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Properties and Performance of Goat Fibre
A review and interpretation of existing research results

A report for the Rural Industries Research and Development Corp by JD Leeder, B A McGregor and R G Steadman
Foreword
A knowledge and understanding of the properties of speciality fibre for effective utilisation in processing to garments.

Process development is increasingly relying on judicious blending of yarn manufacture, knitting, weaving and other operations in producing fabrics.

This study provides a concise documentation of the properties and of speciality fibres.

The study was completed in 1992 and, since that time, industry had access to the unpublished final report. Given this continuing irrelevance of the information, the Corporation has now decided to make the report more readily available by adding it to its catalogue of publications.

Peter Core
Managing Director
Rural Industries Research and Development Corporation
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1. **INTRODUCTION.**

The Textile and Fibre Research Institute has reviewed the literature of the Rural Industries Research and Development Corporation, and the Sub-committee. The aim of this project is to collate the published findings on the properties and uses of mohair and cashmere fibres. A review is timely, since the most recent comprehensive bibliographies of mohair, were those of Srivastava et al. (1976), as updated by Strydom and Turpie (1985).

Cashmere and mohair fibres are generally acknowledged to have properties of softness, smoothness and lustre, when compared to other fibres. Thus goat fibres and other specialty animal fibres have been used for many years to produce unique garments, and in combination with wool, the range of textiles and textile products available to consume fashion industry. Overall world production of textiles has been almost constant for years, although changes in fashion and recessions in industry have had marked effects on world production and prices of animal fibres. The requirement for fine animal fibres has been historically, according to Smith (1988), due to attitudes such as could be available in increasing bulk quantities, there was a need for establishing additional market requirements". This attitude has limit development on the unique properties of the specialty animal fibres.

Although none of the specialty hair fibres is listed among Ford’s principal textile fibres, they are becoming of increasing importance. In some circumstances, goats offer the grazier an advantage over the fibres, may offer the consumer an advantage over wool. However, Pies (1986) pointed out that only 5% of the world’s goats are exploited for fleece.

A knowledge of wool is helpful in assessing the properties of goat hair, least in Australia, production is generally similar in terms of shearing, scouring, processing, dyeing, knitting and weaving. Fibres are in some cases so similar that identification is difficult (Tucker & McCarthy 1991).
<table>
<thead>
<tr>
<th>Source Animal</th>
<th>Mean Diameter (um)</th>
<th>Mean Dehaired Fibre Length (mm)</th>
<th>Price Range $A/kg clean</th>
<th>Producing Regions</th>
<th>Approximate World Production (Tons)</th>
<th>Production Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>17 - 22</td>
<td>50 - 60</td>
<td>6 - 10</td>
<td>Australia</td>
<td>100,000</td>
<td>Static</td>
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<td></td>
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<td></td>
<td>New Zealand</td>
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<td></td>
<td></td>
<td></td>
<td>South Africa</td>
<td></td>
<td></td>
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<tr>
<td>Angora Goat</td>
<td>24 - 40</td>
<td>75 - 100</td>
<td>6 - 18</td>
<td>South Africa</td>
<td>25,000</td>
<td>Growing</td>
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<td>Texas</td>
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<td>Australia</td>
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<td></td>
<td></td>
<td></td>
<td>Argentina</td>
<td></td>
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</tr>
<tr>
<td>Cashmere Goat</td>
<td>15 - 19</td>
<td>25 - 90</td>
<td>35 - 70</td>
<td>China</td>
<td>5,000</td>
<td>Some processed at source.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mongolia</td>
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<td>Iran</td>
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<td>Afghanistan</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Russia</td>
<td>Unknown</td>
<td>Processed at source.</td>
</tr>
<tr>
<td>Angora Goat/ Feral Crossbred</td>
<td>19 - 22</td>
<td>50 - 60</td>
<td>8 - 20</td>
<td>New Zealand</td>
<td>200</td>
<td>Growing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Australia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angora Rabbit</td>
<td>11 - 15</td>
<td>25 - 50</td>
<td>20 - 30</td>
<td>China, Chile</td>
<td>8,500</td>
<td>Growing</td>
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<td></td>
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<td></td>
<td></td>
<td>South Africa</td>
<td></td>
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<td></td>
<td></td>
<td>France</td>
<td></td>
<td></td>
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<tr>
<td>South America</td>
<td>22 - 25</td>
<td>75</td>
<td>12 - 15</td>
<td>Peru/Chile</td>
<td>4,000</td>
<td>Growing</td>
</tr>
</tbody>
</table>
Some information about mohair and other specialty fibres, processing, is contained in books about wool, e.g. Onions (1968), (1963), or mostly about wool, e.g. Harmsworth and Day (1990) an Stephenson (1968). The latter has been partly updated (Ryder, 1990) review focuses on interpreting research about their special character and the special appeal of their products.

A publication by the Standing Committee on Agriculture (1982) provided a good summary of research into primary production in Australia. One of the most valuable recent reviews was that of Wilkinson (1985) which particularly addressed the problems of fibre identification.

Among the books about husbandry, breeding and veterinary practice those that include other aspects of mohair are reviewed here. Gill (1985) includes a good set of references to that time. The book of Hill (1985) although brief, is international in scope, and describes the process well.

The most comprehensive reviews of the goat fibre industries were presented at the Post-graduate Committee in Veterinary Science Courses in 1980 and 1990. The history of goat breeding, production and prospects for the mohair and cashmere industries are covered. Gainsford (1985) provided guidelines for breeding finer cashmere fibres with widespread exploitation of feral goats, Smith (1985) warned of potential limitations.

Wool Record provides an annual review on specialty fibres. The reviewed fibre properties and processing characteristics. Ryder (1980) reported on current end-use markets for all the speciality fibres and Bullio (1988) have reported on prospects for these fibres. (1980) lists guidelines governing trading in specialty animal fibres, (very) loosely defined to include mohair, camel hair, alpaca, cashgora and cashgoral.
2. **THE SPECIALTY FIBRES: A BRIEF OVERVIEW**

The fibre from the various breeds of sheep (wool) is by far the most commonly-used animal fibre. However, large quantities of related fibres are used in the manufacture of clothing and other textile assemblies. These fibres are sometimes used alone, but often in conjunction with sheep’s wool. They provide special effects such as additional beauty, texture, colour, softness, durability or lustre. The largest group of these fibres is obtained from the species such as goats and camels, known as specialty hair fibres. The American Wool Act of 1910 defines "wool". Figure 1 shows the varieties yielding the specialty hair fibres most commonly used for apparel (taken from von Bergen (1963)).

![Origin of Specialty Hair Fibres](image)

**Fig. 1. Origin of Specialty Hair Fibres.**

Additional fibres are obtained from cows, horses, humans, and bearing animals such as musk ox and rabbits (see later).

(i) **Mohair**

Mohair is the most commonly-used specialty fibre and forms the coat of the Angora goat, which originated in Turkey. "Angora" is a translation of a Turkish word meaning "selected", or of Ankara, where the goats were originally kept.
production. Present world production amounts to 25 thousand tonn with the major producers (thousand tonnes p.a.) being South Africa (7), Texas (6), Turkey (2), Australia (1), Lesotho (1), Argentina (1) (Mohair Association 1990). World production exceeded 30 thousand 1967 (Hobson, 1980).

von Bergen (1963) and Evans (1980) described the evolution of the world textile trade since about 1920, while South African mohair research to 1985 was reviewed by Turpie (1985).

For current international awareness in the breeding, testing promotion, and uses of mohair, there is probably no better source than the latest annual report of the International Mohair Association (1991).

Each country has a different system of classification (Onions, 1968 (1971) reviewed the classing system in South Africa. Australian a grading can be seen as a refinement of the Turkish system, with fit as an added dimension.

The majority of mohair is generally sold at auction in South Africa Australia. Trading specifications have evolved little from the original definitions, although tops are now described in objective terms.

Australian mohair production was stimulated by, and has greatly increased since the formation of the Australian Mohair Research Foundation (1957) Angora Breed Societies. The Australian Angora Mohair Journal has provided significant updates on the growth in this industry. The importation of Angora breeding stock to improve Australian flocks has been associated with study of fleece properties (Gifford et al., 1985, Holst et al., 1986). Australian goats had lower fleece weight, finer fibre and a higher percent medullated fibres.

Referring to recent halving in world mohair production between 1967 and 1980 (Hobson, 1980) described problems in production, such as kid sensitivity to cold and predators. Drastic devaluation of the current...
United States mohair producers receive over $A60 million ann support payments, about the same as U.S. woolgrowers, equiva $A1.30/kg. (greasy) (USDA, 1990). The 1990 support price fo $US4.53/lb. which approximates to $A17/kg. clean.

A Turkish study (Yalcin, 1972), followed by many others, exam of secondary/primary follicles, a heritable property that offers the breeding for improved fleece density and fineness, but with fleece weight.

Strydom (1983) examined mohair from summer and winter clips, difference in fibre or top properties, or processing performance. I investigated various correlates of medullation in mohair, associations with genetic background and fibre diameter. One important improvements in mohair production, world-wide, is reduction in proportion of kemp fibres, which greatly reduce the fleece - kemp fibres affect spinnability and dyeability. (see later).

Roberts (1977) examined the properties of mohair in the light conditions. The study considered biological factors such as selection, sex and stress. The effects of limited processing on the fibre content of Australian mohair has also been reported (McGreg

(ii) Cashmere:

Cashmere is acknowledged as one of the finest and softest known to the textile industry. It comes from the downy winter by Asiatic down-bearing goats of various breeds (Couch. Traditionally the down was harvested by combing after the ann in Australasia the entire fleece is shorn in mid-winter. Brown reviewed production methods around the world, with special Australia.

Cashmere-bearing goats were first identified in Australia in 197
Annual world production of cashmere, about 5,000 tonnes, is in Central Asia, China, Mongolia (finer than 17 um); and Afghanistan to 20 um). Australia currently produces 0.5% of world production contracted to mills overseas. With political stability returning to most countries, the price boom of the 1980s is unlikely to be. Mauersberger (1954, p. 689-696) described cashmere in depth. A description is that of Dawson (1990). Cashmere is traded in various

With production from a wide variety of goats, raw shorn Australian fleece has commercial cashmere yields from 0.5% to 80% (Couch and Millar (1987) has attempted to define "cashmere" goats. Holst compared skin and fleece properties of feral cashmere goats.

