational agreements covering transactions made between governmental or other organisations representing companies trading in these products within the confines of their own national boundaries. It is understood that the term 'raw silk' in these rules, unless otherwise specified, refers to all types of mulberry silk threads (including douppion and native silk) reeled from several cocoon filaments – each extruded by the gland of the silkworm *Bombyx mori* – into a continuous thread. The term 'raw silk' in these rules also stands for raw silk which has been doubled, cleaned or otherwise conditioned in preparation of an application thereafter on the loom or, the subsequent transformation in the throwing process. It follows that these rules also cover contracts for the sale of raw silk which has undergone the mentioned treatments.

These rules may also be applied for contracts in raw silk filaments produced from types of silk glands other than those of the *Bombyx mori* silk worm. In such case ISA recommends that the non-mulberry nature of the raw silk be stipulated in the contract with the clause 'non-mulberry type', 'wild silk' or with any similar clause.

Details of the reviewal work

The number and structure of provisions in these rules remain unchanged. They range from 'Purpose' to 'Arbitration' and number 19 in total. Out of this total, the five provisions concerning

Quantities and weights
Quality
Specified grades, sizes and qualities
Open grade and/or size contracts and
Packaging and packing

contain specifications which are of exclusive character to the trade in raw silk. The remaining set of 14 provisions cover general trade terms and will be newly referred to as provisions of general scope under the heading of 'Supplementary governance':

Purpose
Supplementary governance
Application
Offers, orders and acceptances
Confirmation of transactions
Price
Terms
Shipment
Force Majeure in the Seller's Country
Force Majeure in the Buyer's Country
Advice of departure
Country of origin
Variations of charges
Arbitration

The following points are new and form part of the final version on hand:

1. under 'Purpose'

In the absence of trade rules for silk products other than raw silk, it is proposed to make applicable the provisions of general scope of these rules – as mentioned above – to other Silk products ranging from thrown silk to boiled-off silk fabrics.

In this context we refer to the 'Rules for Intraeuropean Trade in Raw and Thrown Silks' dating back to January 1972. Those were drawn up as model rules by another sub-committee of Section III and were intended to be tested during a period of some 10 years. To our knowledge that period has passed without further action and the status of the work remains under test and trial until the sections concerned (III/V) take the initiative to have those rules put in force. Furthermore, it is to be noted that there are no particular trade rules in existence for a wide variety of other silk goods, a situation which is rated by many as a long-felt gap waiting to be filled. Therefore, it was considered meaningful that in the interim those parts of the International Trade Rules for Raw Silk which can be considered as provisions of general scope be endowed with the option of a wider scope of governance.

2. under 'Application'

An important source of conflict and instability in cross-cultural business relations are differing concepts of what constitutes a binding agreement. Accordingly, not all cultures have the same notion of the binding force of a written contract and of the importance of detailed regulations. This is particularly grave because people tend to think that their own country's commercial law alone is valid and that the commercial law of any other country is of no consequence. In the interest of reducing misunderstandings and conflicts arising from such differences a stipulation is introduced which does away with the present absence of a clear dividing line between the truly voluntary and the *de facto* binding nature of a contract. In effect these rules say that a contract once concluded is a binding agreement which is unwound only in the case of *Force Majeure* and in the special cases mentioned under 'Terms', 'Shipment' and 'Specified grades, sizes and qualities', but any of these events would not itself call into question the original existence of the contract.

3. under 'Offers, orders and acceptances' and others

Means of communication: Besides 'Airmail' for offers and orders it was considered useful to add for all communication 'facsimile' and 'other means of electronic communication'. The latter point covers the recent type of communication services available in e.g. the internet network such as e-mail.

4. under '*Force Majeure*'

This study group has concluded that the incidence of *Force Majeure* was most clearly treated and presented in the mentioned 'Rules for Intraeuropean Trade in Raw and Thrown Silks' of January 1972. In effect that paper served as basis for some modifications to the old version contained in the present proposal.

5. under 'Arbitration'

The new proposal reads to change the place of arbitration to the 'country of the Buyer'. The old version cited the 'country of destination' as the place for arbitration. The study group feels that this change is a practical one.

6. under 'Quality'

The present and old rules suggest that 'the Seller must furnish the Buyer with official Conditioning House quality tests. Exceptionally, the Buyer and the Seller may agree on another official Conditioning House'. Contrary to this condition of furnishing tests from an official conditioning house, it is, for certain origins, normal practice today to buy and sell raw silk without a certificate produced by an independent testing house but e.g. with a supplier's quality certificate. Therefore, we suggested that the above stipulation should be amended to read as follows: 'Exceptionally, the Buyer and the Seller may agree on another official Conditioning House's quality test or on a quality test issued by either the respective filature or by another mutually approved party.'

7. under 'Packaging and packing'

The evolvement of our trade has led to a number of new norms for skeins which can be considered today as standards: the most common circumference of skein is 150 cm and not 140 cm any more. The production of an evenly sized circumference is an important quality requirement. Likewise the weight of 180 g per skein is dominant and in this context we underlined the importance of uniform skein weights. Also we felt it useful to make mention of an old standard requirement: the diamond formation of skein which is known as Grant Reeling. A somewhat more recent requirement is the bundling of the skeins; they should come flat packed in the make-up of slightly twisted flat skeins. Apart from the packaging in skeins we added the packaging on supports with a listing of the necessary type of specifications to be made for each contract.

Each one of the national organisations will translate these rules – where need be – into the language of its own country. If there are doubts about the interpretation of these texts by the parties which have decided to follow the rules in their business relations, the French text, only, is legally binding.

Section III, Sub-committee for the revision of
the International Trade Rules for Raw Silk
Chairman
Paul Giger

Zurich, November 1997

International trade rules for raw silk and other products of silk

Purpose

These rules are agreed upon and adopted by the International Silk Association for the purpose of defining uniform trade practices between Buyers and Sellers of Raw Silk and for the guidance of arbitrators in the settlement of any disputes arising out of contracts made subject to these rules.

Supplementary governance

The provisions of general scope of these International Trade Rules for Raw Silk may also apply to international contracts covering transactions in other silk products such as:

1 Thrown silk
2 Spun silk
3 Tops
4 All types of silk waste
5 Silk fabrics loom-state
6 Silk fabrics boiled-off

Such provisions of general scope are those stated in these rules subject to the exclusion of the specifications concerning ‘Quantities and weights’, ‘quality’, ‘specified grades, sizes and qualities’, ‘open grade and/or size contracts’ and those for ‘Packaging and packing’.

Application

Contracting parties recognise that these rules will automatically apply to their contract when the transaction is concluded and accept said rules as an irrevocable binding agreement, unless specifically stipulated to the contrary. These rules will therefore validly regulate the contract the parties have entered into and they automatically accept their application to the interpretation of the contract and for the purpose of resolution of disputes.

However, nothing in the following Rules shall be construed as waiving the right in individual transactions to make any special agreement, but the Rules shall govern in cases where no special agreement exists.

Offers, orders and acceptances

Airmail, telegrams, telex, facsimiles or other means of electronic communication containing offers or orders should clearly state the time and date until which the same are valid, and it is understood, unless specifically stated to the contrary, that this time shall be that of the country from which the offer or the order is made.

To eliminate the possibility of misunderstanding, the Seller or the Buyer, upon acceptance of his offer or order, must acknowledge receipt by cable, telex, facsimile or other means of electronic communication.

Confirmation of transactions

Upon concluding a transaction by telegram, telex, facsimile or other means of electronic communication, the Seller shall airmail to the Buyer written confirmation, giving full details of quantity, quality, price and terms, delivery dates and all other relevant details. Failure to protest immediately by telegram, telex, facsimile or other means of electronic communication shall imply acceptance of the contract.

Should it be found that, owing to a fault of telecommunication, an order is confirmed otherwise than had been intended, the Seller shall be bound to execute his contract only in so far as he can do so without material loss to himself. The Buyer has the right to accept the purchase as it is made but need only take delivery of what he has ordered.

Quantities and weights

Total contract quantities shall be expressed in kilograms and in equivalents of the trade unit by specifying the latter's type and weight (bales of approx. 60 kg, cartons of approx. 30 kg or other suitable unit). The total weight in kilograms tendered shall not vary by more than 5 % (five percent) above or below the contracted weight.

Unless otherwise specified, all Raw Silk contracts shall be concluded and delivered on the basis of conditioned weight, which is the absolute dry weight plus 11 %, and Weight Test Certificates made by the Official Conditioning House of the producing market shall be furnished by the Seller to the Buyer and such Weight Test Certificates shall be accepted as final in the absence of irrefutable evidence of error or fraud.

In the absence of such an official body in the producer country, the Buyer and the Seller shall specify that the weight certificate emanates from either the reeler (in such case net unconditioned weight) or from an Official Conditioning House in another country or from another mutually approved party.

Quality

Grading and classification must be established in accordance with the testing and classification method in force in the producer country or in the country where, according to the contract, the raw silk will have been or will be tested. The Seller must furnish the Buyer with Official Conditioning House quality tests of the producer market. Exceptionally, the Buyer and the Seller may agree on another Official Conditioning House's quality test or on a quality test issued by either the respective filature or by another mutually accepted laboratory.

These Tests must be accepted as final in the absence of irrefutable evidence of error, fraud or existence of hidden defect.

Introduction of chemical matter or other adulteration escaping scrutiny at the Conditioning House, calculated to fraudulently increase the weight or quality of the silk, shall be regarded as a hidden defect. *Arté*, i.e. damage caused by insects, is a hidden defect.

Price

Prices shall be mutually arranged between Seller and Buyer in any currency convenient to both parties.

Terms

Unless otherwise specified, all prices stated in offers or orders are understood to be CFR (Incoterms 1990) with goods travelling at the consignee's risk. In this case the buyer must take out insurance and pay the premium.

Sales calling for Banker's Credits require the Buyer to furnish a Banker's Letter of Credit satisfactory to the Seller and in accordance with the conditions of the transaction. Should the Buyer within the term of the performance of a contract default in payment or give the Seller other reasonable cause to consider his credit risk unsatisfactory, the Seller may demand immediate issuance of an irrevocable and confirmed Banker's Credit for all open transactions, notwithstanding the terms originally agreed upon, and the election by the Seller to make such a demand shall not impair the obligation of the Buyer to take delivery.

Should the Buyer unreasonably refuse to comply with such a demand, the Seller may cancel the undelivered portion of his open contracts by notifying the Buyer by cable, telex, facsimile or other means of electronic communication and confirming it in writing by airmail. In such a case the two parties shall be respectively entitled to or responsible for the difference between the contract price and market price of the undelivered portions of the contract or contracts at the time of cancellation.

Shipment

Raw Silk contracted as available for prompt shipment requires the Seller to ship within 15 (fifteen) days from the date of contract or by the first available transportation opportunity provided in the contract (ship, plane, train, lorry, van) after the 15 days period. In the event of the contract terms calling for a Banker's Credit the Seller shall ship within two weeks of receiving the credit, or in default by the first available shipping opportunity after that period.

Silk contracted for forward shipment within a specified month shall be shipped before the last day of that month, but there shall be an allowed latitude of 5 (five) days, which can be extended only by mutual consent or in the event of there being no immediate means of transport to the required destination.

If the contracted shipment is spread over more than one month it is understood that, unless otherwise specified, the Seller must deliver in as nearly equal monthly portions as is possible, except when fewer than twenty bales have been contracted.

The date of the shipping document shall be deemed to be the date of shipment.

A delay in shipment beyond the allowance stated above shall give the Buyer the right to cancel the contract or demand an appropriate rebate or set off corresponding to the market difference at time of cancellation.

Force Majeure in the Seller's Country

Events alleged as a basis for a claim of *Force Majeure* must be confirmed by an official body or official National Association of the Seller's country.

In all cases of *Force Majeure*, the Seller is under an obligation to inform the Buyer by the quickest possible means as soon as possible.

Events recognised as *Force Majeure* may be of two categories, the first justifying a delay in performing the contract, the second resulting in cancellation of the contract.

A: First category – involving delay, includes

GENERAL CASES:

a) Interruption of means of transport, accidents or quarantine.
b) General Strikes, officially declared, and which the Seller is unable to prevent, or strikes of the dockers or of seamen.
c) Government orders or measures taken by any governmental authority.

SPECIAL CASES: covering sales of silk from a specific reeling plant:

d) Epidemic in the mill.
e) Strikes, necessitating the stoppage of the mill operations, officially declared.
f) Other production delays beyond the Seller's control.

In such cases the stipulated date of shipment shall automatically be extended by 30 (thirty) days. When the delay exceeds this period, the Buyer shall have the option of granting a further extension or of cancelling the lot of silk in question without liability to Seller or Buyer.

B: Second category – involving cancellation of contract where performance becomes impossible, includes

GENERAL CASES:

a) Events arising from elements such as fire, floods, earthquake, tidal waves, any other cataclysm and the consequences arising from same, leading to loss of goods.
b) Shipwreck and other transportation accidents leading to loss of goods.
c) Theft during transport.
d) War, state of war, revolution, civil insurrection and all political disturbances and the consequences arising from same.