The feral goat's pattern of fibre growth in a subtropical environment documented (McDonald 1987) and in temperate areas the growth of cashmere goat fleeces has been studied (McGregor 1988). Shearing occurs during the summer and autumn months, followed by shedding in spring. See also Ryder (1990a, p. 185). This points to July-August shearing time, provided that shorn goats are protected at. Couchman and McGregor (1983) measured fleece mass, yield, diameter of adult Australian cashmere goats; on average, males produced 148 g of down fleece, females 148.

Johnson (1985) reported that there were about two million feral goats in Australia, about ten times the number of cashmere goats being suggested approximately 30% of feral goats could be used for cashmere production.

The results of long term genetic studies into cashmere production published for Australian feral goats in a sub-tropical environment (1984, and numerous progress reports published earlier) and for goats in temperate areas (Gifford et al., 1989, Couchman and 1988). Genetic programs have been reviewed and summarised by Bongi (1990).
Improvements in nutrition over a limited range of feed intakes during the cashmere growing season have not affected production of yearling feral goats. (Johnson and Rowe 1984, A: 1984). However, increasing nutrition of selected farmed cashmere goats the entire growing season increased cashmere growth 67% (McIlwraith and Fairley 1987). Further research on the effect of seasonal pastoral condition change and supplementary feeding of grazing adult cashmere goats shown significant responses in cashmere production (McGregor, 1989). Technological developments in Australian Cashmere industry are Holst (1990) and McGregor and Couchman (1992).

Political unrest in China and changes in Chinese marketing are lowering the average quality of Chinese cashmere, which accounts of 60% of the world’s supply (Smith, 1989; Fisher, 1989). After retail marketing changes, improved quality was reported (Stoddart, 1989). Unstable markets caused problems in 1991 (Browne 1991).

Some general characteristics of mohair and cashmere fibres are those of wool in Table 2. Specific chemical and morphological details and fibre, yarn and fabric properties will be considered in Chapers 3 and 4.

(iii) Cashgora:

The name “cashgora” was first used to describe downy feral/cashmere goats where mean fibre diameter was outside cashmere specifications, i.e. 17-18 um mean fibre diameter. (Moylan i 1991).

The Australian Cashmere Marketing Corporation (ACMC) define fleece having coarse guard hair, fine crimped down and longer "intermediate" fibres - i.e. three fibre components. This type is inferior to cashmere and therefore of lower commercial value.
Table 2. Comparison Of Some General Characteristics Of Wool, Mohair and Cashmere.

<table>
<thead>
<tr>
<th>Fibre Diameter (range)</th>
<th>Scale Structure</th>
<th>Length (cm)</th>
<th>Medullation</th>
<th>Ortho-Para Cortex</th>
<th>Strength (relative)</th>
<th>Chemical Stability (relative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 - 27 um</td>
<td>distinct</td>
<td>5 - 8</td>
<td>nil</td>
<td>bilateral O-P</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>15 - 90 um</td>
<td>flat little overlap</td>
<td>20 - 30</td>
<td>high &amp; variable</td>
<td>mostly ortho</td>
<td>140</td>
<td>90</td>
</tr>
<tr>
<td>14 - 30 um</td>
<td>intermediate</td>
<td>2 - 8</td>
<td>low</td>
<td>variable</td>
<td>90</td>
<td>80</td>
</tr>
</tbody>
</table>
The sources of cashgora have been defined (Moylan and McCann 1988). Recent reviews have explained the development of the cashgora relationship to coarse cashmere (McGregor 1991) and given descriptions of characteristics (Couchman 1987). The industry has relied on cashgora style to distinguish the fibre type, i.e. down with "crinkle" or "wavy" down is cashgora, straight fibres are mohair.

The major differences in view about cashgora and coarse whether all cashgora is inferior (ACMC definition) or if high quality exists in addition to poor quality difficult-to-dehair "cashgora". Cashgora in this case is coarser cashmere or superfine mohair.

Still unspecified are a cashgora classing system and the range fibre properties that the fibre covers exclusively.

(iv) Camel Hair

Camel hair is typically considered to be the fine, soft, downy winifred two-humped Bactrian camels of Asia, as described by Mauersbe (1976-7). Most camel hair is collected after moulting or deshedding (Chapman 1985) reported a thorough study of bactrian camels. I described the growth in production of camel-hair blazers in relation to price of cashmere in U.S.A.

Camel hair is normally "willowed" to remove most of the vegetable matter, and de-haired to recover the finer hair. Traditionally, coats and suits, and mens' overcoats, jackets, and socks.

The potential for harvesting feral animals, such as Australian camels, was mentioned occasionally, (e.g. Williams, 1991). According to Sheep Breeder and Sheepman (1986), "shearing camels is an intensive job, requiring two people to spend from 30 to 60 min amounts of hair produced from Australian one-humped camels or..."
(v) **Llama Family:** (Alpaca, Guanaco, Llama, Vicuna)

Mauersberger's (1954, p. 701-714) description provides excellent on these "camelids", the subject of increasing interest in Australia, and other Peruvian workers (1990) examined fleeces of alpaca vicuna, with some speculative work on paco-vicunas. Their included length and diameter from various parts of the bodies.

Alpacas are single coated animals, thus the fleece does not requi Pumayalla and Leyva (1985) reviewed the production of alpaca fibres. Peru is the major alpaca producer with 90% of world trad 3,200,000 alpacas producing a fibre that is from three to fo valuble as wool. there are two types of hair : 'Suri', which straight, and 'Huacaya' which is short and curly. The hair of ranges in colour from black to white, the latter being the most there is an interest in colour inheritance, which could be the same. The amount of hair shorn per animal ranges from 0.9 to 3.6 kg wi 1.8 kg. Crosses between alpaca and llama (huarizo) and with v vicuna) occur frequently and are fertile (Ryder 1975), but the cros type, normally the crosser parent.

Carpio-Pino and Villarroel (1986) reported a census of sheep, alp and vicunas in Peru, along with their production. Their data indic fleece weight among llamas than alpacas.

The International Alpaca Association held its third congress in Nag and examined the effects of political unrest in Peru (Alvigini and I An Alpaca Association has now been established in Australia.

(vi) **Other Animal Fibres for Textile Use**

**Angora:**

Demand for and productivity of farmed Angora rabbits has been Denis (1990). China produces 90% of world trade, while Ch
(1985) obtained approx. 100 g of angora rabbit hair per shear lengths near 50 mm. The fibre may be recovered by combing Angora fibres are smooth and lustrous (mean fibre diameter 13 may be blended with fine lambswool for machine knitting (e. knitwear).

**Musk-ox (giviut):**

Wilkinson (1974) estimated the following properties of giviut registered trade mark of the wool from the Alaskan musk- underwool 2 kg/year, length 62mm; diameter around 10 um. claimed to make up into the softest, finest and most exclusive garments on Earth. Fortunately for the textile industry at large, a few hundred musk ox commercially producing fibre in Alaska, are not made anywhere else in the world.

**Yak:**

Yak fibre comes primarily from the Tibetan plateau that st Central Asia north of the Himalayas. The yak (Bos grunnien animal that produces long coarse outer hair (which is made into mats and tents) and fine, underbelly inner hair.

**Reindeer hair** has enjoyed intermittent success in fashion fabr novelty effects. Sanderson et al. (1990) discussed the fibre of New Zealand.

Other types of fur occasionally used by the textile industry are beaver, raccoon, possum, nutria, fox, wolf, dog and mink. (down) are sometimes blended into wool yarns to produce novel optical effects.
3. **PHYSICAL AND CHEMICAL STRUCTURE OF ANIMAL F**

The physical and chemical composition of the wool fibre has been of extensive study. The same parameters of mohair have been limited extent and those of cashmere even less.

While there are differences in the morphological and chemical co wool, mohair and cashmere, there are basic similarities. However, extensive systematic study has been attempted on goat fibres, a been published appeared prior to the early nineteen seventies. Sir there have been significant advances in microscopy and automated chemical analysis and measurement of surface properties. The brief summary of what is currently known about the structure of cashmere, based mainly on extensive studies on the wool fibre.

(i) **Physical (Morphological) Structure**

Figure 2 is an exploded diagram of the physical or morphological of typical fine wool fibre. All animal fibres have a similar composition; the main differences occur in the shape and arrangement of the (scale) cells and the existence of a central core (medulla) in m: fibres. Medullation is an important economic and performanc in mohair and cashmere fibres, and will be considered separately section of this review.
The outer surface of animal fibres consists of cuticle cells that overlap like tiles of a roof to give the well-known range of dist structures of the various fibres. The thickness of the cuticle ranges for fine fibres such as wool, cashmere and mohair, up to cells for coarser fibres such as human hair or goat guard hair.

A schematic representation of the cuticle of a wool fibre is shown. Similar structures occur in the cuticle of other animal fibres (Lee it is likely that this also applies to mohair and cashmere. (Bradby 1970).

![Schematic Representation of the Cuticle Structure of Wool](image)

**Fig 3. Schematic Representation of the Cuticle Structure of Wool (Leeder 1986).**

The cuticle of animal fibres is obviously of great practical importance for the interface between the fibre and the environment, for example processing media and the wearer of the product! Very little is known about the surface morphology of goat fibres, but we can extrapolate knowledge of the wool fibre. Of particular importance is the outermost layer - the epicuticle which is just a few nanometres in thickness.
The surface of the epicuticle is covered by a chemically-bound thin layer (probably a monolayer) of fatty acid with an unusual structure (Leeder et al. 1985). This is responsible for the natural repellency of animal fibres. The amount of this fatty acid is greater in cashmere and mohair fibres, and this difference has been tentatively shown as a method for differentiating between various specialty fibres (Scott 1988).

The cuticle constitutes 10-20% of the weight of a fibre, and provides a protective layer for the 80-90% bulk of the fibre, which is composed of spindle-shaped cortical cells (and, of course, medulla cells when present).
Cortical cells consist of two types - so-called ortho and para (se with slightly different physical and chemical properties. Their importance in animal fibres. When these are arranged bilaterally they are responsible for the formation of crimp in fine fibres. Bulk, resilience and resulting warmth and comfort to textile assembly is formed by differential hardening or keratinisation of the growth of the follicle below the skin surface, and the result is shown in Fig. 6.

![Diagram of Crimp Formation in a Wool Fibre](image)

**Fig. 6** Crimp Formation in a Wool Fibre.

Kulkarni (1975) commented that the orthocortex of mohair is "different from each other" when viewed under the transmission microscope.

Tester (1987) used the transmission electron microscope to study the structure of cashmere and superfine Merino wool. At high magnification, cashmere has a predominance of orthocortical and mesocortical cells. Mesocortical cells have a structure that is intermediate between ortho and para. Wool, on the other hand, has a predominance of orthocortical cells. Most fibres can be distinguished by this mesocortical difference found between cashmere and wool in this study. The fine structure of mesocortical and paracortical cells. Cashmere, mesocortical cells, has a higher microfibril packing density and
Tucker et al. (1990) studied the physical structure of a range of animal fibres at low magnification using the transmission electron after first staining with phosphotungstic acid. Cashmere and angora samples from individual goats as well as a commercial cashmere contained a range of structures from classical bilateral to non-bilateral and para-like cortical cells were present in most of the fibres as which appeared 'intermediate' between the two types. Some fibres contained only ortho-type cells. In addition, variation in stain uptake by ir was observed. One pastora/cashmere crossbred sample did not contain bilateral fibres at all. Camel, Mongolian yak, guanaco and vicuna had a bilateral structure although it was less obvious with vicuna. Nor alpaca were bilateral and llama was difficult to classify.

Another important structural feature of animal fibres is the so-called "bricks and mortar" arrangement of the cuticle and cortical cells - depicted (Leeder 1986).

Fig. 7. The "Bricks and Mortar" Composite Structure of Ani

Animal fibres can be considered as an assembly of cuticle and held together by a "cell membrane complex" (CMC). The CMC is only a few percent of the weight of the fibre, but is of great importance as it controls or influences most fibre properties. Mechanical properties such as abrasion resistance or wear life are dependant on the CMC and CMC constitutes the only continuous phase in the fibre.
The epicuticle is considered to be a component of the CMC. Very little has been published on this important structural component of fibres.

We believe that there is an urgent need for a study of consequence of any differences between the CMC - epicuticle - goat fibres and wool.

Mohair fibre is more crystalline than wool. This less amorphous nature makes the mohair fibre slightly stronger, more wear resistant, and stiffer. X-ray diffraction studies (Zahn, 1990) on mohair have shown knowledge of keratin structure in general. Likewise, Heidemar (1970) used mohair, swollen in various liquids, to examine the spacing of alpha-keratin.

Tester (1987) found a slightly lower proportion of ortho-crest material in cashmere than in wool. Kulkarni (1975) used stained fibrillar electron microscopy, and found interfibrillar material in the ortho-mohair but not of wool.

Satlow (1965) has summarised much of the morphological research on cashmere prior to 1965. He concluded from his own work that Mongolian cashmere was bilateral and that on average the amount of cytoplasmic material in cashmere was less than in wool. Roberts (1970) transmission electron microscopy (TEM) studies on 16.9 um Mongolian cashmere and 17.3 um South African lambswool. He concluded that the percentage ortho was percentage para 49.6. His lambswool was 65.2% ortho and 35% para. His TEM studies he also concluded that the sulphur contents of para cortical cells of cashmere were similar whereas in his ortho contained more sulphur than the para cells.

Wildman (1954) has published a frequency diagram which shows the distribution of scales/100 um for samples of commercial cashm
the Merino fibres he examined had the same scale frequency/unit 1 cashmere.

Tucker et al. (1988, 1989, 1990), in a preliminary study of 17.6 white cashmere down from Australian feral goats using a scan microscope (SEM), found the scale frequency to be 5-7/100 um. diameter pen grown merino wool he found the frequency scales/100 um. The scale edges of his cashmere did not protrude those of the wool. This latter observation was also made by Ro using Mongolian cashmere, using an SEM. He also concluded there were more pronounced on coarse cashmere than fine and attribute the smoothness of fine cashmere to the reduced scale protrusion wool. Roberts also concluded that the (supposed) lower cashmere compared to wool was due to the less pronounced scale

In a recent examination of Angora/cashmere crossbred goat colour, 17-18 um diameter) Tucker found that the scale frequer (SEM) was 3-4.5 scales/100 um. Although the sample was main diameter some of the fibres examined were 30-35 um diameter. fibres tended to have about 3 scales/100 um, but not enough examined to enable a statistically significant result to be obtained. taken from the same goat as the crossbred down, ranged in diam 126 um and the scale frequency was 10-11/100 um. The scale different to that of the crossbred down.

Roberts (1973) using TEM, found that Mongolian cashmere contains two apparent scale edges per cuticle cells ("false" scale edges) a made by Tucker on Angora/cashmere crossbred down and Lee various animal fibres. Roberts also claimed to see skin flakes on Tucker has observed material on both down from feral goat Angora/cashmere crossbred that could be skin debris.

It is obvious from the above reports that considerable variation surface morphology of goat fibres. However, there is a general, that rose fibre have flatter cuticle cell profiles.
These differences in physical structure of the surface of goat fit to wool, will be at least partially responsible for the greater processing mohair and cashmere - but will also contribute aesthetic advantages such as softness and lustre.

(ii) **Medullation**

Fibres which have a hollow or a partially-filled central canal in a continuous or fragmented form along their length (see Fig. 8) are medullated fibres, and are usually present to a greater or lesser extent in the fleece of all animals. Some of these fibres have a chalky whitish surface which is often referred to as "kemp". ASTM distinguishes between medullated fibres. The medullated fibres are those in which the medulla is less than 60% of the diameter of the fibre, and in which the diameter of the medulla is 60% of the diameter of the fibre when viewed in longitudinal section. This is established by the ASTM's Committee D-13, which recognizes medullated fibres as the source of more visible problems than undyed fibres. Reported observations on dyed mohair fibres (Smuts and Hunt) suggest that the critical value for undyed fibres is a medulla diameter ratio of 0.5.

While the occurrence of kempy or medullated fibres is occasional or even desirable for special effects, the presence of even a small proportion of high quality mohair may have a pronounced adverse effect on end-use potential.
Because medullated fibres and particularly kemp, tend to lie on the yarn and fabric and are generally much thicker than the surrounding fibres, the visual and other effects they produce can be out of proportion to the quantity present. Furthermore, dyed kemp fibres generally appear thicker than the surrounding dyed non-medullated fibres, and show up on the fabric. From this it follows that it is important, not only to know the number of kemp fibres to a minimum, but also to be able to measure the proportion, so as to avoid using fibres with an unacceptable proportion of kemp in certain end-uses.

Attempts have been made to reduce the proportion of kemp fibres by selective breeding (Bigham et al. 1990).

(iii) Chemical Composition

Smith and Harris (1937) found cashmere to have a sulphur content and a nitrogen content of 16.4%. Satlow (1965) carried out an analysis to see whether it was possible to distinguish between sheep's wool, camel hair, cashmere and mohair using a series of chemical tests. He found that the cystine and cysteic acid contents, alkali solubility, urea-bisulphite and the effect of acids, alkalies and enzymes, and concluded that the differences between the fibres were insignificant. Many of the tests, however, are not very sensitive and the interpretation of many of the results is difficult. Satlow did not find any cysteic acid in the three cashmeres he examined.

Roberts (1973) carried out a more detailed analysis of cashmere fibres by subjecting the fibres to the action of water, steam, oxidising agents, acids and alkalis. He successively extracted his cashmere with a soxhlet apparatus with diethyl ether and ethanol (24 hours each solvent). After ethanol extraction the samples were rinsed with distilled water to remove any suint and then allowed to dry. Remaining dirt was removed by shaking the fibres. The guard hair was removed from the down by passing the cashmere through a comb. The remaining cardiopodium was then extracted as above.
Prior to the extraction the tips of the wool fibres were removed with the extraction procedure, is standard practice for wool pu fundamental research studies are to be performed. Tip removal that photochemically degraded wool is not included in subst Roberts did not remove the tips from his cashmere down it impossible given the physical state of the cashmere. He also ca to be important "because undercoat is unlikely to be subject to degradation". However, because many of the samples of cast Australia have shorter guard hairs than down (Garner, 1967) ca exercised before concluding that the guard hairs will protect from photochemical degradation.

Tucker and Roberts appear to be the only workers to have ana to ascertain the amino acid composition. Roberts compared composition of 16.9 micron diameter Mongolian cashmere wi South African lambswool. The amino acid compositions of the very similar. Only cystine, tyrosine (12% more of each in cashr and proline (9% lower in cashmere than in wool) were signific All of these five amino acids are more difficult to determine tha 14 amino acids. Roberts explains the differences in serine ar being due to resolution problems during analysis and the differ contents as being due to the problem of reproducibility. I difficult to analyse because of its poor colour yield with ninhydrin used for amino acid analysis. Roberts says that even though in the analysis for cystine the possibility that a real difference the cystine contents of cashmere and wool cannot be overloke

Roberts found that the cysteic acid content of cashmere and w 27 micromoles/g respectively (0.42g/100g and 0.46g/100g, ep expressed on an oven dry basis). This finding is at variance wi Satlow 1965) who did not detect any cysteic acid. Roberts also amide content (glutamine and asparagine) was the same for eac

Tucker analysed ten cashmere samples from Restall's feral goat
between the various samples for cystine in particular, as well a glutamic acid and proline. These differences may be associated or age variation or nutritional status. Such differences are com fibres.

Apart from the amino acids mentioned there is a remarkable similit the other 13 amino acids if the results are "normalised" on a similarity is even more marked when it is considered that ten of samples are from feral goats and that the other two are from G4. The cashmere samples are also, as a group, very similar to the merino wool.

Tucker found cysteic acid in all of the twelve cashmere samples. Whilst the amounts are quite small (9-17 umoles/g) it would appear photochemical degradation of the fibre has occurred during grown grown merino wool did not have any cysteic acid. Clearly there investigate the formation of cysteic acid (formed from the p oxidation of cystine) during fibre growth and also to ascertain the of the guard hairs as "protectors against ultraviolet light".