SPECIAL CASES: covering sales of Silk of a specific reeling plant:

e) Total or partial destruction of a factory by fire, flood or earthquake.
f) Involuntary failure, bankruptcy or liquidation of the producer in the country of origin.

In such cases where it appears to be materially impossible to deliver the goods, the contract or the undelivered portion thereof shall be cancelled without liability to

Seller or Buyer, after refusal by the Buyer to receive similar goods from another filature in the producer country.

Force Majeure in the Buyer's Country

A case of *Force Majeure* may arise in the event of government regulations delaying or preventing the importation of raw silk into the country of the Buyer.

Events alleged as a basis for a claim of *Force Majeure* must be confirmed by an official body of the Buyer's country, and the Buyer is under an obligation to inform the Seller by the quickest possible means as soon as possible.

In the event of government regulations involving a delay, the stipulated shipment shall be automatically extended by 30 (thirty) days. If the delay exceeds this period, the Seller shall have the option of granting a further extension or of cancelling the lot of silk in question without liability to Seller or Buyer.

In the event of government regulations completely preventing the importation of raw silk into the country of the Buyer, the contract or undelivered portion thereof shall be cancelled without liability to Seller or Buyer.

Specified grades, sizes and qualities

If, under the heading 'quality', the Silk Conditioning House Tests show the silk to be of a grade lower than, or of a size different from the description given in the contract, the Buyer has the option of accepting the same with an appropriate rebate or he may cancel the contract or demand an appropriate replacement.

If the replacement too proves to be lower in grade and/or different in size, the Buyer is again entitled to cancel or to ask for an appropriate rebate or replacement.

If the contract permits any latitude in grade or size and the Seller tenders silk within said latitude, the Buyer must accept delivery.

Open grade and/or size contracts

Contracts calling for delivery of various grades and/or sizes at the Buyer's or Seller's option require the Buyer or the Seller to notify the Seller or the Buyer of the grades and sizes to be delivered at least 30 (thirty) days in advance of delivery month.

Advice of departure

The Seller is under an obligation to advise the Buyer by telegram, telex, facsimile or other means of electronic communication as soon as possible after departure of the name of the steamer by which silk has been shipped, or of any other relevant information; for instance flight number in the case of air freight, or shipment by road, rail, etc., and to recall relevant contract references.

Country of origin

All bales, cartons or other suitable packing units must be marked with the country of origin. Unless otherwise specified, it is understood that silk reeled in a particular country is reeled from cocoons produced in that country.

Packaging and packing

In skeins: unless otherwise specified, skeins should be taken as measuring approximately 150 cm circumference, a tolerance of 1% (one percent) more or less is allowed. Unless otherwise specified, the skeins should be produced by the method of diamond thread traverse system and weigh a minimum of 180 g. The weight of the skeins should – within reasonable tolerance – be evenly matched. Unless otherwise specified, a skein is to come with a minimum of 4 (four) lacings, be flat packed in the make-up of slightly twisted flat skeins. The packing should be fit to withstand the journey to the country of destination.

On supports:
Buyer and Seller must agree on all necessary specifications such as: type and make-up (cones or tubes), type of winding (pineapple or other), weight per cone/tube, soaking type and soaking percentage. The packing must ensure that silk on supports is protected from friction and outside pressure during the transport to the country of destination.

Variations of charges

Any variations in duties or export taxes imposed by the country of origin after the date of contract are for the Seller's account.

Arbitration

It is hoped that with the aid of these rules amicable solutions may be found to disputes arising in the sale and purchase of raw silk.

If agreement cannot be reached, the dispute shall be submitted to arbitration in the country of the Buyer unless another place of arbitration has been stipulated in the contract under dispute.

The decision of the arbitrator or arbitrators shall be final and binding upon both Buyer and Seller.

Appendix 2

Spider silk

MRS JOYCE DALTON

Spider silk has long fascinated human beings for its elegant evolutionary solution – a unique combination of enormous tensile strength and elasticity with an ultra-light-weight fibre. The fibre is produced within the silk glands of spiders and other insects, and is composed completely of silk proteins which have made an irreversible transition from a soluble silk protein solution inside the spider into an insoluble fibre once it has been extruded and entered into contact with the air.

Spiders produce a number of silks with different mechanical properties for use in spinning webs or for forming cocoons. Of these, the 'dragline' or 'frame' silk has been the object of desire for materials engineers because of the extreme performance of its mechanical properties, particularly its tenacity.

Despite its superior mechanical properties, spider silk is not used commercially because of an absolute constraint on supply. Spider farming is simply not practical. Unlike that of silkworms, the spider's territorial and aggressive nature precludes intensive cultivation. Further, it is not the spider cocoon silk that is desired but certain of the components of the web silk.

A remarkable biomaterial has been produced from simple protein building blocks over 400 million years of evolution. Native silk from orb-weaving spiders is extremely tough (10.5 J kg), and strong (1–5 Gpa). An inch-thick rope of this material would be able to stop a jet fighter when landing on an aircraft carrier. [Quote: Randy Lewis, University of Wyoming]

In Canada, a company called Nexia Biotechnologies is working on producing real spider silk by transferring the silk-producing gene from the spider into the mammary glands of pygmy goats. The spider silk protein is produced in the goats' milk, from which it is extracted and extruded into silk yarn much as polyester yarn is extruded. The goats currently produce 5 grams of protein per litre of milk.

According to this company's literature, they currently have three advanced materials:

BioSteel® Industrial Fibres, for:

1 Military and law enforcement use (ballistic protection).
2 Structural engineering (aerospace and transportation).
3 Advanced packaging materials.

BioSilx™ Proteins, for:

1 Cosmetics (make-up, e.g. mascara and lipstick).
2 Skin care.

Their suppleness and softness make them ideal for these applications.

BioSteel® Extreme Performance fibres, are:

1 Strong/flexible with power ten times stronger than that of steel.
2 Versatile for advanced engineering applications.

The fibre is eco-friendly, one of Nature's engineering wonders, a protein filament produced on a large scale and without pollution.

Dalton Lucerne have already fire tested spider silk with the very surprising discovery that it has a high degree of natural fire retardancy. Spider web can also be washed in warm water, which turns it into an incredibly soft, silken ball.

Editor's note
Mr Ron Currie, author of the chapter on silk, has informed me of the possibility of genetically modifying the silkworm *Bombyx mori* to enable it to spin spider silk. Should this idea come to fruition, it would provide an alternative way of producing spider silk industrially.

Appendix 3

Composition of mohair fibres and of amino acids

Physical and chemical composition of mohair fibres

Chemically, mohair is very similar to wool but because it is predominantly ortho-cortex, which is chemically less resistant than the para-cortex,[74] it is generally more sensitive to various chemicals than is wool and more attention should therefore be given to the chemicals and conditions used during scouring, dyeing, carbonising and finishing.[1,38] Ward et al.[75] produced Table A3.1 for the chemical composition of mohair and other fibres.

Tucker et al.[58,65] reviewed the chemistry of speciality animal fibres, stating that the fine speciality animal fibres, such as mohair, consist mainly of protein, water and internal and external lipids. They comprise long spindle-shaped cortical cells surrounded by a flattened sheath of cuticle cells held together by the Cell Membrane Complex (CMC), referred to as the intercellular region or intercellular cement. It surrounds individual cortical cells[76] and is composed of lipids, non-keratinous proteins and resistant membranes.[72] Cuticle cells are separated from the underlying cortical cells by the CMC.[76] Together with proteins, the cell membrane lipids (i.e. internal lipids) are the main components of the cell membrane complex (CMC),[58,77] the latter forming a network throughout the whole fibre, thus contributing to cell cohesion (it surrounds the cuticle and cortical cells and holds them together).[78] The cell membrane complex has a dramatic influence on fibre and fabric properties (Leeder[79] quoted by Tucker et al.[58]). Tucker et al.[58] have reviewed work done on the composition of internal lipids.

Spei and Holzem[64] reviewed the characterisation of fibre keratins, including mohair, by X-ray, microscope and thermo-analysis methods and presented the following summary: 'The three main morphological components of fibres, such as mohair, are the cuticle, cortex and membrane complex, with each consisting of further sub-components.[64] The cortex consists of individual cortex cells, which are in turn built up from macrofibrils (+ intermacrofibrillar matrix (cement)), microfibrils, protofibrils and α-helices.'[64]

The microfibril matrix complex largely determines the mechanical properties of fibre keratins and also contributes towards determining other physical properties. The microfibril matrix complex consists of partly helical, low-sulphur microfibrils embedded in a non-helical sulphur-rich matrix. X-ray small-angle studies on chemically modified, extended fibre keratins have shown that at least two ordered regions exist along the fibre axis, and that the matrix, which was previously regarded as amorphous, must have a certain structure.

Table A3.1 Comparative analysis of wool, mohair and feathers

	Wool (this research)*	Wool (Graham et al.)	Wool (Lindley ⊥)	Wool (Simmonds)	Wool (Speakman)	Mohair (this research)	Feather (this research)	Feather (Graham et al.)
	Grams from 100 g of dry keratin							
Constituent								
Total nitrogen	16.82	16.2	16.9	16.62	(17.23)↕	17.02	16.2	1
Ammonia (amide) nitrogen	1.10			1.42	1.37	1.21	1.09	
Amino nitrogen	0.33				(0.33)↕	0.35	0.25	
Sulphur	3.70		3.76	3.68	(3.65)↕	3.19	2.70	
Amino acid								
Alanine	3.85		3.4	3.71	4.4	4.26	5.4§	
Arginine	9.15	10.6	10.5	10.49	10.4	8.94	6.88	
Aspartic acid	6.40	7.2		6.69	7.3	7.32	5.82	
Cystine	11.0	13.7	11.6	11.30	13.1		6.8§	
Glutamic acid	13.1	15.6		14.98	16.0	14.2	9.02	
Glycine	5.30			5.16	6.5	4.77	7.2	
Histidine	0.96	1.1		0.90	0.7	0.90	0.33	
Hydroxylysine					0.2			
Isoleucine	3.80	4.5		3.07		3.90	5.3	
Leucine	7.72	8.1	10.6	7.63	11.6	8.14	7.4	
Lysine	3.08	3.3		2.82	3.3	3.07	1.00	

Methionine	0.54	0.6		0.69	0.7	0.52	0.38
Phenylalanine	3.40	4.0	3.8	3.43	4.0	3.66	4.65
Proline	6.38	8.1	5.3	7.28	7.2	5.64	10.0
Serine	7.16			9.04	9.5	6.05	14
Threonine	6.55	6.7	16.7⊥	6.55	6.6	5.62	4.8
Tryptophan				2.10	1.8		
Tyrosine	4.00	5.6	5.7	6.38	6.1	2.39	2.00
Valine	5.90	5.7	5.1	4.96	5.5	6.12	8.8
	Percentage accounted for						
Recoveries							
Total weight	84.1	82.3	62.6	93.5‖	98.4	73.3	84.7
Total nitrogen	87.8	79.1	62.6	98.5‖		78.2	91.0
Amino nitrogen	89.0					92.0	38.0
Sulphur	82.5		82.4	86.0			69.0

* Average values are given for contract (WC) wools.
⊥ Calculated from results given. The value for serine plus threonine assumes equal weights of each, with allowance for 0.2% of hydroxylysine.
‡ The highest values are used for comparison. The total nitrogen, amino nitrogen, and sulphur given at the head of this column are those computed from the amino acid and ammonia nitrogen contents.
§ The alanine and cystine contents reported here for feathers are from weighted averages of analysis of feather fractions.
‖ One of the two unidentified substances found by Simmonds is allowed for in computing recovery of total weight and nitrogen.
Source: Ward et al.[75]

Zahn[40,63] reviewed the structure of mohair, stating that the strength and resistance to wear of mohair are considered to be a consequence of the regular cortical layer built up from spindle-shaped cells.[40] The cortex of mohair comprises microfibrils which are up to 0.2 µm wide, the macrofibrils consisting of bundles of microfibrils which are in hexagonal packing. The microfibrils or keratin intermediate filaments (KIF) represent about 60 to 70 % of the fibre mass. The sub-bundles of the KIF are 8 keratins of 40 to 70 kilodaltons. Each has a central alpha-helical rod domain of 311–314 amino acids. The fundamental building blocks of the KIF are four-chained coiled-coil units consisting of a pair of two-chain coiled-coil molecules. Eight keratins constitute the KIF in cortical cells of both mohair and merino wool fibres.[40]

Zahn[40,63] summarised the work done to date on mohair chemical structure as follows:

1. The resistance to wear of mohair is related to the regular structure of the macrofibrils in the cortex.
2. Eight keratins constitute the Keratin Intermediate Filaments (KIF) in cortical cells, not only of merino wool but also of mohair.
3. Mohair has the highest helix content as found by differential scanning calorimetry (DSC).
4. Lysine residues in the KIF of mohair have an axial periodicity of 39 Å in agreement with our present knowledge of the position of lysine in keratins.
5. X-ray studies on mohair gave early evidence for microfibrillar swelling.
6. The presence of a structural regularity at 198 Å has been identified by X-ray work on mohair.
7. Stretching mohair fibres under specified conditions revealed the phenomenon of bimodal elongation of filaments.
8. By combination of these data, a structural model for wool and mohair is proposed: in engineering terms the ‘fibre/matrix’ composite is provided mainly by the KIF. The 50 % non-helical sections are the main components of the ‘matrix’.