Tucker has also examined by thin layer and gas chromato graph the chloroform/methanol extract of cashmere fibres which has been soxhlet extracted with petroleum ether and water. The removes lipids (often referred to as the internal lipids) not petroleum or diethyl ether. The amounts of material extracted an 0.1 - 0.2% based on the conditioned mass of the cashmere). cashmere samples were from feral goats and two from G4 stock pen-grown merino sample was analysed (the 13 samples were all amino acid studies referred to earlier). Preliminary results show composition of cashmere is different to wool and that the lipid c fibre from G4-bred stock is different to fibre from feral stock. To enable cashmere to be positively distinguished from wool of the diameter and G4-type goats to be distinguished from feral st differences also suggest a possible reason for the renouned
Logan et al. 1989 analysed lipids of wool, mohair, alpaca, llama. Some fibres, notably mohair, human hair and llama hair, had distributions sufficiently different from the average to suggest consideration of this analysis for forensic work. The extract for alpaca was more than twice as high as any other animal fibre. It contains a useful list of references.

(iv) **Surface Lipids**

Keratin (animal) fibres have been found to possess a chemical-biological monolayer of fatty acid on the fibre surface. This layer is responsible for the hydrophobic nature of animal fibres, and affects processes such as finishing (dyeing) performance, and end-use (aesthetic) properties. It can handle, softness, washing shrinkage etc. Removal of this surface layer is an important consideration in the specification and control of all surface properties. Most work on this has been carried out by Leeder, Rippon and Rivett (1985) on wool, with indications that the amount (and influence) of this surface lipid varies between different fibres (Rivett et al. 1988).
### Table 3. Some Properties of Mohair and Mohair/Wool Blend Fabrics (Hunter et al. 1979)

<table>
<thead>
<tr>
<th>Y</th>
<th>FABRICS</th>
<th>55/45 Mohair/Wool Blend</th>
<th>100% MOHAIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Warp</td>
<td>Weft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.1</td>
<td>20.1</td>
</tr>
<tr>
<td>xation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>relaxation</td>
<td></td>
<td>0.421</td>
<td>0.431</td>
</tr>
<tr>
<td>σ/cm²/98Pa</td>
<td></td>
<td>0.489</td>
<td>0.492</td>
</tr>
<tr>
<td>σ/cm²/490Pa</td>
<td></td>
<td>19.4</td>
<td>20.4</td>
</tr>
<tr>
<td>relaxation 98Pa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>relaxation 490Pa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>after relaxation</td>
<td></td>
<td>1.55</td>
<td>1.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.49</td>
<td>1.72</td>
</tr>
<tr>
<td>% mass loss after 10,000 cycles</td>
<td></td>
<td>52.4</td>
<td>54.4</td>
</tr>
<tr>
<td>(m²)</td>
<td></td>
<td>4.99</td>
<td>4.55</td>
</tr>
<tr>
<td>ge (TWS-TM9)</td>
<td></td>
<td>869</td>
<td>874</td>
</tr>
<tr>
<td>e (TWS-TM 185)</td>
<td></td>
<td>300</td>
<td>329</td>
</tr>
<tr>
<td>γ (%) Aged</td>
<td></td>
<td>35.5</td>
<td>21.8</td>
</tr>
<tr>
<td>γ (%) Desged.</td>
<td></td>
<td>2.6</td>
<td>0</td>
</tr>
<tr>
<td>v Aged (mm) 1 hour</td>
<td></td>
<td>16.3</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>74.7</td>
<td>75.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41.0</td>
<td>49.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

The scientific literature contains very few reports of systematic fibre, yarn, and fabric properties of mohair, done of cashmere. One comprehensive is that of Hunter et al. (1979), summarised in Table 3.
(i) **Tensile Properties**

Single fibre strength values of mohair were said to be comparable with those of better wools (Onions, 1968), reporting on unreferenced data. Because of the smoother fibre, slippage tends to make mohair weaker than wool, but the data of Onions (p. 215) show ample twist to be stronger than wool yarns. For worsted yarns, relationships between twist and strength are shown in Table 4.

**Table 4. Yarn Twist vs. Strength - Wool and Mohair (Omc)**

<table>
<thead>
<tr>
<th>Yarn Twist (turns / metre)</th>
<th>Strength (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wool (22 μm)</td>
</tr>
<tr>
<td>290</td>
<td>3.6</td>
</tr>
<tr>
<td>390</td>
<td>4.9</td>
</tr>
<tr>
<td>480</td>
<td>5.6</td>
</tr>
<tr>
<td>650</td>
<td>6.5</td>
</tr>
<tr>
<td>740</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Kondo et al. (1971) showed a sharper peak in the stress-strain curve relative to wool. (See Fig. 9). They attributed this to a stronger bond between the scales and the cortex in mohair.

Hunter and Smuts (1985) performed both bundle and single-filament mohair, showing tenacity to be independent of fibre diameter. They commented on the effect of bundle mass on measured extensibility advantages over staple testing.

(ii) Wrinkle Recovery

Good wrinkle resistance and recovery are commonly associated with mohair, and some studies in this field have been carried out using a mohair development at SAWTRI, called the SAWTRI Wrinklemeter. This instrument has been used to quantify the severity of wrinkles inserted by the inflation method. These, together with some very recent data, indicated (Fig. 10) that the percentage wrinkle recovery deteriorated as the fibre diameter increased from the Kid through the Young Goat to the Adult. Figure 11 shows this expressed in another way, namely that the severity of wrinkles increased as mean fibre diameter increased. In end-uses where wrinkle recovery is of paramount importance, it therefore appears advisable to use the finer grades of mohair.

Hunter et al. (1979) found that fibre coarseness contributes less to wrinkle recovery. However, this also leads to more severe deformation, as assessed in the AKU instrument. Mohair fabric wrinkle recovery was compared to fibre, yarn and fabric properties, using the Wrinklemeter (Hunter et al., 1985).
Fig. 10  Wrinkle recovery versus fibre diameter

Fig. 11  Wrinkle severity versus fibre diameter
(iii) **Shrinkage - Dimensional Stability**

The flatter scales of mohair retard felting shrinkage, although machine washing is equally harmful to wool and mohair fabrics. It quoted by Onions (1968 p. 215) show shrinkages of 33.0% a woven fabrics of wool and mohair respectively; and 23.0 comparable knitted fabrics. With both knitted fabrics capable ultimate shrinkage, neither had reached their potential.

O'Connell et al. (1972) made and tested durable cellulose/polyester fabrics containing mohair. Unlike wool ble blends needed no extra shrinkproofing, but some wear scratchiness.

Den Heiger (1966) tested both area shrinkage of fabrics and feltin of loose fibres. They recommended acid conditions (pH 1-1.5) for the feltability of blends. Table 5 illustrates the lower felting rate the mohair content of blends is increased.

### Table 5. **Felting shrinkage of wool and wool/mohair knitted fabrics**

<table>
<thead>
<tr>
<th>Sample</th>
<th>% Mean area felting shrinkage after</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 min.</td>
</tr>
<tr>
<td>South African Merino Wool</td>
<td>5.5</td>
</tr>
<tr>
<td>20% Mohair/80% Wool</td>
<td>5.3</td>
</tr>
<tr>
<td>40% Mohair/60% Wool</td>
<td>2.8</td>
</tr>
<tr>
<td>80% Mohair/20% Wool</td>
<td>0.7</td>
</tr>
</tbody>
</table>
The dimensional properties of various blends of mohair and wool fabrics have been investigated by Hunter et al. (1972). Feltin unshrinkproofed fabrics during machine washing was found to increasing wool content, that of the pure mohair fabrics being worst. Loop distortion (cockling) due to the washing, on the other hand, considerably with increasing mohair content for both the shrinkproof and the unshrinkproofed fabrics. The distortion of all the fabrics was so severe that it rendered the fabrics completely unserviceable if they were to be washed during use. If these results are verified by further work at TFRI, it will have an important influence on the type of fabric envisaged.

Fabric distortion was also found to be particularly bad during solvent dyeing.

It was suggested that the loop distortion occurring during washing was in some way related to short term variation in the torque (twist line) in the yarn. This, in turn, was thought to be introduced, or at least exacerbated, during the actual knitting and to be related to yarn irregularity (i.e., possibly fibre diameter).

Setting the yarns prior to knitting only reduced the fabric distortion to a limited extent. By autoclave setting (for two minutes at a pressure of 205 kPa) or autoclave decatising (at a pressure of 100 kPa), two minutes in each direction, the fabrics knitted from DCCA-treated yarn or the fabrics knitted from unshrinkproofed yarn with Synthappret shrinkage and distortion could be reduced considerably. This treatment proved the most effective for reducing fabric shrinkage and distortion.

It was concluded that an acceptable washable fabric could be obtained if fabrics were treated with 2.5 percent Synthappret LKF from a size vat followed by autoclaving, provided the mohair content was not
From this study it appears than no particular blend can be recognised optimum. In practice the actual choice of blend would depend on the type of garment required, cost considerations and various other factors.

(iv) **Thermal Insulation**

Respondents to a survey in Knitting International (1974) gave winter warmth most common reason for wearing wool knitwear (31%), so importance of winter apparel as a market for specialty fibres.

Alvigini and Bullio (1988b) described the thermal resistance of wool with several other properties; and a more general discussion about bulkiness (1988c). Because the thermal resistance of a fabric depends on the amount of entrapped air, fine speciality fibres and the furry surface of mohair are advantageous. Slater’s (1977) comprehensive review of textile comments on no reference to specialty fibres.

(v) **Lustre**

The lustre of mohair has been studied, e.g., Barmby and Towr (1985) studied the effects of fibre chemical treatment on lustre. However, no data could be found on the mechanism of lustre formation or on ways to control or increase (advantageous) proper of mohair and cashmere fibres - other than comment that lustre is probably related to less-prominent scale structure, particularly with mohair.

(vi) **Frictional Properties**

As mohair differs from wool in this respect, the property has attracted research attention. Martin and Mittleman (1946) were among those who observed the lower differential friction due to less-prominent scale structure. Kruger (1972) examined mohair yarn friction.
be reduced considerably and became approximately independent content of the yarn. It was therefore suggested that it was differences between the mohair and wool fibres, as such, which yarn friction but that it was extractable matter (grease, additive processing, etc.) present on the mohair which adversely performance of the paraffin wax.

The paraffin wax with the highest melting point (63°C) general better all round performance than two other waxes used.

(vii) **Burning Behaviour**

Table 6 summarises the burning behaviour of the common Cotton and viscose rayon are easily ignited, they burn rapidly to extinguish - a dangerous combination. The burning material ash. These fibres can be treated to improve their burning behavior of the desirable properties of the fabric are affected.

<table>
<thead>
<tr>
<th>Textile</th>
<th>Burning Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton, Linen, Viscose</td>
<td>Burns very easily,</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Burns readily, melts and then dri</td>
</tr>
<tr>
<td>Polyester, Nylon</td>
<td>Shrinks and melts away from the</td>
</tr>
<tr>
<td>Wool, Silk</td>
<td>Slow to start, slow to burn.</td>
</tr>
</tbody>
</table>

When judging the flammability properties of a textile, several factors considered -
- ease of ignition,
- rate of spread of the flame,
- amount of heat given out during burning,
Nylons and polyesters are slow to ignite; the flames spread slowly difficult to extinguish. However, the burning mass is molten, very cause serious burns by sticking to the skin.

Acrylics burn hotter and more rapidly than nylon and polyesters produce an equally dangerous molten residue.

Wool is difficult to ignite. Any flame produced spreads slowly extinguished. The residue is a low-temperature fragile non-sticking.

When wool burns it gives off a characteristic warning smell - safety feature. The scientific reasons for wool's fire resistance chemical composition and its high water absorption.

Mohair and Cashmere have very similar chemical and physical wool. Thus it can be safely assumed that the burning behaviour and other specialty animal fibres will also be very similar to that of

Never-the-less because animal fibres are used mostly in apparel applications, flammability properties must be considered. This makes application of topical finishes (van Rensburg, 1975). Goen et al. (Antiblaze 19 to mohair/synthetic blends. Treatments developed as the IWS ZIRPRO treatment, are readily applicable to cashmere. However, such treatments will need to be considered in terms of negative effect on the advantageous aesthetic properties of goss as smoothness, lustre and comfort.

(viii) Allergenic Reactions/Comfort

We found no references to skin allergies, only to scratchiness: evidence that many Americans are "allergic" to wool and mohair to fibre prickling and stiffness, probably from coarser fibres > : true allergic reactions seem due to dyestuffs and finishes, formaldehyde, than to fibres. All apparel fibres are finer than
(ix) **Degradation, Insect Attack**

Hagege and Connet (1980) used differential thermal analysis to study degradation of mohair. Strydom (1975) examined the yellowing of mohair, and this was followed by his work (Louw 1958). Rivett and Logan (1990) described the current mothproofing specialty fibres, concluding that insecticides provide a satisfactory solution. Again, the similarity in chemical structure between wool and goat fibres means that established chemical treatments can be applied when needed, e.g. in carpet and rug uses.

(x) **Wettability**

Pittman (1971) measured wettability of single wool and mohair fibres at medium and very low humidities, with very little differences between them. However, cashmere processors have observed that the fibre does not wet readily in water as well as wool.

Roberts (1973) believed that the surface of cashmere is more hydrophobic than wool and that the ease of wettability is due to the increased hydrophobic nature. He added known amounts of paraffin oil to both wool and cashmere samples, then scoured the samples in soap solutions under the same conditions. The cashmere retained more of the oil than did the mohair, and from this he concluded that the surface of the cashmere was less hydrophobic (i.e. more hydrophilic) than the surface of the wool. Roberts also observed that cashmere contains more polar amino acids, serine, threonine and tyrosine than wool. It is believed that the cuticle of cashmere is richer in these amino acids than wool.

Tucker (1988-1990) determined the critical surface tension (Yc) of cashmere fibres taken from feral goats (the same samples were used for analysis of lipid composition) and for penned grown Merino fibres of different diameters. He used the sink/float technique. The following results were obtained:
Given that the Yc for distilled water is 72mN/m and assume wettability to occur water must spread on the surface of the therefore ideally Yc for the fibre must be greater than Yc for the clearly Yc is not the only parameter governing wettability. Other determined Yc for human hair to be 26mN/m and Yc for mohair to

(xi) **Dyeability**

Wool and cashmere were dyed with Kiton Red G and Me respectively by Roberts. For cashmere he observed 60% dye up wool 40% uptake when the two fibres were dyed under the same. The dyeing of the cashmere was more ‘patchy’ than the wool. That the greater unevenness of the staining on cashmere was epicuticle of cashmere being more porous than the epicuticle of wool ruled out localised mechanical damage as the cause of the uneven cashmere but did not show any evidence. Methylene Blue gave to Kiton Red G but the staining was more uniform. The authors do not agree with Roberts' interpretation - obviously more work on this important subject.

(xii) **Yarn Properties**

The hairiness of mohair yarns is an interesting property. For so such as hand-knitted ladies cardigans, shawls and blankets, h asset, enhancing the appearance of the fabric. For this purpose mohair yarns and fabrics is commonplace in the industry. In other however, such as in men's worsted suits, hairiness is a disadvant to be minimised. Mohair is inclined to produce a hairy yarn, and to be minimised various precautions are necessary. Result involving a hairiness meter showed that the hairiness of mohair y linearly with increasing fibre diameter, and that re-winding hairiness of singles yarns and two-ply by 40% and 20%, respect (1985). Hairiness was considerably reduced by dying, although i
Friction is another very important property of yarns destined for knitting. Its importance in determining knitting efficiency and also in determining stitch length when knitting takes place is well established for various fibres. Paraffin was an effective means of reducing yarn friction, but its effectiveness was adversely affected by the presence of excessive amounts of additives.

(xiii) Fabric Properties

Recent SAWTRI studies (reported in Turpie, 1985) have shown that various fibre properties, mean fibre diameter is again of importance in determining fabric properties. It can be seen from the graphs showing flexural rigidity (stiffness), air permeability and drape coefficients for two different fabric states, all increase with an increase in fibre diameter.

![Graphs showing flexural rigidity, air permeability, and drape coefficient vs. fibre diameter.]

Fig. 12 Effect of fibre diameter on fabric properties (o = Dry-relaxed, o = Wet-relaxed) - Turpie, 1985

Tester and Foley (1986) showed that cashmere and superfine length and diameter showed differences in processing behaviour. The outstanding difference in processing was cohesion exhibited by cashmere. During fabric finishing the cashmere shrank very little compared to the wool fabric and this was
The differences found in fabric mechanical properties have been related to fibre crimp differences and differences in fabric construction, shrinkage differences and associated yarn bulking during finishing. Differences in fibre and yarn friction appear to play a role in the bending differences found between the cashmere and superfine. Whereas the properties attributable to setting differences are difficult to separate from those caused by crimp and friction differences.

There is no doubt that mohair has many characteristics which are desirable and valued by consumers all over the world. These include durability, resilience and comfort, its ability to be dyed to bright colours, and a low felting propensity. However, it should be stressed that, in the high-technology age in which the technologies keep advancing and change is essential that research on mohair and its processing is carried on in a continuing, ongoing basis to enable the fibre to maintain its prestige, image and desirability in the textile world of tomorrow.

To summarise the properties of mohair and cashmere:

Mohair properties generally similar to wool, except for less-prorosity and a lower cohesion in processing and slower felting. Mohair has a narrower range of diameters (24 - 32 um) than wool (18 - 36 um).

Those fibres that require some depilating - cashmere, camel hair, llama hair, etc. - generally need to be exported for processing between fleece and guard hair are few but commercially important; breeding is more advanced for wool than for other hair fibres, so direction directed to cashmere may be rewarding.

There is some evidence that altitude stress makes wool finer - alpaca and llama fibres may be coarser in Australia.

The main advantage of cashmere is its fineness and related softness. A drawback is short mean fibre length, although Australian cashmere is longer than Chinese. This increased length should have
According to the provisions of the textile characterisation law the of textile materials must be clearly stated. This means at the sar must be a possibility of verifying the composition. In addition to animal hairs are being used to an increasing extent, alone or in wool and with synthetic fibres. Labels such as "100% miscellaneous" and "100% acrylic mohair" are still to be found on garments.

If animal hairs are mixed with synthetic fibres the determin proportion of synthetic fibres normally presents no difficulties; the methods evolved for the fibre analysis of wool with synthetic used for this.

Conditions are very different in the identification of the hair of a specific species and in the analysis of mixtures of animal fibres.

Comprehensive round robin tests of the working committee Mixtures of Protein Fibres of the International Wool Secretariat that a distinction between sheep's wool and mohair is not possi microscopic methods alone.

Many of the papers presented at the two Aachen Conferences Fibres (1988 and 1990) were about problems of reliably identif fibres. Two early books, (Wildman (1954) and Appleyard ( devoted entirely to the problems of distinguishing between mammalian hairs. They tend to avoid the problem that the fibre change drastically from root to tip, and that the profiles of ma overlap. Not only is there generally some guard hair pres individual fleeces have a range of diameters and scale pat identification has been mainly the concern of archaeologists.

In recent decades legal liability for product description, custom d etc. has focussed attention on reliable identification and desc

Increasing emphasis on quality control provides another development of quantitative analytical techniques. For example, industry, mixture analysis can aid process control - efforts are the loss of high quality animal hair components as low as in production stages such as milling and raising (Kusch and Stephan).

The main (most likely) methods for identification of specialty fit to McCarthy (1991) -

- Amino acid analysis
- Scale height measurement
- Image analysis
- PAGE analysis of extracted proteins
- Internal and external lipid analysis
- DNA fibre profiling.

(i) **Microscopy**

Optical techniques were applied at the USDA Albany distinguishing between various animal fibres. This Institute is co the Wool Products Labelling Act, with identification of most o fibres, but does not recognise cashgora.

Skinkle (1940) recommended the parameter (scale length) distinguishing wool and mohair, the former having values below latter above 150. By multiplying each fibre by the square of its method has been used with limited success in quantitative ana are, for example, Argentinian wools that partly analyse as moh.; this criterion. Ryder (1990b) listed cuticular scale mean diameters for a range of goats. Mohair has a high diameter/sect
African mohair; and the almost convex scales of camel hair. Scal
useful criterion for distinguishing wool from other animal fibres, t
investigation revealed some overlap in the distributions (Welde
1985). Mohair from Lesotho, Argentina, New Zealand and Austra
have more variable profiles than South African mohair.

Langley and Kennedy (1981) concluded that specific criteria sucli
evenness, scale length and angle, and scale length cubed divided
were unreliable. Throughout their paper they discussed th
differences, using light microscopic techniques, between the comi
fibres. For example, in a discussion of differentiating between
white mohair and second clip Buenos Aires wool, they state :

"Even in this worst-case example the pattern holds th
differences are seen in thickness and evenness of the scal
revealed only if a mountant such as glycerine jelly is used.
refractive index sufficiently different from that of the fibre”.

Nowhere in their paper do they conclude that identification cann
light microscopy; however, they do acknowledge that identific
microscopy does require a high degree of skill and experience.
analysts do not have the opportunity to develop and practice.