Various other articles (see Hunter[2]) also deal with topics related to those covered in this discussion on mohair.

The cortical cells of keratin fibres, such as mohair, consist of filaments (aligned) of relatively low cystine (sulphur) content and high α-helix content (low-sulphur proteins),[80,81] surrounded by a non-filamentous matrix containing two protein types, one cystine-rich (high-sulphur proteins) and the other rich in glycine and tyrosine (high-tyrosine proteins)[82] and[83] (as quoted by Tucker et al.[58]). There are important differences in composition between keratin fibres which are mainly caused by differences in the amount and type of constituent high-sulphur proteins,[84] which could hold the key to the differences in physical properties of keratins.[85]

Although the constituent proteins of merino wool and mohair appear to contain some remarkable similarities, the overall chemical, physical and morphological properties of these fibre types differ in many respects. There also appears to be evidence that there are differences between Kid mohair and Adult mohair.[43]

Broadly speaking, two types of cortical cells generally occur, namely para-cortex and ortho-cortex, which differ somewhat in chemical and physical properties. The cystine (sulphur) content of the para-cortex is about twice that of the ortho-cortex,[86] and the latter is less stable than the former.[70] Mohair (particularly Kid mohair), is predominantly ortho-cortex, but also contains some para-cortex.

Amino acid composition

The amino acid composition of Kid mohair was found to be largely similar to that of merino and of Lincoln wool.[80] Ward et al.[75] found that the amino acid values of wool and mohair did not differ very notably, except possibly in the cases of tyrosine, aspartic acid, serine and threonine. The most interesting apparent chemical differences were in the relatively low sulphur (and therefore cystine) contents and the relatively high values for aspartic acid.[75]

Various investigations into the high-sulphur proteins of both oxidised and reduced mohair have been conducted.[87,88,89,90,91] Amino acid analyses have been carried out on mohair by, for example, Swart and co-workers[87,92,93,94,95] and Gillespie.[96] Swart et al.[87] compared the soluble proteins of oxidised mohair and reduced mohair with those of wool. They found that the amino acid composition of wool and mohair as well as the α-, β- and γ-keratose isolated from the two fibre types were very similar, with the high-sulphur proteins revealing marked differences. They also showed that oxidised mohair contained more α- and less β-keratose than wool. The physical properties of mohair and wool γ-keratins sub-fractions were similar, although amino acid analysis revealed interesting differences for the sub-fractions. Chromatographic separation, on DEAE-cellulose, indicated that the high-sulphur protein fraction (SCMKB) of wool contained protein compounds which could not be accounted for in similar fractions of mohair.

Swart et al.[87] presented Table A3.2. Gillespie and Inglis[84] compared the high-sulphur proteins (SCMKB) from various α-keratins, including mohair (see Table A3.3).

Swart[56] showed that the amino acid composition of kemp was different from that of Adult mohair, the former containing more β-keratose but less γ-keratose than the latter. Swart et al.[97] subsequently compared the proteins of Adult mohair, Kid mohair and kemp fibres, the amino acid composition of the fibres revealing differences. This was further supported by the different proportions of the α-, β- and γ-keratoses of the fibres and the amino acid composition of these keratoses. Swart et al.[97] gave a table summarising the physical measurements on sub-fractions of γ-keratose found in Adult mohair, Kid mohair and kemp and also gave the amino acid composition of the sub-fractions of γ-keratose from Adult mohair, Kid mohair and kemp (Table A3.4).

The elucidation of the first complete amino acid sequence of a keratin protein was achieved by Haylett and Swart.[92] One of the first and most extensive surveys on the high-sulphur proteins (SCMKB) from reduced mohair was carried out by Joubert[90,91] who defined 5 major proteins by differences in their molecular weights

Table A3.2 Keratose contents in mohair and wool

Keratose	Origin	Mohair %	Wool %
α-Keratose	KIF	58.1	53.4
β-Keratose	Nonkeratins	10.3	15.8
γ-Keratose	Matrix (IFAP)	30.0	30.7

Source: Swart et al.[87] quoted in Zahn.[40]

Table A3.3 The amino acid composition of high-sulphur proteins from wool and mohair

Amino acid	Lincoln	Merino	Romney Marsh	Southdown	Soay	Dorset Horn	Mohair
Lysine	1.27	0.95	0.67	0.68	0.83	0.75	0.62
Histidine	2.60	1.83	1.61	1.53	2.00	1.68	1.43
Arginine	18.1	18.3	15.6	16.4	14.0	19.8	16.7
SCMC	14.4	14.6	15.7	16.6	16.7	17.7	14.8
Aspartic acid	2.22	2.29	2.42	2.05	1.41	2.05	2.01
Threonine	7.59	7.90	7.12	7.68	7.50	7.55	7.38
Serine	9.00	9.80	7.80	8.70	8.75	8.76	8.65
Glutamine	5.27	6.50	5.51	5.63	5.50	5.50	5.82
Proline	8.82	9.60	10.2	9.72	9.33	10.4	9.55
Glycine	4.41	5.30	4.30	4.44	4.08	4.38	4.78
Alanine	2.25	2.26	2.15	2.05	1.83	2.05	2.35
Valine	4.54	4.35	4.30	4.09	4.00	4.29	4.03
Isoleucine	2.27	2.75	2.28	2.22	1.91	2.14	2.31
Leucine	2.81	2.98	3.09	2.73	2.08	2.80	2.84
Tyrosine	1.81	1.64	0.81	1.19	1.08	1.58	1.01
Phenylalanine	1.36	1.45	1.61	1.36	0.91	1.40	1.60

Results expressed as amino acid nitrogen/100 g total nitrogen.

These proteins were hydrolysed under reflux and the SCMC content reported was obtained from the sum of half cystine and residual SCMC.

Source: Gillespie[84].

(approximately 9900, 12 200, 15 500, 19 000 and 22 500), electrophoretic mobilities and amino-acid compositions. Swart et al.[98] presented amino acid sequence data on the high-sulphur proteins from the 16 000 dalton groups of mohair and wool, a five-amino acid-residue repeating unit in the 16 000 dalton group previously being demonstrated by Joubert and Swart (quoted by Swart et al.[98]).

(References are to be found at the end of Chapter 2.)

Table A3.4 Amino acid composition of subfractions of γ-keratose from Adult mohair, Kid mohair and kemp

	γ_1-keratose			γ_2-keratose			γ_3-keratose			γ_4-keratose		
Amino acid	Adult mohair	Kid mohair	Kemp	Adult mohair	Kid mohair	Kemp	Adult mohair	Kid mohair	Kemp	Adult mohair	Kid mohair	Kemp
Alanine	1.82	2.06	2.03	2.31	2.45	2.32	1.95	2.04	2.00	2.75	2.92	3.04
Ammonia	10.45	10.16	9.08	8.24	9.14	9.11	6.84	7.01	7.05	7.23	7.49	7.39
Arginine	15.57	14.78	14.62	19.35	18.47	17.95	27.62	27.60	26.39	18.80	16.68	15.47
Aspartic acid	0.80	0.56	0.62	1.52	1.40	1.72	1.53	1.56	1.62	3.97	4.73	5.33
Cysteic acid	18.39	18.66	17.74	16.50	17.24	15.90	15.18	15.03	15.28	11.73	11.40	11.19
Glutamic acid	7.91	8.16	8.50	6.29	6.38	6.39	5.24	5.27	5.14	4.15	4.39	3.56
Glycine	5.02	5.43	5.71	3.89	4.15	4.01	3.32	3.36	3.44	4.36	4.41	4.54
Histidine	0.73	0.56	0.37	1.35	1.21	1.48	0.54	0.58	0.58	3.17	4.22	4.23
Isoleucine	2.72	3.08	3.18	2.40	2.55	2.47	1.48	1.45	1.49	2.36	2.43	2.78
Leucine	1.24	1.36	1.31	2.49	2.50	2.75	2.14	2.17	2.17	4.06	4.57	5.17
Lysine	0.45	0.44	0.22	0.56	0.73	0.64	0.35	0.32	0.42	1.14	1.34	1.49
Phenylalanine	0.63	0.74	0.83	1.06	0.89	1.15	1.40	1.53	1.60	2.17	2.47	2.70
Proline	8.54	8.78	8.43	10.07	9.95	10.21	10.05	9.71	10.01	9.93	9.92	10.13
Serine	11.98	11.26	12.07	9.99	9.81	10.25	7.50	7.94	7.08	9.13	9.17	8.22
Threonine	8.42	8.26	8.82	8.01	7.45	8.23	7.93	7.90	7.78	7.62	7.85	7.69
Tyrosine	1.08	1.13	1.11	0.87	0.64	0.77	0.62	0.65	0.58	0.96	1.08	1.01
Valine	2.94	3.11	2.90	4.17	4.19	3.95	4.91	4.19	4.92	4.83	5.01	4.61
TOTAL	98.09	98.53	97.60	99.07	99.15	99.30	98.60	99.03	97.55	98.41	100.08	98.55

Source: Swart et al.[97]

Appendix 4

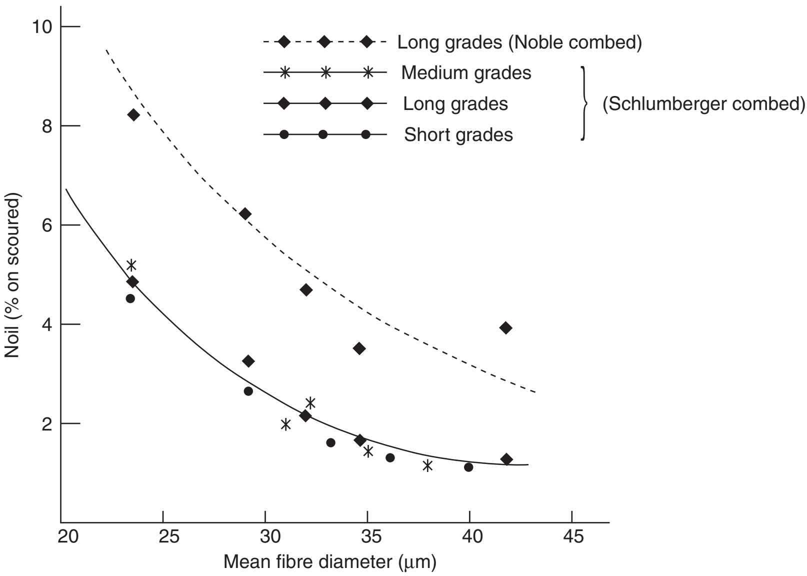
Mohair yarn spinning and properties

Mohair yarn spinning

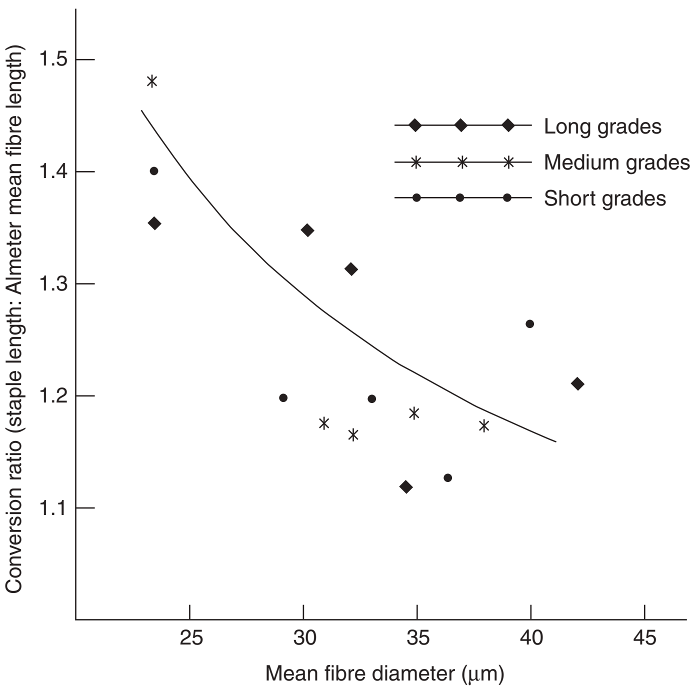
The most detailed processing studies on mohair were undertaken at the South African Wool Textile Research Institute (SAWTRI) during the 1980s, using the Continental Worsted System, with some lots also being processed on the Noble comb. The studies were aimed at elucidating, amongst other things, the effects of fibre diameter and length on processing behaviour and yarn and fabric properties. In one of the first studies, Turpie and Hunter[246] found that spinning potential was mainly affected by fibre diameter, deteriorating with an increase in fibre diameter. In a later study Strydom[247] found that the Noble comb removed 2 to 3 % more noil than the French comb (Fig. A4.1), producing tops 4 to 6 mm longer with a lower CV of length. Finer mohair suffered more fibre breakage during processing and as a result exhibited poorer conversion ratios (Fig. A4.2). Nevertheless, they tended to spin better than the coarser qualities, even for the same number of fibres in the yarn cross-section (Fig. A4.3). Mean fibre length, mean fibre diameter and number of fibres in the yarn cross-section were found to explain some 85 % of the observed variation in spinning potential, with the contribution of other variables, such as CV of length and diameter, being non-significant in this particular case.