When properly applied, light microscopy techniques may permit
and fibre-blend identification.

The transmission electron microscope (TEM) is gaining favour a
method for fibre identification. The evidence presented by Wortr
including statistical analyses, support his contention that this mel
for identifying fibres, particularly blends of specialty fibres with
there are major differences in scale heights.

Sich (1990) provided evidence to support the contention that br
scanning electron microscope (SEM) examination are needed
specialty fibres. Dawson are supporting research (Robson and W
Discriminant analysis using two properties, fibre diameter and scaliness, was shown to provide better distinction between yak fibre and cashmere or whether measure alone (Wortmann, 1990a). Teasdale (1988) and Wortmann et al. (1989a) favoured using the SEM. They pointed out that 70% of submitted samples were mislabelled (Wortmann, 1990b). Smith (1988a), however, was sceptical about electron microscopy, and provided views on the order of effectiveness of identifying specialty hair fibres.

Robson and Weedall (1990a) used SEM to examine both long and short cross-sectional properties of lambswool and cashmere, in conjunction with image analysis. The overlap between the two fibres was striking.

(ii) Chemical Techniques

An Australian paper described chemical analysis of specialty fibres by chromatography (Tucker et al., 1990). The results showed that the ranges of various amino acids, with differences between the species, were usually too small for reliable identification. Speakman and Hor Laumen et al. (1990) reported relative success with electrophoresis.

Tucker et al. (1988) examined the extent of bilateral differentiation and para cortex by staining and SEM examination, finding it difficult to distinguish mohair and alpaca. They began the estimation of cystine content of identification. Despite variability and the effects of weathering, different distributions of amino acids between fleece and guard hair were seen.

Tucker et al. (1990b) had some success in distinguishing between means of amino acid analysis but in cashgora the results were not always reliable. Hocker (1990) examined several techniques, and concluded that a combination of methods and measurements must be used. Wortmann et al. (1989) claimed success in analysing wool/angora rabbit hair blends.
After applying a variety of chemical techniques, Sagar et al. (1991) that the poor reproducibility of results was sometimes due to chemical composition from the raw state through processing. Th and McCarthy (1991), expressed promise for a new technique residual genetic material, DNA analysis. An investigation using t (Hamlyn et al. 1990) referred to the need for several days of tes analysis and the likelihood of DNA being degraded during Bleaching, for instance, largely destroys DNA. The conclusion of (1990) was that DNA analysis would be able to distinguish be fibres in the raw state, but not if they had undergone any heat treatment. Nelson et al. (1990) described developments in DNA reduced the preparation time to one day.

Earlier work (Swart et al., 1967) examined the distribution of pro (1985) claimed to have identified differences between wool a protein composition.

The results of an investigation by Tucker et. al. (1989) ave show PAGE (two-dimensional polyacrylamide gel electrophoresis) tec uses an alkaline gel in the first dimension and SDS in the secon can distinguish between samples from individual goats, betwe blends, and between samples from individual goats and goat. Because of the variations in protein patterns obtained the techni used to unequivocally distinguish cashmere from mohair or an crossbred samples. If, however it is used in conjunction with electron microscopy (Tucker et al. 1988) and lipid analysis (Rivet) then it does materially assist in the identification of specialty including goat fibres.

Logan et al. (1987) reported on their analysis of the sterol composition of wools from different breeds of sheep and from dif zones. The results are compared with analyses of other Cholesterol, desmosterol, palmitic, stearic and oleic acids ac majority of the internal lipids in animal fibres, with the exception and fibres of the camel family. They concluded that sterol i
(iii) **Other Techniques**

Smith and Gee (1980) proposed exploiting the different friction mohair and wool to analyse blend components. The slip distribution in raw fibre friction becomes more significant in full finished fabrics. Landwehr (1981) measured the frequency of slippage as the against-scale forces were measured along the fibre. Mohair is much less frequent than in merino wool, but comparable with other fibres. Their measurements allowed all mohair fibres studied to be distinguished from all wool fibres of comparable diameter.

Subramaniam et al. (1985) used tensile properties to distinguish mohair and wool, but claimed success only for fibres coarser than 30
6. **Fibre Testing.**

Lineberry et al. (1974) described U.S. procedures for sampling greas.
Gifford (1989) recommends sampling goats at the mid-side position
fibre tests.

Simple testing methods, useful in fleece testing and herd improvem
described from cashmere (Brown 1984) and mohair (Stepleton 1988
(1988) described the role of the International Mohair Assoc
standardising testing. Erasmus (1987) described a wide range of f
and breeding properties that are recorded in a South African moh
scheme.

With biannual shearing, Koratkar and Patil (1984) tested fleece π
length, diameter, kemp content and medullation of mohair. Re
approximately equal to those from annual shearing.

Lupton et al. (1990) reported results of ongoing measurements, ov
of eight years, of fleece yield, fibre diameter, lock length and ken
mohair. Strydom and Gee (1985) have examined the relationsh
mohair’s fibre and processing properties.

(i) **Fleece Yield**

Corresponding to their different properties, (notably the presenc
hair), raw cashmere, camel and llama hair call for an extra test (fl
and some modifications to other tests. Teasdale et al. (1985) revi
They are described for the benefit of the trade in an A.W.T.A. (19
This was updated by Hopkins (1985), Stubbs and Mahler (1990).

Two different fleece characteristics are referred to generally as fleec
(a) **Clean Washing Yield or Fibre Base.**

The International Wool Textile Organisation (IWTO) has sta
designed to estimate the clean fibre base on raw greasy fu
tests are used for mohair. Contaminants removed include
Mohair Base is the amount of clean dry fibre free from expressed as a percentage of the greasy fibre mass. Mohair converted to the IWTO Scoured Yield basis. This relates to normal commercial yields for scouring greasy mohair, calculated from the Mohair Base to include all vegetable standard residuals of grease and dirt retained after comm and allows for a moisture regain of 17%.

(b) **Dehairing Yield**

For cashmere, which requires dehairing, the yield is calculated as a percentage of the greasy fibres (% w/w). This yield is determined by the desirable downy undercoat fibre from the coarser guard hair fibres. In the absence of a reliable method of calibration, standards exist yet but the AWTA is seeking to have approved adopted.

Traditionally, dehairing has been a closely-kept trade secret and are proud of their ability to remove most of the coarser some processors claim to be superior to others. The dehairing has to be repeated numerous times to reduce the contamination to < 0.5 % w/w. A consequence of this is that the length of the downy (dehaired) portion is considerably reduced and breakage of the fine downy fibres is impossible to avoid in procedures.

The literature is full of reports of cashmere production which weight of *combed* cashmere. Such combed cashmere can be further refined with guard hairs, suint, grease and dust. Australian researchers refer to commercial cashmere yields, dehaired by AWTA. This fully discussed by McGregor et al. (1991). Unfortunately many cashmere literature e.g. Millar (1987) fail to distinguish between combing "yield" and a clean commercial yield, thus coming to conclusions about cashmere production.
Couchman (1985) described the development of dehairing for test subsequent paper (Couchman, 1986, p. 257) included details of a dehairing procedure for use with a Shirley Analyser. Subsequent r shown, under conditions of moderate humidity, the superiority of Shirley Trash Separator over the Shirley Analyser in separati components of cashmere (Couchman and Holt, 1990).

(ii) Scouring Yield

Tucker et al. (1985) measured scourable impurities, notably greas and found these to be lower in Australian than in Chinese Couchman (1985) has analogously advised the segregation of goat high and low yielding lines.

(iii) Fibre Diameter

Fibre diameter is commercially one of the most important fibre proj is mainly because it determines spinning performance, yarn properties and the end-use potential of the fibre. It is therefore in fibre diameter be measured accurately on a routine basis.

Determination of fibre diameter by the airflow method is rela convenient and fairly accurate, and it is consequently widely a used for obtaining fineness estimates of both mohair and wool.

Theoretically, the degree of medullation and the CV of diamet the results obtained by the airflow method. However, a study (Turpie, 1985) indicated that degree of medullation had little eff measured diameter within the fairly wide range of area medullatic the study. More work needs to be done in this area.

CV of diameter, on the other hand, had a significant effect the study. Unfortunately, however, this was only about half that wh
shown, therefore, that within the ranges covered, the air-
diameter of mohair is fairly good estimate of the projection m

diameter.

Table 7. The Effect of CV of Diameter on Air-flow C

<table>
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<tr>
<th>PROJECTION MICROSCOPIC (µm)</th>
<th>AIR-FLOW (µm)</th>
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<tbody>
<tr>
<td></td>
<td>CV (%)</td>
</tr>
<tr>
<td>26</td>
<td>25.6</td>
</tr>
<tr>
<td>32</td>
<td>31.5</td>
</tr>
<tr>
<td>38</td>
<td>37.4</td>
</tr>
<tr>
<td>44</td>
<td>43.4</td>
</tr>
</tbody>
</table>

Steadman (1990) showed, using a plot of wool prices againsts
fibres per unit mass, why buyers make up consignments havin
diameter. Mixing can reduce the value of good style mohair t
per kg. It follows also that lots should be segregated by fin
possible, and that any potential process for separating bulk f
may be rewarding.

Millar (1987) and Ryder (1990b) reviewed the mean diameter
of goat fibres.

Couchman (1984) measured diameter distributions of cashmer
and many other countries. The mean diameter of Australian
17.4 µm. Cashgora was coarser, and Couchman reported
mechanically separated into coarse and fine components. It
reported the seasonal changes and effects of management
of fineness grades to mohair as well as to alpaca (1985).
Ray et al. (1974) measured scoured mohair fineness by the Port-Ar, good correlation with projection microscope readings.

Many specialty fibres contain a few individual fibres coarser than the limit of the FFDA single fibre instrument is exceeded. This favors FIDAM or OFDA-type optical equipment if fibre diameter distribution is desired. Consensus is that airflow methods give an accurate guide to fibre diameter, except that increasing medullation of mohair biases the average fibre diameter towards finer diameters with the latter method. IWTO (E)-18-90 has the FFDA labelled as a "test method under examination" measurement of the mean and distribution of fibre diameter of wool, and mohair." Modifications are under development to increase the FFDA measurement to around 200 μm, thus allowing coarse fibre or guard hair samples to be measured.