Goen[248] reported on the processing of cut mohair top (38 mm length), in various blends with cotton, on a short-staple (cotton) system, blending taking place in the opening room. Although the lower levels of mohair were processed without much difficulty it became increasingly problematic to process the blends as the mohair content increased; it was very difficult to process the 40/60 mohair/cotton blend, more roving twist also being required.[248] This caused snarling and the roving had to be steamed. Spinning also became increasingly demanding as the level of mohair increased, yarns ranging from 50 to 75 tex being spun.

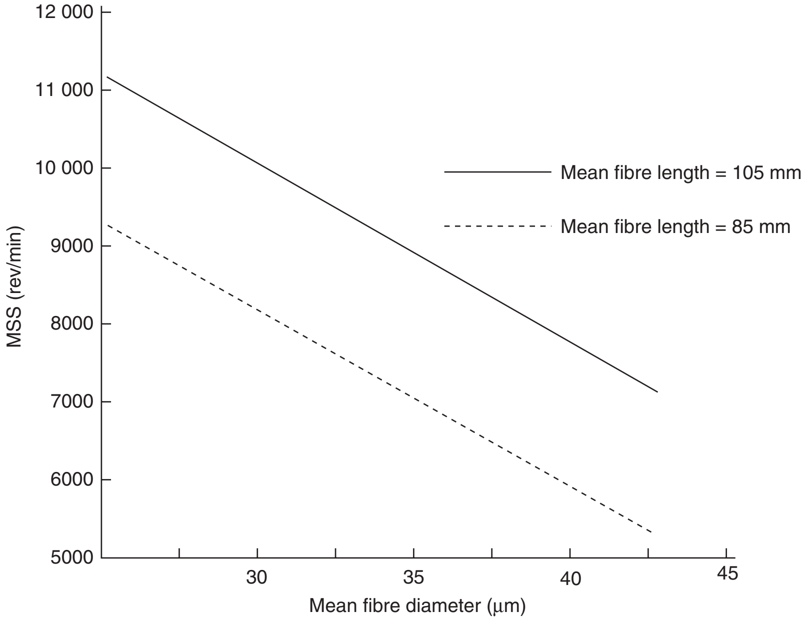
Strydom[249] compared the processing behaviour (Continental System) of Summer and Winter Cape Mohair. He found that once differences in mean staple length and mean fibre diameter, associated with season, had been allowed for (Fig. A4.4 and A4.5), no residual effect of season could be found in any of the relationships governing scoured yields, card wastes, comb noil, top and noil yields, mean fibre diameter in the top, top Hauteur or conversion ratio.[249] Season therefore only affected processing performance in so far as it affected the measurable fibre properties, such as staple length and mean fibre diameter. In a follow-up study, Strydom[250] compared the processing behaviour of blends of mohair types differing in length.



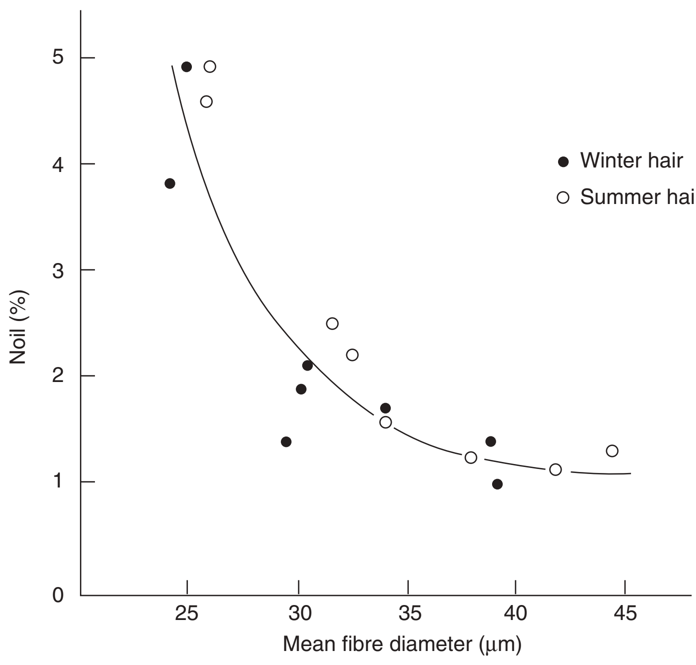
A4.1 The effect of mean fibre diameter of the raw hair on percentage noil.[247]



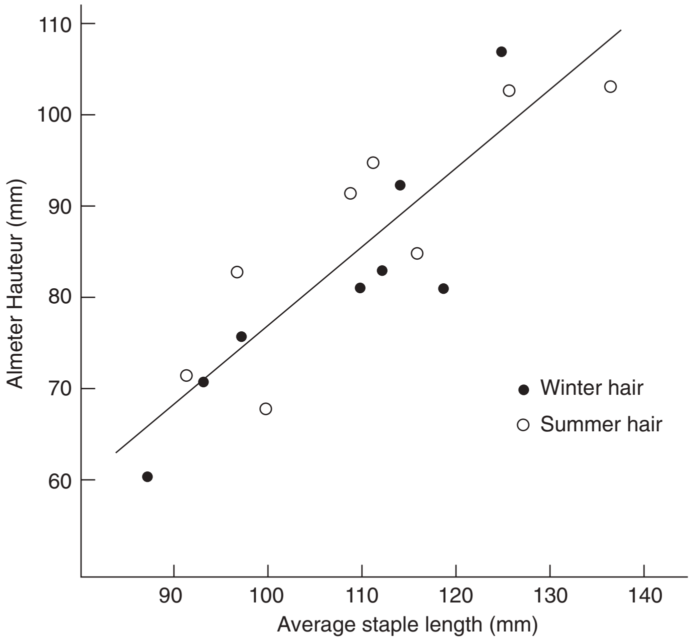
A4.2 The effect of mean fibre diameter on the conversion ratio (Schlumberger combing).[247]



A4.3 Regression curves illustrating the effect of mean fibre diameter on MSS (no. of fibres/cross-section = 40).[247]



A4.4 The relationship between mean fibre diameter in the grease and percentage noil.[249]



A4.5 The relationship between average staple length in the grease and Almeter Hauteur mean fibre length in the top.[249]

In a final report on the various studies on the processing of mohair on the continental system, Strydom and Gee[251] concluded as follows. Wave frequency (i.e. waviness or crimp) decreased with age, it being negatively correlated with fibre diameter and slightly positively correlated with grease content. The scouring yields observed varied between 78 and 91 %, while card losses varied from 3 to 12 %. Table A4.1 summarises their results.

The fibre diameter means and CVs of the top were found to be closely related to those of the unprocessed hair. The top tended to be coarser than the raw hair, from about 0.5 μm coarser at the fine end of the scale (i.e. Kid hair of about 25 μm) to about 1.3 μm coarser at the coarser end of the scale (Adult hair of about 45 μm). (Keller and colleagues at the USDA, quoted by Strydom and Gee,[251] found similar differences for Kid hair but only about half this difference for Adult hair.[251] Staple length on its own did not appear to be a very good predictor of Hauteur, but by including data on diameter (D), diameter variability (CV_d) and wave frequency (WV), some 83 % of the observed variation in hauteur could be explained. Dry-combed top and noil yields varied from 73 to 89 %, depending largely upon mohair base.[251] There were no systematic differences between the yields estimated from core test data and the actual yields obtained. Diameter played a very important role in determining noil, the latter decreasing almost linearly with an increase in mean fibre diameter; part of this could be due to the correlation between staple length and mean fibre diameter. Their results suggested that mohair, either more variable in length or diameter or both, tended to yield lower top and noil values. The small contribution of a term involving staple length and wave frequency (SL × WV) sug-

Table A4.1 Means and ranges of raw hair characteristics and processing data

Independent variable (Greasy mohair data)	Symbol used in text	Kids			Young goats			Adults		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Mean fibre diameter (μm)	D	27.6	23.1	31.6	32.2	29.1	35.3	38.5	33.0	44.5
CV of diameter (%)	CV_d	26.0	21.0	33.0	22.7	20.0	26.0	25.9	21.0	29.0
Mean staple length (mm)	SL	107	78	127	110	84	137	111	91	126
CV of staple length (%)	CV_{SL}	15.0	10.0	22.0	15.5	10.0	27.0	15.0	10.0	22.0
Mean single fibre length (mm)	–	106	78	133	115	95	147	110	88	129
CV of fibre length (%)	–	37.0	29.0	44.5	32.6	26.2	36.3	25.9	28.5	42.4
Wave frequency (cm^{-1})	WV	0.52	0.45	0.66	0.47	0.42	0.53	0.39	0.28	0.46
CV of wave frequency (%)	CV_{WV}	21.0	10.0	30.0	21.3	10.0	35.0	24.4	10.0	42.0
Grease content (%)	GC	4.9	3.3	8.0	4.9	4.0	5.6	4.1	2.9	5.5
Suint content (%)	SC	2.7	2.2	4.0	2.9	2.4	4.2	2.5	1.8	3.2
Mohair base (%)	MB	70.9	64.3	75.1	70.0	65.7	74.1	73.1	66.5	77.3
VM base (%)	VMB	0.30	0.1	0.7	0.20	0.04	0.4	0.3	0.1	1.5

Dependent variable (Processing factor)									
Scoured yield (%)	84.0	77.7	91.0	82.5	79.4	86.9	86.1	80.1	90.6
Card rejects (%)	4.3	7.8	8.0	4.0	2.9	5.9	5.2	3.5	12.5
Comb noil (%)	3.5	1.2	6.3	1.8	1.1	2.5	1.3	0.6	2.0
Top and noil yield (%)	81.6	72.8	89.2	80.5	78.1	85.9	83.0	76.4	87.9
Mean fibre diameter (μm)	28.5	24.0	33.8	32.8	29.3	36.2	38.9	31.5	45.6
CV of diameter (%)	25.7	19.0	33.0	22.5	20.0	25.0	25.4	22.0	28.0
Hauteur (mm)	84	60	104	91	76	109	93	71	107
CV of Hauteur (%)	46.2	35.5	66.3	44.9	29.8	55.6	39.4	34.2	48.0
Short fibre (% < 25 mm)	6.4	1.3	23.6	6.4	0.6	17.1	3.8	0.3	12.8
Long fibre (L @ 5%)	137	112	165	143	112	169	141	114	158
Single fibre length (mm)	99	81	122	103	84	118	101	79	114
CV of single fibre length	35.6	22.0	43.0	35.3	30.0	49.0	35.3	28.0	42.0
Short fibre (% < 25 mm)	3.6	1.2	7.3	3.3	1.1	5.9	3.6	1.1	7.3
Long fibre (L @ 5%)	150	133	167	155	122	189	152	131	175

Source: Strydom and Gee[251]

Table A4.2 Regression analysis: spinning performance as measured by MSS technique

Basis of analysis	r^2	Regression equation
No of fibres in yarn cross-section (n)	0.642	$-3.0\ D^2 + 0.57\ (H \times n) + 1.3\ (H \times CV_H) + 1.5\ CV_d^2 + 2546$
Yarn linear density (tex)	0.658	$-5.2\ D^2 + 0.63\ (H \times tex) + 1.1\ (H \times CV_H) - 0.2\ (tex)^2 + 6481$

Source: Strydom and Gee[251]

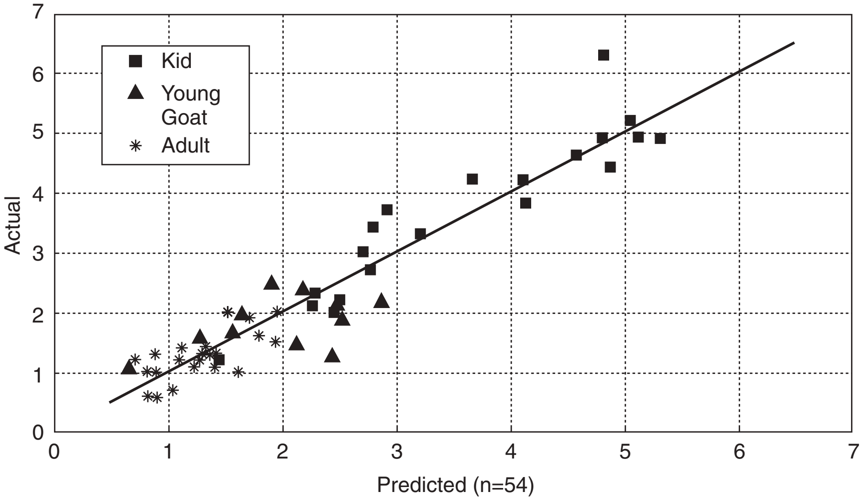
gested that hair either longer or more curly, or both, tended to yield slightly better top and noil values.

Strydom and Gee[251] found that wave frequency affected the relationship between Almeter and single fibre length results, also confirming that coarser fibres had poorer spinning performance than finer fibres, even when the number of fibres in the yarn cross-section was constant. Table A4.2 summarises the results of their statistical analyses. In both equations a term ($H \times CV_H$) appears, which suggested that hair either longer, or more variable in length, or both had better spinning performance. The primary determining factors for MSS, however, remained the number of fibres in the yarn cross-section (n) and mean fibre length (H), with the effect of CV_H being of secondary importance in terms of its magnitude.[251]

In parallel studies[252] on the Noble and rectilinear (i.e. French or Continental) combs it was found that, as expected, more noil was produced on the Noble comb than on the rectilinear comb (Fig. A4.1). The noil ranged from as little as 1 to about 5 % during rectilinear combing and from about 4 to 8 % during Noble combing, the amount of noil being dependent upon the diameter of the hair, but not on the length. The increase in noil with decreasing fibre diameter was probably due to more breakage being suffered by the finer fibres during processing. Conversion ratios from the staple to the top ranged from about 1.1 : 1 to 1.4 : 1.[252]

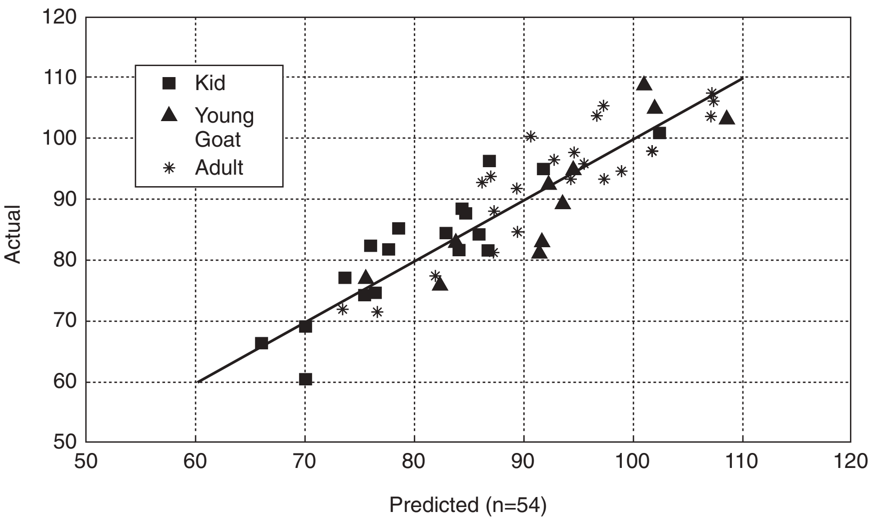
Hunter and Dorfling[253] investigated the effect of Angora goat age on mohair processing performance on the Continental (French) System. They showed that, provided corrections are introduced for differences in the measurable fibre properties, notably diameter and length, goat age has no effect on processing performance and top properties, such as percentage noil and Hauteur (Fig. A4.6 and A4.7). What this essentially means is that provided the fibre characteristics, such as diameter and length, are constant, the age of the goat has no additional effect on mechanical processing performance up to and including spinning performance.

In another study[254] it was found that mohair of better Style and Character performed better during processing and also showed better textile performance criteria as demonstrated in Fig. A4.8. Minikhiem et al.[256] found differences in subjectively assessed style and character to be reflected in top characteristics, such as kemp, diameter and medulla content. Turpie[257] has summarised the work done at SAWTRI on the effects of mohair fibre properties, diameter in particular, on processing performance, including spinning. Smith[258] discussed some of the processing requirements of the various speciality fibres.



Noil(%) = –0.7684 D + 0.02548 L + 0.008257 D^2 + 0.002560 Vd^2 + 14.15

A4.6 Percentage noil.[255]

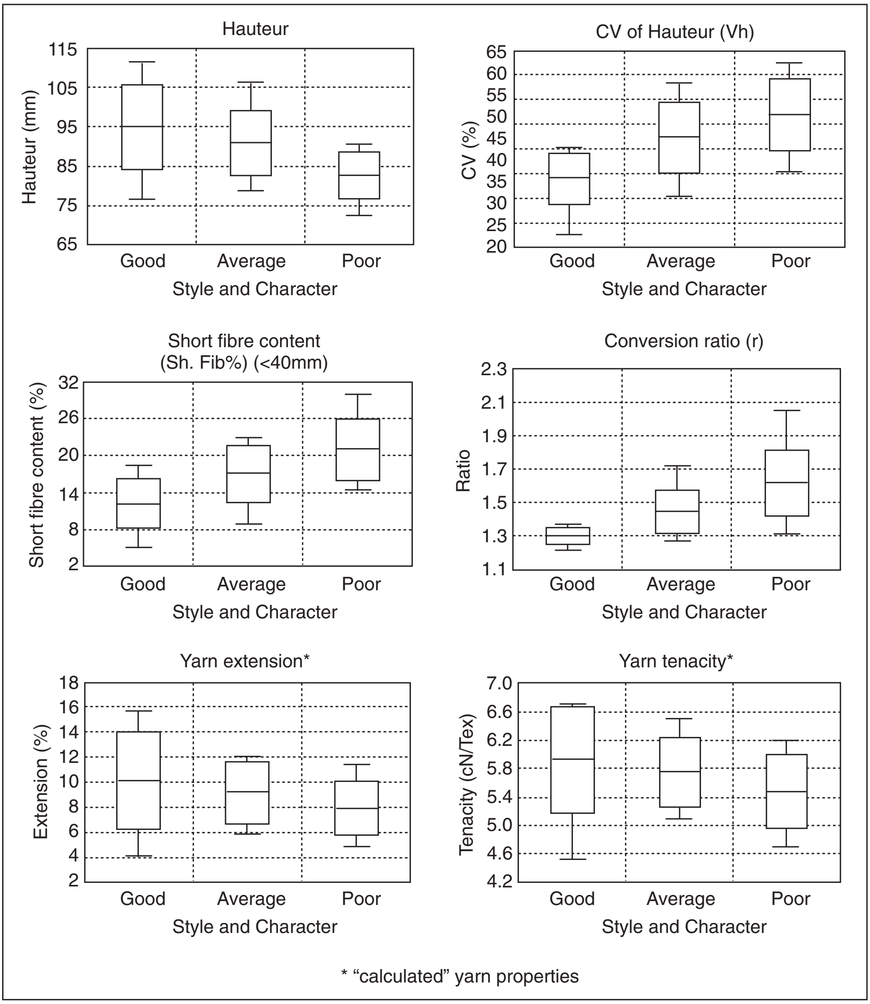


Hauteur = –1.239 Vd – 0.02385 D^2 + 0.02067 L.D + 71.31, %Fit = 81.5

A4.7 Hauteur (mm).[255]

Repco-wrapped core spun yarns

Various researchers at SAWTRI carried out considerable work on the spinning of mohair yarns,[261,262] including slub yarns,[263] on the Repco Self-twist spinner, without[264] and with nylon filaments.[265] It was concluded that the best results were obtained when two multi-filament yarns (usually 17 or 22 dtex nylon) were introduced, the

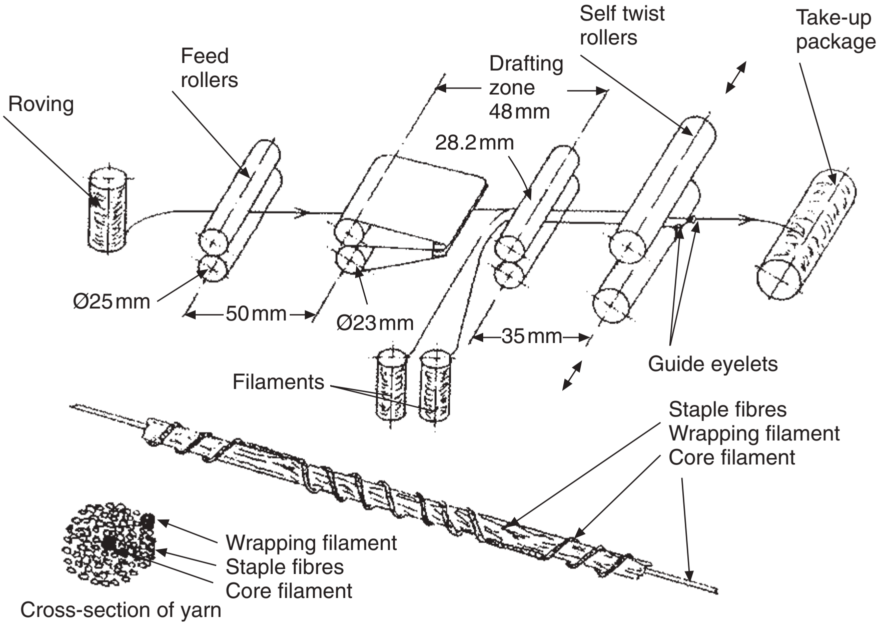


A4.8 Box plots illustrating the effect of mohair style and character on certain textile performance criteria.[254]

one to act as a core and the other as wrapper. Yarns so spun (and generally up-twisted after spinning – STT) were designated as Repco-Wrapped Core-Spun (RWCS) yarns. Two strands of mohair and one nylon filament core were drafted and self-twisted with a filament binder yarn to form an RWCS yarn[265] (see Fig. A4.9). Different variations were developed. The yarns were converted into light-weight fabrics, generally with highly acceptable properties.

DREF friction spinning

Robinson et al.[266] used the novel feature of the DREF II open-end friction spinning machine that enables the radial positions of the fibres in the yarn cross-section to



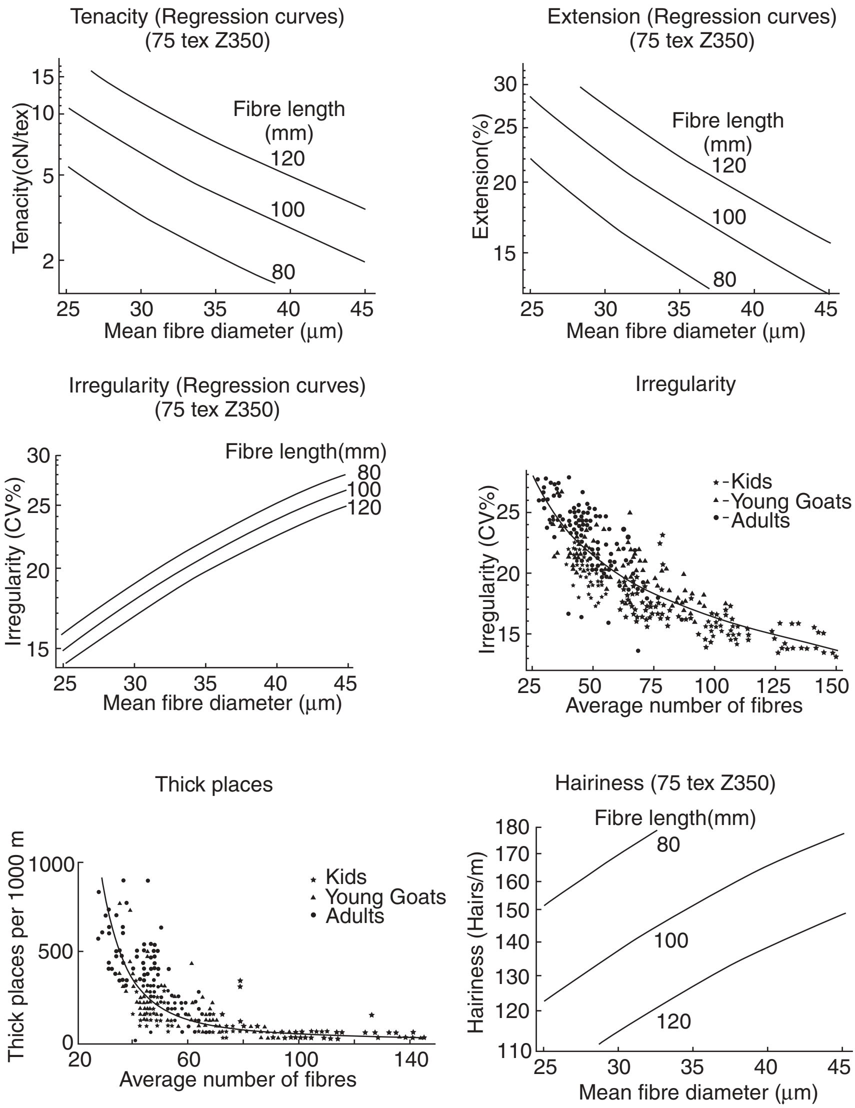
A4.9 RWCS system.[157]

be predetermined to show how a speciality fibre, such as camelhair or mohair (e.g. noils), can be made to predominate on the yarn surface whilst a cheaper fibre makes up the body of the yarn. In this manner the yarn, and subsequent fabric, has the aesthetic qualities of the speciality fibre in spite of the fact that the latter only makes up a small proportion of the whole.

Worsted yarn properties

The most comprehensive studies on the relationship between mohair fibre and yarn properties were carried out by Hunter and co-workers.[267,268,269] In a wide ranging study, involving the processing of some 50 mohair lots on the Continental worsted system followed by ring spinning, Hunter et al.[269] investigated the effect of fibre properties, notably diameter and length, on yarn and fabric (knitted and woven) properties. They derived multiple regression equations by means of which the yarn and fabric properties could be predicted from fibre diameter, fibre length and yarn linear density and twist. Within the ranges covered, the effect of fibre diameter on yarn properties was far greater than that of fibre length, while the effects of variability (CV) of fibre diameter and fibre length and short fibre content were relatively small. Virtually all the yarn properties deteriorated with an increase in mean fibre diameter (or with a decrease in the number of fibres in the yarn cross-section), while an increase in mean fibre length generally had a beneficial effect.[269] Figure A4.10 illustrates some of the main trends.