For all specialty fibres, to varying extents, there exists a problem of fine fleece (down) fibres, coarse non-medullated fibres, fine hair/kemp/medullated fibres and coarse guard hairs. Thus there is overlap when considered on the basis of fibre diameter - see Fig. 13.

![Diameter Distribution Diagram](image)
There is an obvious need for more research on the behaviour of components of specialty fibre fleeces during processing and finish. The role of these components in determining the (aesthetic) properties of the product. These considerations also have a bearing on the value of the yield for commercial transactions, and the relationship between yield and yield testing. This is currently being addressed at TFRI.

(iv) **Fibre Length**

Longer fibres are more valuable, especially if single-fibre length. Some finer fibres, such as cashmere and especially vicuna, have a shorter than the shortest setting of a comb, resulting in high noise. Ryder (1990, p. 188) draws attention to the problem of a cotton of middle of the staple if the mohair goat is shorn annually.

Van Aardt (1986) found that storage of mohair top for up to a negligible effect on mean fibre length as measured by the Almeter.

Turpie and Cizek (1985) described the combined length and strength of mohair and wool, including extension profiles. Generally, Aus wool does not have blocky enough staples to be effectively tested with automatic instruments. The effect of length of mohair on performance is discussed by Turpie (1985).

(v) **Crimp**

Smuts et al. (1984) revived the much earlier work of van Wyk, that crimp is the most important correlate of resistance to combing and also considered the degree of medullation.

(vi) **Medullation**

At least two standard methods are currently used to quantify mohair. The ASTM and British Standard methods both require
which medullated and kemp contents can be estimated. (The au review question whether this relationship holds for fibres \, medulas).

This instrument was based on a design developed at The W Organisation of New Zealand. After suitable refinements, the was claimed to be capable of accurate and reproducible measure degree of medullation in mohair, even at levels of medullation of 1%, and calibration and test methods have been developed laboratory use. The relation between medullameter reading an area medullation is shown in Fig. 14.

Fig. 14. Percentage Area Medullation versus Medullameter (Turpie, 1985)

Smutts and Hunter (1987) found that if the medulla exceeds 0.64 diameter, the fibre is likely to be kempy. Smuts et al. (1985) medullation has no effect on the measured airflow diameter contrast to other work on wool, but CV of diameter raised all about half as much as predicted.

Hutchings and Ryder (1985) recently described the use of a S Film and Sc in combination with a computer for measuring fibe
There is obviously still a need for future work, aimed at characterising medullated fibres which show up differently after dyeing standardising a method whereby the quantity of such fibres in a sample can be determined with the necessary speed and accuracy.

The Leitz Company (1988) introduced the use of image analysis for measuring medullation in mohair, and a faster alternative method using a computerised system was announced by Blakeman et al. (1988). Bassett (1986) used a microscope to estimate kemp contents of mohair samples from locations on Angora goats.
7. PROCESSING.

Very little published information is available on the processing performance characteristics of goat fibres. What information there is has been a hard way over many decades by those very few organisations in which specialise in mohair and cashmere, and much of this information is quite naturally, regarded as private and confidential. Without the availability of sound scientific knowledge on the processing performance and characteristics of goat fibres, any industrialist wishing to enter the field for the first time would therefore be placed at a significant disadvantage. Ultimately, therefore, the fibre producer. It follows that "it is vitally important for the goat fibre industry, and the fibre producer in particular, for research to be carried out on the fibres and their processing" (Turpie, 1985 - refer to South African mohair industry). These comments apply equally to the Australian goat fibre industry. Almost nothing has been published on the processing of cashmere, so what follows is based mainly on data principally from SAWTRI.

(i) General

Townend (1976) provided a comprehensive review of mohair processing, with 42 references. Scotland claims to process 60% of cashmere (Anon., 1986). Given that textile processing accounts for 20% of the retail value of fibre products, or three times as much as the cost of the fibre landed at the mill, little is published about the processing of these fibres, especially about dehairing. This may be related to the fact that these fibres enter world trade as raw fibre. Texas, e.g. is said to be the world's mohair, but to process only 2% (Cahill, 1990).

Much of the mohair processing research has been done at SAWTRI. Results seem to have had little impact on commercial specialty-fibre use. However, there have been important attempts to take advantage of mohair's properties, especially of mohair, in effect yarns and their fabrics. Such investigations are mentioned below. Spencer (1970) provided a general overview.
Millmore (1990) reviewed the various functions and space ret manufacturer specialising in mohair and alpaca. Smith's (1986) comprehensive, covering all steps from sorting to finishing an stage to what he saw as relevant fibre properties. Some I reviewed separately.

A cottage industry has developed in Lesotho (Snickus, 1987) produce hand-spun mohair yarns. In Swaziland there is a new cottage industry producing mohair curtains (Wool Record, 1984). No detailed references have been found for woollen-system processing of these fibres.

(ii) Early Cleaning Processes

The literature on commercial dehairing is scant, because of the limited availability of centrifugal action, high humidity and of dehairing. A brochure on dehairing became available for the first time only at the International Textile Machinery Exhibition in Hannover (Tatham, 1983).

Although the research was done on a sample scale, Couch (1989) found less fibre breakage in longer, stronger fibres, with a difference in dehairing efficiency between machines.

Mohair, which normally needs no dehairing, benefits from a treatment available on many modern scourers. Wu et al. (1985) have found commercial application.

Turpie and Godawa (1974) discussed the carbonising of mohair, which reappeared (Turpie, 1988) with estimates of residual vegetable matter. They argued that total removal of V.M. by drastic carbonising was neither nor desirable, and advocated a milder carbonising process.

(iii) Topmaking
In a study at SAWTRI (Turpie, 1985), long types of hair were combed with Noble and rectilinear combs, while the medium and short hair were combed on the rectilinear comb only. More noil was produced on the comb than on the rectilinear comb. The noil ranged from as little as 5% during rectilinear combing and from about 4% to 8% during combing. An interesting fact emerged, namely that the amount of noil was dependent upon the diameter of the hair, but was independent of the comb used.

Combing greatly reduces medullated fibre, as does frequent combing, especially of stripper rollers. Because of the smoother fibre surface, medullated fibre is difficult to remove. Backwashing of combs is not recommended (Veldsman, 1970).

The artificial crimping process, developed for carpet wool, has been successful in reducing the leanness of mohair worsted yarns and fabrics (Veldsman, 1970) but with a higher end-break rate in spinning. The Schlumberger crimping machine, beginning with the PB-29 model, has provision for crimping the fibre. This should improve cohesiveness of mohair top.

(iv) Reduction of Kemp and Medullated Fibres during Processing

While breeding and selection is probably the most effective way of reducing medullated fibres, there are also ways of reducing them during processing. During carding, some of the kemp fibres become entangled in the card clothing and fall off at regular intervals can reduce over significantly. Another source of kemp removal is the burr beating machine since much of the fibre ejected along with the vegetal matter is actually kemp. At certain other points on such machines such as the swift and doffer kemp fibres are only loosely attached to the ware and drop out. Attention to machine design setting and handling can increase the removal of kemp at the carding stage. Further kemp fibre can be accomplished by combing on a Noble Comb using a suitable pin density and temperatures of the large and small circles to ensure effective suppression of the drawing-off rollers (Turpie, 1985).
(v) **Yarn Manufacture.**

Primentas (1964) reported progress in preparation; and Cillier and Hibbert (1976) reported progress in spinning. Spin fin subject of research by Turpie and Hunter (1977) and, in the land and King (1975). Kul and Smith (1971) also examined "lubrica. Two South African papers were devoted to mohair lubrication 1972; Hunter and Kruger, 1972).

Veldsman (1970) gave a good account of the special problem the smooth surface of mohair, especially in the preparatory sta after combing, and described ways of reducing these problems (Veldsman, 1980) described progress in processing mohair.

Because of the low cohesive properties of mohair, proper sp utmost importance. The correct lubricants must be selected an appropriate stages, to allow sufficient control of the fibres combing and spinning.

Turpie (1985) reported on a study of the spinning performance mohair rovings which had been sprayed at the top stage wi different formulations; an interesting relationship was found withdrawal force of the tops and the end breakage rate during:

The results showed that an optimum value exists for the with other words, a certain minimum level of cohesion between necessary to produce a good spin, but excessive cohesion is a insufficient cohesion.

It is widely accepted that spinning performance is largely de average number of fibres in the yarn, and for a given yarn cou dependent on the diameter of the fibres. A recent SAWTR 1985) found, however, that even for the same number of fi cross-section, an increase in mean fibre diameter caused a
is a marked one, and could be due to changes in fibre surface with changing fibre diameter resulting in changes in fibre cohe stiffness also increases rapidly as the diameter increases, and if expected to influence spinning performance. It is also possi flexural rigidity played a role.

![Graph showing Spinning Potential (MSS) versus Mean Fibre Diameter](image)

**Fig. 15** Spinning Potential (MSS) versus Mean Fibre Diameter

Not surprisingly, much of the mohair research has dealt with Techniques for making fancy yarns, usually from mohair, have be e.g. anon. (1958). Marsland and Turpie (1976) applied Rep spinning to the production of mohair effect yarns. Other South e.g. Robinson et al. (1981), exploited DREF 2 processing to make using mohair on the surface. Shorthouse and Robinson (1986) a special problems of spinning, dyeing and finishing brushed loop m

South African research on self-twist spinning (e.g. Robinson included variants such as core yarns and wrapped yarns cont: Tests of evenness, (e.g. Turpie and Hunter, 1977) gave good res

Cilliers (1966) observed a tendency toward fibre migration ir blends, the mohair fibres being more frequent near the surface yarns of medium or low twist, as in knitwear. The effect is to scratchy.

Strydom (1981 and 1983) examined correlations between fi properties, finding much the same relationships as apply to showed that spinnability was limited by fibre diameter and th length enabled lower twist.

(vi) Knitting and Weaving

One of the few special articles on mohair weaving was that of Some attempts have been made at woven mohair fabric (Robinson et al., 1974; Robinson and Silver, 1975).


Swanepoel and Veldsman (1969) described post-weaving treatm

(vii) Brushing/Raising

Mohair is very popular in brushed end-uses where its attractiv fully exploited. Some limited work has been carried out at Sj 1985) on the spinning, brushing and weaving of mohair loop yar of 25 to 40 microns in diameter. The brushed yarns were
fibre lost during brushing was dependent both on fibre diameter and number of wraps, increasing with an increase in either of these. Fibre loss during yarn brushing ranged from 0.3 to 3.6%, and at some 4% of fibre occurred during fabric raising.