Hunter and Kruger[270] investigated the effect of different levels of paraffin wax on the friction of mohair/wool yarns of different blends. They found that this property



A4.10 The effect of mohair fibre properties on yarn properties.[269]

increased with increasing mohair content. The phenomenon was ascribed to the extractable matter on the mohair rather than the mohair fibre itself, since solvent extraction or scouring of the yarns prior to waxing eliminated the effect.

An important property of textiles, and also therefore of mohair, is its low bending stiffness (flexural rigidity) which makes it suitable for many end-uses, in particular apparel. Understanding the role of the many factors involved in determining flexural rigidity, or bending stiffness, is essential for a better understanding of the broader issue of fabric drape and handle which play such an important role in determining the suitability of a fabric for a particular end-use. It is generally accepted that fibre stiffness plays a dominant role in yarn and fabric stiffness and handle (softness), with fibre stiffness largely a function of fibre diameter, increasing with the fourth power of diameter.

Yarn flexural rigidity is important because of its large effect on the bending properties and behaviour of a fabric. Yarn stiffness affects the drape coefficient and, because it is related to fabric flexural rigidity, it also affects the handle of a fabric, handle being closely related to fabric flexural rigidity. It is also of some importance during fabric forming processes (e.g. knitting).

(References are to be found at the end of Chapter 2.)

Appendix 5

Mohair fibre and fabric properties

The relationship between fibre properties and the physical properties of fabrics

In a comprehensive study, Hunter et al.[269] investigated the effects of mohair fibre properties, particularly diameter, length and yarn twist, on the physical properties of plain and twill weave mohair and mohair/wool fabrics. Their conclusions are detailed in the following paragraph.

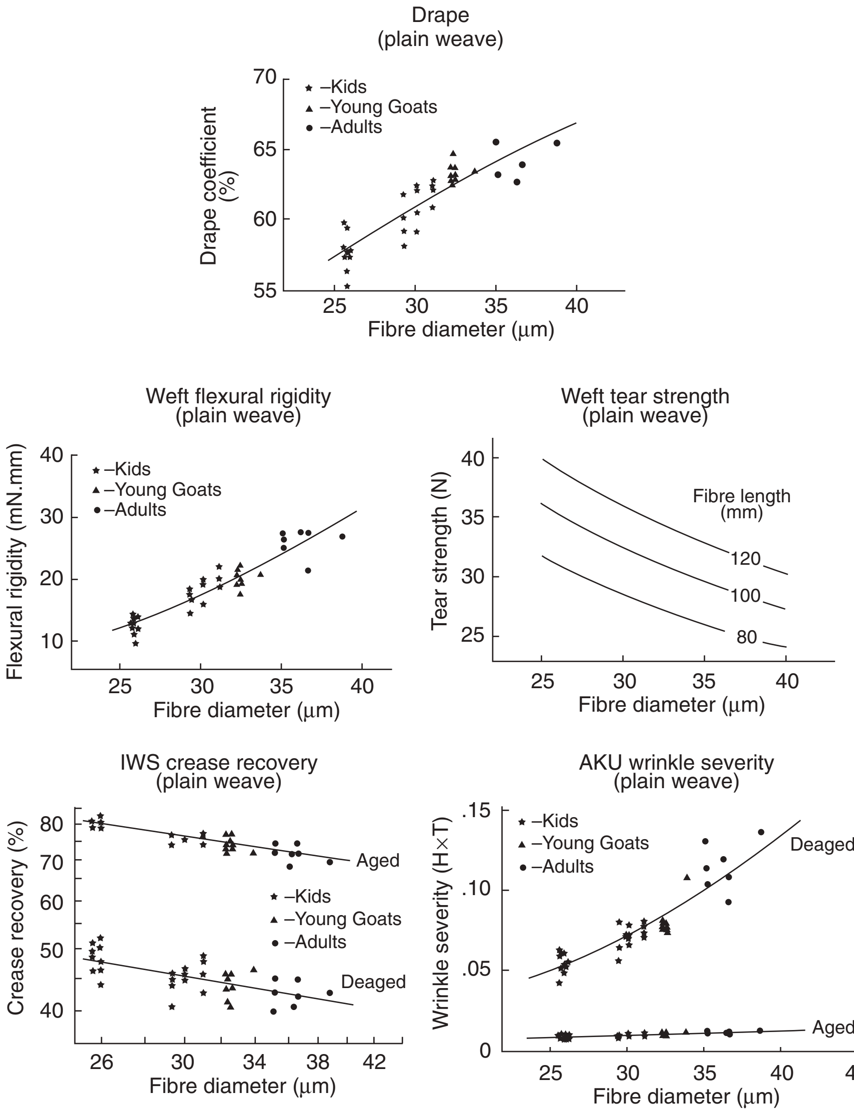
Fibre length generally had little effect on the fabric physical properties, whereas fibre diameter in most cases had an important effect. Drape coefficient, stiffness, abrasion resistance and hygral expansion increased with an increase in fibre diameter, while wrinkle recovery (IWS Thermobench and AKU methods), shrinkage (felting and relaxation), strength and extension decreased with an increase in mean fibre diameter.[269] Fibre length and yarn twist, within the ranges covered, generally had little effect of any practical consequence. It also emerged that once differences in mean fibre diameter were corrected for there was little difference between the fabrics containing Kid, Young Goats and Adult mohair. Figure A5.1 illustrates some of the main trends.

Galuszynski and Robinson[271] investigated the making-up of mohair/wool blend fabrics, recommending the chain-stitch for reducing seam pucker due to the sewing thread.

Fabric objective measurement

Those fabric properties important in the making-up (tailorability) and in the appearance of the garment after making-up as well as those playing a role in fabric handle are increasingly being measured. Two systems of fabric objective measurement, namely Kawabata (KES-F) and FAST, have reached the market. Carnaby et al.[272] and Kawabata et al.[273] reported on the use of objectively measured properties (Kawabata system) of summer (tropical) suitings, including mohair/wool blend weft and 22 μm merino wool warp, to design a suitable fabric containing New Zealand wool. (See also Appendix 4 on the relationship between fibre properties and the physical properties of fabrics.)

Fujiwara[274] described the design of a mohair blended fabric, with emphasis on the control of fabric handle and quality by objective measurement. He also showed[275]



A5.1 The effect of fibre diameter on certain woven fabric properties.

how a high quality (good tailorability) mohair/wool fabric could be designed and characterised by objectively measured fabric properties as measured on the Kawabata (KES-F) system. He showed how different parameters, measured by means of the Kawabata system, could be used to distinguish between 'good' and 'bad' mohair fabrics. For example, the 'good' fabrics had shearing (G) values lying between 0.4 and 0.6 while the 'bad' fabrics generally had values greater than 0.6. The fabric objective (Kawabata system)-measured properties of a mohair/wool tropical suiting fabric were given,[276,277] and so, too, the related yarn properties.[277]

Niwa et al.[278] reported on the important handle, suit appearance and other objectively measured characteristics of a high quality mohair/wool tropical suiting fabric, using the Kawabata system of fabric objective measurement. Properties of particular importance included high SHARI (a cool feeling coming from a pleasant rough surface touch), and moderately strong KOSHI (springy stiffness) and/or HARI (spread/anti-cling), the latter being important for producing an air space between the fabric and the skin of the wearer. The TAV (Total Appearance Value) derived from the Kawabata system of fabric objective measurement provided a means of predicting suit making-up performance and appearance, with a value of 5 being excellent and 1 poor.[278]

Smuts et al.[279] have reviewed the work published on the objective measurement of fabric properties, principally by the Kawabata KES-F and the FAST system, including a limited amount of work done on wool/mohair tropical suiting fabrics which had the desired crisp (SHARI) handle.

(References may be found at the end of Chapter 2.)

Appendix 6
Mohair dyeing and finishing

Swanepoel[283] investigated the dyeing behaviour (rates of dyeing and dye appearance) of wool and mohair, with fibres of both ranging in diameter from 21 to 30 μm. Difference in depth of shade and the rate of dyeing of wool and mohair differed from one dyestuff to another, although the trends were similar for all the dyestuffs. The rate of dyeing of mohair exceeded that of wool of the same diameter, with finer fibres dyeing more rapidly than coarser fibres. The depth of shade of the mohair was greater than that of the wool of the same diameter and containing the same concentration of dyestuff, this being ascribed to the differences in the surface structures of the two fibre types (i.e. the more lustrous nature of the mohair fibre surface).[283] For both wool and mohair, the depth of shade of fibres containing the same concentration of dyestuff increased with increasing average fibre diameter. According to Veldsman,[284] mohair dyes more rapidly than wool of similar fibre diameter, because of its greater proportion of ortho-cortex, and also appears darker for the same dye uptake, because of its higher lustre.

Roberts and Gee[285] compared the dyeing behaviour of mohair with that of Corriedale wool of similar diameter. The rate of dyeing of the mohair was found to be greater than that of the Corriedale wool, this conclusion being in line with that of Swanepoel.[283] In addition, the equilibrium exhaustion was found to be higher in the case of the mohair. When mohair and the Corriedale wool were dyed to the same nominal depth of shade, differences in apparent depth of shade were very small when assessed both visually and by an instrumental technique. It was speculated that the frequently claimed greater depth of shade obtained on mohair relative to wool was caused by the greater lustre of mohair relative to that, for example, of merino wool and that, when this lustre difference was absent, the apparent strength difference falls away.

According to work done by Gandhi[286] (quoted by Kidd[287]) and Onions[32] mohair is set more readily than wool, Onions[32] stating that the relative ease with which mohair sets accounts for its use in curled pile rugs and simulated Astrakhan fabrics. Grenner and Blankenburg[288] investigated the chemical setting, and associated damage, of crinkled mohair and wool yarns and found that a good degree of set could be obtained by boiling for one hour in a pH range of 4 to 6. This was, however, associated with relatively high fibre damage in the case of the mohair. Reducing the setting time to 30 minutes led to an improvement in setting with less fibre damage. Setting and dyeing could be combined into one process.[289]

Appendix 7
Mohair product list

Accessories (hats, gloves, handbags, etc)
Airgun darts
Airline blankets
Ankle socks (girls')
Artificial hair
Astrakhan
Athletic socks (hosiery)
Auto-textiles (floor coverings, carpets, boot liners, hoods, door trims, seats, upholstery, panel shelf)
Automobile seat covers

Bath mats
Bath sets
Bed covers
Bedspreads
Beltings and press cloths
Blankets
Blazers
Blousons
Bobby socks
Boot linings (automobile)
Braid
Brilliantine
Bunting (flag cloth)

Candlewick (bedspreads and dressing gowns)
Capes
Car coats
Cardigans
Carpet tiles
Carpets, rugs and mats (Axminster, Wilton, tufted, needle-punched, hand-knotted, knitted)
Casual wear
Ceremonial robes
Chenilles (carpets, socks, etc)

Cloaks
Coats
Coffin linings
Cords and tassels
Crepon goods
Curtains (damask, brocades, satins or velvet)
Cushion covers

Decorative trimmings (e.g. for coats, hats, shoes)
Dinner jackets
Dolls' wigs
Domestic textiles
Drapes/draperies (automobiles, aeroplanes, furnishings, trains, buses, domestic, office and industrial)
Dress suits
Dresser covers
Dressing gowns
Duvets

Eiderdowns
Evening gowns
Evening wear

Fabric art
Fabric panels
Fabric sculptures
Fake furs
Fancy yarns
Fibre art
Fire blankets
Flags
Fleecewear
Floor carpeting (aircraft, automobiles and buildings)
Foot muffs
Foot warmers
Fringes
Fur (imitation)
Furnishings

Gilets
Gloves
Golf club head covers
Golf shirts
Gowns

Half-hose
Hand-crocheted articles (shawls, stoles, etc)
Hand-knitting yarn
Hand-knotted carpets

Handwear
Home furnishings
Horse blankets
House slippers (felt)
Household textiles

Imitation furs
Infants' blankets
Ink-transfer pads
Interior panels
Interlinings

Jackets
Jerseys
Jumpers

Kelims
Kimono-look jackets
Knitted jerseys
Knitting yarn
Knitwear

Ladies' wear
Lamp covers (shades)
Leg warmers
Leisure wear
Linings

Machine-knitting yarns
Mantle cloths
Mats
Men's suits
Menswear
Mops
Mourning scarves
Mufflers

Neck ties
Neckwear
Needle-punched carpets, blankets, etc
Nets (laces and drapery materials)
Nightgowns
Nightwear
Novelty yarns

Oriental rugs
Overcoats

Paint brushes
Paint rollers

Palm Beach cloth
Panama suits
Persian carpets and rugs
Pile fabrics (upholstery, etc)
Plaids
Plush fabrics
Ponchos
Pram hoods
Press cloths (e.g. filters)

Quilts

Raincoats
Residential upholstery
Reversible lining
Robes
Roller brushes
Rugs (prayer, etc)
Runners (table, etc)

Saddle blankets
Scarves
Scatter cushions
Scatter rugs
Seat covers (cars, trains, planes)
Shawls
Sheepskin covers (real and imitation)
Sicilians
Skirts
Slippers
Smoking jackets
Snow and ski gear
Socks
Soft furnishings
Soft furs
Soft toys
Soldiers' uniform
Sports clothes (knitted)
Sports jackets
Stoles
Stuffed toys (pile fabrics, shaggy or cut)
Sweaters

Table covers (e.g. cloths, mats and runners)
Tam-o'-shanters
Tapestries
Tapestry yarns
Teddy bears
Theatrical wigs
Thigh-length cardigans

Ties
Toilet covers
Track suits
Travel rugs
Tray cloths
Trench coats
Trimmings (for coats, dresses, shoes, etc)
Trunk linings
Tunics
Tweeds
Tyre cords

Underblankets
Underlays
Uniforms
Upholstery

Velours
Velvets

Waistcoats
Wall covers
Wall hangings
Wigs and switches (e.g. for theatrical purposes)
Women's wear
Wraps

Appendix 8

Rules for the use of the Mohair trade mark (label)

Knitting yarns/garments

Gold Label

- Yarns containing 70 % mohair and above. Not exceeding 27 µm – Superkid.
- Yarns containing 70 % mohair and above. Not exceeding 32 µm – Kid.
- Yarns containing 70 % mohair and above. 32 µm and higher – mohair.

Silver Label

- Yarns containing 40 % mohair and above. Not exceeding 27 µm – Superkid.
- Yarns containing 40 % mohair and above. Not exceeding 32 µm – Kid.
- Yarns containing 40 % mohair and above. 32 µm and higher – mohair.

Any other fibres constitute the balance in each case. Control is dependent upon appearance and handle as well as fibre composition. Micron tolerance is $2^1/_2$ %.

Ladies' fabrics, blankets, scarves, etc

- *Gold Label* – minimum of 70 % virgin mohair by weight.
- *Silver Label* – minimum of 25 % virgin mohair by weight.

In all cases, the balance of the fabric must be composed of natural fibres. A tolerance of a maximum of 10 % of other fibres in the fabric is permitted provided such fibres are for reinforcement or visible decorative effects.

Menswear fabrics

- *Gold Label* – Qualities containing 50 % or more mohair by finished weight, or, qualities containing at least 30 % of Kid mohair by finished weight – the Kid mohair conforming to the official IMA definition of Kid mohair (i.e. 32 µm or finer).
- *Silver Label* – Qualities containing at least 25 % mohair by finished weight.

In all cases, the balance of the fabric must be composed of natural fibre. A tolerance of maximum of 10 % of other fibres (but not man-made fibres) in the fabric is permitted provided such fibres are for visible decorative effects.

Appendix 9

Trade environment database Scotland and China and cashmere trade (CASHMERE)

CASE NUMBER: 275
CASE MNEMONIC: Cashmere
CASE NAME: Scotland and China and Cashmere Trade

A. IDENTIFICATION

1. The Issue

Since the Victorian Era, British textiles have been regarded among the world's finest knits. Dawson International, Britain's largest textile company, requires one metric ton of cashmere wool per day to operate, while Britain's cashmere breeders produce less than one metric ton annually.[1] Presently, China supplies 60 % of the world's cashmere, which amounts to 3000 metric tons per year.[2] With economic liberalization, growth in textile and apparel industries, and direct access to cashmere wool, the Chinese are encroaching upon the domain of the British knitters and rival the British for the limited supply of cashmere wool. With the limits of wool produced globally, the increased popularity of cashmere apparel, and the inexpensive textiles from China, Scotland is faced with the possibility of inadequate supplies of quality cashmere wool at elevated prices.[3] While China seeks to expand markets and continue economic growth, Britain fights to maintain the cashmere supply at responsible prices while carrying on the tradition of high-quality woolen knitwear. Environmentally, the Scottish Highlands and the Himalayan regions of China will be impacted by increased herding, over-grazing, deforestation, and increased textile manufacturing. Within China, an environmentally unstable country, goat herding seems to attract little concern. More pressing environmental issues, such as elevated carbon dioxide levels and polluted water supplies, are the focus of a quickly modernizing China.

2. Description

Cashmere cloth is prized for its softness, warmth, and long life. Cashmere fibers become increasingly soft with wearing and [it] is referred [to] as the Fiber of Kings.[4] 'Ring shawls,' which are named for the process of pulling the shawl through a ring, are often passed down through the generations.[5] In addition to its softness and flexibility, cashmere wool, which experts claim is eight times warmer than sheep's wool, provides the necessary warmth for the harsh Himalayan climate.[6] Although cashmere is no longer limited to royalty, a king's ransom is required to buy cashmere with the current rate of $190 per pound for quality cashmere wool.[7] The economic stakes, competition over the supply of cashmere, and its significance to China and Britain, is understandable.

The name cashmere originates from the Kashmiri goats of the Himalayas. Cashmere wool is the downy undercoat that grows from midsummer to winter in varying quality by all goats.[8] Long guard hair protects the cashmere undercoat from the elements and is removed in the spring by shearing or gradually combing the hair to remove the down.[9] Each goat produces 3 to 8 ounces of cashmere down per year and the average single-ply women's sweater requires the wool of 3 or 4 goats or approximately 10 ounces of wool.[10] The quality of the wool is defined by the length, texture, and diameter of the fibers. These quality standards are affected by the climate in which the goats are raised and the nutrients that they consume.[11]

Mongolia's climate and geography is suited for herding cashmere goats, who thrive in harsh dry mountainous climates and produce the highest quality of wool. In moderate climates, goats lose the ability to grow the downy coats that produce quality cashmere for garments.[12] A significant quality differential exists between wool produced in Britain and the Himalayas. The British were content to import raw wool from China until the recent competition over the cashmere supply became a concern.

Previously, Chinese wool producers brought raw wool to a central market to sell at set prices; however, this operation changed.[13] With the economic liberalization of the mid-1980s, the mountain farmers were free to sell 25 % of their crops on the open market for cash.[14] The transition towards a market economy removed the central authority that set prices, standards, and amount of wool sold in China. To replace the government control, middlemen entered the equation and capitalized on the new economic operations by exacting high prices from the Western buyers. As restraints are removed, the quality of the raw wool decreases and prices soar as much as 50 % in 1990. With the substantial price increase for raw materials, Dawson International, Inc., the largest British knitwear company, estimated that the volume of cashmere sweaters sold fell by 30 % in 1990.[15]

The increased interest in the market economy led Chinese industries to expand beyond raw materials to begin processing and spinning the raw wool into cheap alternatives to Scottish knits. These inexpensive garments have already entered the Asian markets and may begin to enter the Western markets, which poses a threat to the British textile industry. According to Dawson International, the problem is not that the Scots will have to compete with the Chinese, rather, the limited amount of cashmere available.[16]

With the lessening of governmental control over the economic forces, China began to evolve from a raw material supplier to a cloth and apparel producer. The changes in production diminished the amount of raw wool for sale to British textile firms without relying on the Chinese processing techniques.[17] The British argue that the Chinese processing techniques ruin the length of the fibers, which (high-quality) woolen knits require. During the latter half of the nineteenth century, Joseph Dawson, the founder of Dawson International, perfected the processing of cashmere wool. Since Dawson invented this process, it has been a strictly guarded secret and remains unchanged.[18]

Liberalization efforts affected the Chinese economy. Fluctuations within the reform movement caused imbalances within the textile industrial structure. This hesitant reform process fragmented certain sectors such as spinning and weaving, which remained under government control through the Fall of 1991. As the Chinese government loosened its hold over the people, political turmoil has obstructed cashmere supplies, and prompted Britain to search for alternative sources of cashmere.[19] Further, the industries will have to overcome obstacles that accompany an inadequate infrastructure, to allow goods to reach their export markets.

The greatest threat to China's burgeoning textile industry is the possibility of export market protectionism. The Sino-US bilateral textile agreement (under the Multi-Fiber Arrangement of 1985) was profitable for China through the 1980s.[20] Beginning in 1988, trade restrictions intensified as the United States began to experience a slowdown in the economy and an increase in the federal and trade deficits; yet, China continued to supply over 12 % of the textile and apparel imports to the American markets. Within China, economic growth elevated the incomes of the workers, which benefited the textile and apparel industry through an expansion of the consumer base.[21] Reports show that both imports of raw materials and exports of finished goods from China have multiplied since the initiation of economic reform measures.

In the wake of economic liberalization, the Chinese made efforts to establish standards, price limits and trade laws to counter the problems of poor quality and fluctuating prices. In August of 1989, the State Administration for the Inspection of Import and Export Commodities instituted laws that serve to raise the quality of import and export commodities. China introduced and revised 19 laws and regulations throughout 1989 to increase the number of products that are inspected. Furthermore, the government has increased the number of inspection laboratories to increase examination abilities.[22] With the large increase in the demand for cashmere and relaxed governmental controls, small local companies capitalized on the increased demand by selling inferior wool at inflated prices. These practices raised questions as to the reputation of China's cashmere.

In 1990, the Chinese government took steps to ensure quality standards and price uniformity within the textile industry. To improve the quality standards, the Ministry of Foreign Economic Regulations and Trade (MOFERT) established China's Cashmere Foreign Trade Center to manage cashmere exports. The Center sponsors four trade fairs per year to sell cashmere, to set limits for export prices, and to issue licenses for the Center.[23] Another measure to define economic policy was the textile export announcement that was issued on February 21, 1991 by the Chinese Ministry of Foreign Economic Relations and Trade. This announcement states that textile products produced in China or processed with imported materials require labels of origin, cannot exceed quota restrictions, and may not be exported to countries that have not signed bilateral agreements. Currently, bilateral agreements exist with the European Union, the United States, Canada, Norway, and Finland.[24] With the projected growth of the textile and apparel exports and the institution of management and quality control measures, one believes that efficient practices and higher quality products will be forthcoming.[25]

As the economy of China changes, the British textile companies must search for alternative sources of cashmere wool to satisfy their supply requirements. The EU funded a project (£500 000) in Scotland to breed indigenous goats that would produce a comparable quality of cashmere fiber to that produced in China, Afghanistan, Iran, and Mongolia was initiated in the late 1980s. The projected outcome of the program would expand into an industry worth £5 million by 1997.[26]

Additionally, Scottish Cashmere Producers Association (SCPA) initiated a program to 'increase cashmere production by 25-fold within the next decade' (2004). Presently, the SCPA produces no more than a metric ton of cashmere a year, which would not supply Dawson for a day. They offer incentives to farmers to raise goats. The Association provides 'goatpacks', which consist of 12 does and the hire of a buck for the breeding season.[27]

To protect the supply of cashmere coming to the British textile industries, joint ventures have been initiated in China. One joint venture in textile manufacturing is the Shanghai United Wooltex Corp. Ltd, the first joint venture in the textile and apparel industry, which started in 1981. This company began as a wool spinning and knitting operation and has expanded to develop goods, including cashmere garments, that target foreign markets.[28] Another way the British are attempting to stave off the lesser quality inexpensive cashmere knits is based on expanded clothes lines, more boutiques, and enhanced marketing schemes.[29] The challenge, however, remains to be the need for a continuing and reliable supply of wool, more so than a market for the garments.

With the rise in demand for cashmere products, environmental repercussions will follow unless the farmers take measures to prevent overpopulation, deforestation, and become environmentally conscious. Goats are notorious for being indiscriminate eaters. In addition to grain and water, goats consume over 10 % of their body weight in roughage daily.[30] With the land overstocked, the eating habits of the goats are likely to cause deforestation. In the arid Himalayan region, deforestation can kill pasture land, encourage the growth of weeds, initiate soil erosion, and desertification.[31] Further, the increased breeding and raising of goats in Scotland, Australia, New Zealand, the United States, Iran, Afghanistan, Tibet, and Tasmania will impact the environment.

In Scotland, the highland cattle are being forced to share the land and limited vegetation with increasing numbers of goats.[32] With less food available, fewer nutrients will be consumed and the quality of the cashmere fibers will suffer.[33] During the industrialization period, a large portion of Britain's land was deforested for ship building and manufacturing. According to experts, goats may improve pasture land and aid reforestation by eating rough plants and brush.[34] The danger, however, stems from the maximization of profit through increased herd sizes, which may result in environmental crises.

The challenge to supply the markets with cashmere wool serves as a significant economic struggle to meet increasing demand and maximize profits. One must look beyond fashion and luxury of cashmere garments to the possible detrimental effects on the environment.

3. Related Cases

CEDARS Case
OTOMI Case
ECFURBAN Case
BABYSEAL Case

Keyword Clusters

(1): Trade Product = CASHMERE
(2): Bio-geography = DRY
(3): Environmental Problem = DEFORestation

4. Draft Author: Theresa Purcell (May, 1996)

B. LEGAL CLUSTERS

5. Discourse and Status: In Progress

6. Forum and Scope: China and Scotland and BILATeral

7. Decision Breadth: 1 and China

8. Legal Standing: TREATY

C. GEOGRAPHIC CLUSTERS

9. Geographic Locations

 a. Geographic Domain: ASIA
 b. Geographic Site: WEST ASIA
 c. Geographic Impact: CHINA

10. Sub-National Factors: No

Mongolia, Kashmir, Tibet economically center around herding animals (yaks, sheep, goats). The best cashmere is produced in these harsh mountainous regions and provides a source of income within the region.

11. Type of Habitat: DRY

D. TRADE CLUSTERS

12. Type of Measure: QUOTA, LICENsing, LAW

Through China's bilateral trade agreements, quotas were set, export licenses were instituted, and labels of origin were required on cashmere. Also, laws on inspection of import and export commodities were implemented August 29, 1990.

13. Direct vs Indirect Impacts: INDirect

14. Relation of Measure to Environmental Impact

 a. Directly Related: NO
 b. Indirectly Related: YES GOAT
 c. Not Related: NO
 d. Process Related: YES DEFORestation

15. Trade Product Identification: Cashmere wool

16. Economic Data:

China produces 3000 metric tons of cashmere per year at a current price of $.14 per pound (de-haired) or retail to spinners $12 per ounce. After spinning, cashmere is valued between $120 and $190 per pound. Currently, the highest quality of cashmere is being sold for more than $190 per pound. In 1989 revenues of $575 million were recorded by Dawson International, the leading British textile firm. The EU awarded £500 500 in 1987 for a ten year study on breeding goats for high quality cashmere. The projected worth of the project, based on increased quality of cashmere output, is estimated to be £5 million by 1997.

17. Impact of Measure on Trade Competitiveness: LOW

18. Industry Sector: Textile and Apparel [TEXTAPP]

19. Exporter and Importer: China and (Scotland) UK

E. ENVIRONMENT CLUSTERS

20. Environmental Problem Type: DEFORestation

21. Name, Type, and Diversity of Species

    Name: Goat (pasang or bezoar)
    Type: Cashmere (originally from Kashmir and Tibet)
    Diversity: 300 varieties domestic goats

22. Impact and Effect: MEDIUM and PRODuct

23. Urgency and Lifetime: LOW and 5–10 Years

24. Substitutes: SYNTHetic and LIKE

F. OTHER FACTORS

25. Culture: YES

According to historical accounts, cashmere was used to line and cover the Ark of the Covenant.

26. Human Rights: NO

27. Trans-Border: NO

28. Relevant Literature

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Appendix 10

Quality assessment of goat hair for textile use

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SUMMARY
The paper shortly describes changes that have occurred in the production of goat hairs, especially cashmere, for textile use as well as in the structure of the processing industry in the last 2 decades. Attempts are made to classify different types of goat hair according to their origins and their characteristics. Factors affecting price of goat hair are cited. Technical methods for the evaluation of goat hair are presented. Problems of fraudulent labelling of cashmere garments are discussed.

1. PRODUCTION OF GOAT FIBRE FOR TEXTILE USE

1.1 Mohair: fibre of Angora goats living in South Africa, Texas/USA and Turkey. The world total production has decreased from ca. 21 000 t in 1986 to approximately 7500 t in 1999, whereby 60 % (4500 t) originate from South Africa.[1]

1.2 Cashgora (*Cash* = cashmere, *gora* = Angora): this is a natural fibre type produced by cross-breeding an Angora goat with a feral goat (in New Zealand since the mid-1980s) or with a cashmere goat (in Iran, Mongolia, Kazachstan). The production of Cashgora was approximately 50 t in 1986, but has sharply decreased since the customers' acceptance for this fibre type has remained reserved.

1.3 Cashmere: fine undercoat fibre (down) of cashmere goats.

– Traditional sources: China, Mongolia, Himalayan regions (local name: Pashmina), Afghanistan, Iran (coarser qualities), Kazachstan, Kirghiz, Uzbekistan (Cashgora type).
– New sources: Australia/New Zealand, Scotland, since the early 1980s.

The world total production of cashmere is estimated at ca. 6000 t in 1998, mainly in China, Mongolia, Iran, Afghanistan. Attempts to breed goats bearing fine undercoat fibres have also been made in the USA (Colorado), South Africa (Kwazulu-Natal)[2] and in some other European countries (Spain, Italy, Norway).

2. CASHMERE PROCESSING

The most crucial step in cashmere processing – the industrial dehairing process – was invented by Dawson in Scotland during the latter half of the 19th century and it has been a strictly guarded secret. Until the 1970s, only a few European companies had mastered this technique, so that the Asian cashmere producers had to export most of their raw material to Europe for dehairing and processing into high quality garments. Since the economic liberalisation, Chinese as well as Mongolian companies have co-operated with Japanese counterparts and successfully boosted the local cashmere dehairing and processing industry. Mongolia actually enacted an embargo on raw cashmere export to support the establishment of local cashmere enterprises. The 1980s also witnessed European and American cashmere industry's efforts in protecting the cashmere raw material supply which had become a problem. Joint ventures have been established in China and Mongolia by renowned Western enterprises. Nowadays China has developed its dehairing and garment making industry to the point of over-capacity. By the end of 1996, China had approximately 2000 cashmere-knitwear producers with a total processing capacity of 15000 t of raw cashmere a year.[5]

3. CLASSIFICATION OF GOAT FIBRES

3.1 Mohair: according to the mean fibre fineness, mohair is generally classed into Kid mohair (Fine Kid, Good/Average Kid), Young Goat and Adult mohair.
3.2 Cashgora: the mean fibre fineness of this fibre type ranges from 18 to 23 μm.
3.3 Cashmere: contrary to mohair, cashmere originating from various regions of the world shows a pronounced diversity. In the following more details are described because cashmere is the most expensive generic type among the speciality fibres (except vicuña) for textile use.
3.3.1 Mean fibre diameter MFD (mean fibre fineness): Chinese cashmere is the finest (14–16.5 μm). Mongolian is fine, but is currently becoming coarser due to intensive cross-breeding for increased yield (up to 17–18 μm). Iranian/Afghan cashmere is 2–3 μm coarser than Chinese cashmere (17–19 μm). Cashmere from New Zealand/Australia is generally coarse (17–17.5 μm), '*with perhaps 30 % of the clips being under 16.5 microns, and with virtually no cashmere in the traditional high quality knitwear range of 15 to 15.5 microns*'.[7] In well dehaired samples, the individual diameter of cashmere fibres varies from 8 μm to 24–25 μm.

Besides some coarse Iranian/Afghan samples having an MFD of ca. 20 μm, the upper threshold of the MFD observed for most commercial samples has usually been 19 μm. In conformance with the fibre qualities on the market, the upper limit for the MFD of cashmere has therefore been set at 16.0 (+0.5) μm by the Chinese National Standard,[6] at 18.5 ± 0.5 μm by the CCMI (Cashmere and Camel Hair Manufacturers Institute, the trade organisation of reputable companies in the USA, Europe and Japan), at 18.5 μm by the AATCC[3] (American Association of Textile Chemists and Colorists) and at 19 μm by the ASTM[4] (American Society for Testing and Materials), both in the USA. In the last few years, coloured goat hairs having an MFD of 20–26 μm have also been sold on the German market as cashmere as well. It is worth noticing that these coarse qualities cannot be recognised as cashmere according to the current regulations. Only fine cashmere type up to 15.5 μm has been used for high quality knitwear. The coarser qualities from Iran/Afghanistan, New Zealand/Australia (up to 19 μm) are generally used in the weaving industry.
3.3.2 Mean fibre length: fine undercoat fibre of Chinese cashmere raw material has a *mean* fibre length between 21 mm and 40 mm (super grade). The *individual* fibre fineness runs from 5 mm to 80–90 mm, depending on the quality of the sample being investigated.
3.3.3 Colour: dehaired cashmere raw material from China/Mongolia as well as from Iran/Afghanistan has shades of white, light grey, dark grey and brown. Cream, fawn and dark brown are typical colours for Iran/Afghan cashmere.
3.3.4 Surface morphology: classical Asian cashmere exhibits quite similar surface structures despite the different goat strains. The typical cylindrical and semi-cylindrical scale shapes are regular and usually have a mean scale frequency (i.e. number of scale shapes per 100 μm fibre length) of 6–7. Cashmere from the new

sources shows quite different scale shape on the fibre surface compared to that of the Asian types.[14,15,16,20] The fibres usually have a higher scale frequency (more than 8) and look more complex, resembling the surface morphology of mohair. This is perhaps the reason for their highly lustrous, slippery character and comparatively harsh handle. It is also responsible for problems during processing these fibre types, as described by the purchaser of 60 % of the Australian production, 40 % of New Zealand and 100 % of the USA.[7]

At DWI, this fibre type has been classified as 'crossbred-cashmere'.[16] In the last few years, an increasing number of cashmere samples from Outer Mongolia and Iran being investigated at DWI have been classified as 'crossbred-cashmere'. Samples coarser than 20 μm have been classed as 'Cashgora'.

4. FACTORS INFLUENCING PRICES OF DEHAIRED PURE CASHMERE

The *mean fibre diameter* is a very important characteristic for the value of cashmere products. The finer the fibre, the smoother is the handle and the lighter the weight of the cashmere. The difference of 2–3 μm in MFD between Chinese cashmere (ca. 15 μm) and Iranian/Afghan cashmere makes the former approximately 50 % more expensive. The natural *colour* also influences its value greatly. White is the most expensive, because dark cashmere must usually be bleached before dyeing, particularly in pastel colours.

Worsted yarn can only be spun when the *mean fibre length* is high enough. Lots with short fibres must therefore be spun on carded system. Other factors affect the price of dehaired cashmere raw material: the more of the *coarse hairs* and other *contamination* (*dandruff* etc.) that had been removed, the purer the cashmere, the more expensive it is.

5. MEASURING THE CHARACTERISTICS OF GOAT HAIR

5.1 Mean fibre diameter: various instruments can be used to measure mean fibre fineness. The most common and affordable tool has been the projection microscopy according to IWTO-8-97 of the IWTO (International Wool Textile Organisation) and the Airflow method according to IWTO-6-98.[9] Two modern techniques have been standardised but require expensive instruments: the Sirolan-Laserscan Fibre Diameter Analyser according to IWTO-12-98 and the OFDA (Optical Fibre Diameter Analyser) according to IWTO-47-95, whereby several thousand fibres can automatically be measured.[9] Two further techniques are not standardised, the scanning electron microscopic (SEM) and the cross-sectional (CS) method. Besides the MFD the coarse hair percentage of the sample can also be determined.

5.2 Fibre length: the mean fibre length can be determined according to the standardised test methods, such as IWTO-Draft TM-5-97 using a single fibre length measuring machine, IWTO-17-85 using an Almeter and IWTO-16-67 using a WIRA Fibre Diagram Machine.[9]

6. PROBLEMS OF FIBRE ADULTERATION

Stringent labelling regulations for textile products at all stages of processing compel the manufacturers to state not only the types of fibres but also their weight percentages contained in their goods. Despite the regulations, substantial price differences of wool and speciality fibres, especially cashmere, have been the incentive for mislabelling for all forms of textile products. The current market prices of keratin fibres for textile use vary from approx. 3–5 USD/kg for sheep's wool to an amount of 100 USD/kg for first grade Chinese cashmere. It is therefore not surprising that well over 60 % of the textile samples containing speciality fibres investigated at DWI between 1990 and 1999 were found to be mislabelled. For decades the cheaper generic type has been blended with the expensive one without declaring the true fibre content of the garments. In cashmere and cashmere blend garments, sheep's wool has long been identified as substitute. Even the almost worthless recycled wool fibres being regenerated from rags or waste have also been declared as cashmere. But yak, Angora rabbit and camel hair have also been identified as adulterants. High prices and short supply worsen the situation.

The problem of mislabelling is so widespread that CCMI has regularly purchased garments at stores in a variety of cities across the USA and tested individual garments for accuracy of labelling. It has been estimated that 15 % of garments claiming to contain genuine cashmere and cashmere blend are indeed mislabelled.[19] Another severe problem has been highlighted after international round trials being organised by CCMI in the last few years: some well-respected laboratories specialising in the analysis of animal fibres failed to quantify blind samples of known composition and origin.[17,18] As a consequence, CCMI has recommended only a few of the laboratories as being able to offer reliability.[8]

7. FIBRE IDENTIFICATION

Contrary to synthetic fibres, all animal fibre types for textile use are very similar regarding their chemical and physical properties, so that light microscopy was the most commonly used method for recognising animal fibres until the beginning of the 1980s.[11,20] Although the method has been standardised in the USA,[3,4] its accuracy has up to the present not been satisfactory for the demand of the textile industry. Since the introduction of the scanning electron microscope (SEM) by DWI,[10,14–16,21–23] 'topographic fingerprints' of each generic fibre can be revealed which cannot be seen using the light microscope. Besides the MFD, three other criteria of the surface structure are decisive for fibre identification and analysis: the height of the cuticle scale edge (the most important criterion for distinguishing sheep's wool on one side and all other speciality fibres on the other side), the mean scale frequency and the scale appearance. With the aid of the SEM, mohair and cashmere of different origins can be differentiated and classified.[14,15] The SEM method was recognised as a Draft Test Method (DTM-58-97) for the quantitative analysis of blends of sheep's wool with other speciality fibres by the IWTO in 1997.[9] Besides the routine LM and SEM method, the DNA profiling techniques[13] and the gel electrophoresis method[12,24] can also be used for fibre identification, but the textile processing steps (bleaching, dyeing) can negatively affect the analysis results.

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