(viii) **Bleaching and Depigmentation**

With various amounts of pigmentation in valuable fibres like alpaca, including piebald animals, there is much interest in bleaching and related compounds without undue fibre damage. Knott (1990) described the most complete summary of the depigmentation process. He described peroxide treatment with iron salts and analysed oxidase. This is probably the most complete guide to mordant bleaching fibres, but is complemented by the work of Sanchez and Guillemin.

Related work on the use of sequestering agents in depigmentation to 50% strength loss under similar bleaching conditions (Cegarra...)

Nazarov et al. (1983) measured trace elements in pigmented and found copper, zinc, and manganese to be higher than in white hair.

(ix) **Dyeing and Finishing**

Some research has been devoted specifically to mohair dyeing, Grove (1966). Hunter et al. (1990) described the complicated nature of mohair containing kemp. Uptake varies with the class of dye, disguised in fabrics dyed yellow, but is conspicuous in black, shades (Veldsman, 1970), especially if the latter are heavy shade.

In recent years, many attempts have been made to improve various dyeing, and new technologies have been developed to reduce fibre damage, decrease energy consumption and increase productivity. It is well known that mohair tends to lose its lustre when dyed, and to preserve its lustre it is generally necessary to take this into account. A single..
In recent studies on mohair it was found (Table 9) that dyeing drastically reduced from the conventional 90 minutes to 35 minutes of the radio frequency technique, only 5 minutes of the 35 minute actual exposure to the radio frequency field. An estimated 80% in dyeing energy costs could be achieved. Furthermore, improved slightly from 93% to 96%. Alkali and urea bisulphite were marginally lower for the RF dyed lots possibly indicating damage had occurred. The lustre of a 36.7 μm sample taken was measured on a Goniophotometer and the higher value shows the RF dyed lot indicates that a better lustre was recorded carried out without re-combing, and spinning performance then.

The spinning results appeared to be more favourable for the RF particular interest to small mills is the fact that RF dyeing lend changes and small runs, which is of particular advantage cashmere.

Table 9. Conventional Versus Radio Frequency Dy
*Unpublished work by F.A. Barkhuysen & A.P.B. Maasdorp

<table>
<thead>
<tr>
<th></th>
<th>Aqueous (100°C)</th>
<th>T</th>
<th>35 (only 5 n to RF)</th>
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<tr>
<td>Treatment Time (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dye fixation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkali Solubility (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea Bisulphite Solubility (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lustre Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinning Potential</td>
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<td></td>
</tr>
</tbody>
</table>

93
14.5
51
68.8
Turpie (1985) quoted unpublished data in which radio-frequency produced better lustre and enabled higher maximum spinning speed compared to conventional dyeing of mohair. Smith (1988), promoting a subsidiary Engineering, claimed advantages of radio-frequency dyeing and blanching: no thermal gradients, reduced chemical damage because of exposure to 100°C; and reduced energy, water and effluent costs.

Galek (1980) described the special problems of dyeing these fine mohair yarns. Mohair is easily dyed like wool; rabbit hair is hard to handle. Mohair/nylon blends are easy to dye except in pale shades. Walt and van Rensburg, 1985). Foam dyeing of mohair has been investigated.

Hunter et al. (1978) examined the effects of liquid ammonia on mohair. Most effects were negative, but there was some increase in the significance of which is limited.

Van Rensburg (1978) studied light degradation of mohair, and repolyacrylate pigment binder, an ultraviolet absorber or certain detergents.


The important and frequent process of drying was mentioned by (1988), who advocated radio-frequency drying because of temperature and uniformity.

In the past, little thought has been given to the need to shrink mohair, since mohair articles are usually either dry-cleaned or washed. In addition mohair has a relatively low felting potential shown, however, that if one subjects a mohair knitted fabric to high pressure it can shrink considerably. Some
Thorsen and Landwehr (1971) claimed improvement in properties, including yarn tensile strength, by corona treatment (ibid, 1970) was developed mainly to reduce felting shrinkage.

Although one of mohair’s most attractive features is its high luster, certain grades and qualities which do not have such a high lustre and a new research development could herald a process where such mohair types could be greatly increased. The process involves treating mohair slivers with chlorine gas dissolved in water, and is SAWTRI invention patented by the South African Inventor Corporation. The process is primarily aimed at rounding the sliver fibres to prevent their subsequent interlocking and felting due to the chlorine treatment. This makes the fibre smoother, which results in increased spectral diffusion, reflection of light, thereby increasing lustre. However, can also produce longitudinal striations on the fibre surface, evidence of damage, and lustre can decrease as a result.

Guirgis and Onions (1970) examined the setting of mohair, virgin mohair. This led to doubt and about the claim for specific ortho-kid mohair. Kid mohair can be set better than human hair, but not as well as merino wool. Tester and Foley (1986) found that cashmere leathers set to a better finish than did merino wool.

The I.W.S. developed a procedure to give wool the “dry, elastic of mohair” (Anon. 1985). Smuts and Slinger (1972) related mohair to fabric handle.
8. OTHER TOPICS

(i) Garments, Cleaning

In view of the importance of fashion/merchandising and the high retail price that it accounts for, only a few articles have appeared in the literature. Specialty fibres are sensitive to fashion changes and require careful handling. Moylan (1971) and Judd (1986) discussed the use of blends in interlinings.

The Wool Record (1990) reported the popularity of kid mohair in Japan, notably in Japanese golf jackets. Judd (1986) described the use of blends in interlinings.

Galuszyński and Robinson (1988) examined the making-up of mohair-wool blends, and advocated chainstitching to avoid any problems due to the sewing thread. The problem of pucker due to the fabric was also addressed.

Oehlke (1988) drew attention to problems of cleaning protein fibres such as silk and cashmere, especially hand treatment of damp fabrics. He described the designer’s art in making decorative mohair felts, and published guidelines for consumers on the correct methods of stain removal for cashmere and mohair garments etc.

Bar-Yecheskel and Weinberg (1988) have developed an instrument for measuring the shedding of fibres in finished fabrics. This instrument is important in evaluating the overall performance of products containing "slippery" fibres such as mohair and cashmere.

(ii) Blends

For many reasons, specialty fibres are blended with wool. Sande and Wilkinson (1990) reported on New Zealand experience in coarse animal fibres (cattle, horse, etc.) and blending with wool. Oehlke (1987) found evidence that blending mohair enhances quality of...
Generally the blending of "lustre" wools are often preferred especially since these often match the mohair in terms of extremely difficult, if not impossible, for even an expert to detect with the naked eye, the presence of certain of these lustre wool fibres blend with mohair. For the purpose of checking a blend composition, it is important to be able to identify the fibres quantitatively. The method has been based upon the differences in the anti-scale friction of wool and mohair fibres. The method, however, was time-consuming and not infallible, and it has now been superseded by a more reliable method developed in Germany in which the height of the fibres is measured on a scanning electron mention earlier, the heights of the scales are clearly lower for wool.

Blends of mohair with polyester and rayon were shown to improve the worsted system. (O'Connell et al. 1972). When treated with press chemicals and cured, the fabrics and garments made firm, stable and smooth following machine washing and tumble dryin the treated fabric surface was smooth. When squeezed, it was and bouncy with a somewhat crisp feel. While the hand of half-mohair was definitely superior, the hand of fabrics with 24 um kid mohair was very good, and the fabrics made from 30 um considered by some to be slightly wiry and scratchy. During of all the fabrics was excellent and wear-wrinkles were claimed.

(iii) **By Products**

Australia formerly imported large amounts of goat guard hair irradiated in Melbourne with Cobalt 60, then carded and embossed, coated backing cloth to make inexpensive Minster carpets. J Debnath et al. (1987) examined applications, especially in guard hair.
Moffat et al. (1990) described reprocessing of cashmere and claimed resistance to pilling than in virgin cashmere.
9. FUTURE R & D - PERCEIVED NEEDS OF THE AUSTRALIAN GOAT FIBRE INDUSTRY

(i) Fundamental Fibre Properties

This review has highlighted the fragmentary nature of research and knowledge on the fundamental chemical and histological structural properties of wool fibres. It is perhaps not surprising that much of the good work in this area was carried out in Australia by Rivett, Tucker and co-workers at the DWI (Germany Wool Laboratories). These researchers applied their experience in wool research to goat and other fibres, thereby focusing on the obvious next step has not yet been taken - application of this knowledge to relate fundamental fibre properties to processing and end-use performance.

Many examples of the value of this approach to the wool industry have been documented (Leeder 1984 and 1986). For example, studies of the relationship between structure and performance have led to new approaches to comfort, washability, wear and printing. Increased knowledge of internal structure, and in particular the "membrane complex" has directly resulted in new approaches to damage chemical finishing and wear-life.

The fundamental studies mentioned above already suggest that there is potential for differences in surface and internal structure between wool and goat fibres. We recommend that this work should be extended. Thus TFRI should undertake an unfunded study of the surface structure of goat fibres vs. sheep wool, with the aim of understanding the differences between the two. This study will be extended - aimed at (i) improving comfort and softness during processing by control of surface properties, interfibre and interyarn friction, and (ii) preserving and enhancing the long-wear-life characteristics of these fibres during mechanical processing and finishing.

Many anomalies, inconsistencies and gaps in our knowledge of fibres and their properties have become apparent during this review, e.g. correlation of single-fibre, with diameter of each fibre type; measurement of differences...
diameter, length and stiffness in sliver cohesion, etc. Again advantage of prior studies and techniques of wool research (although it is important to attempt to define differences from similarities to wool, to maximise advantageous properties of goat overcome deficiencies.

(ii) **Testing**

There is an urgent need to identify/develop/calibrate fibre diameter techniques for mohair and cashmere. Again we can take advantage of considerable research on development of techniques for measurement of wool, particularly the work of CSIRO, IWTO an

As detailed earlier in this review, goat fibres "suffer" from probable medullation, differing surface structure, wider range of fibre presence of coloured fibres, compared to wool.

Improvements in the cost, reproducibility and predictability/re-testing are also needed - for breeding, marketing and predicting end-use performance. Definition/measurement of fibre length uniformity (distribution) is becoming of increasing importance in processing performance and end usage. The dehairing of cast mohair!) must also be related to yield testing - ideally, the measurement of dehairing in yield testing should be identical to commercial attention should be given to minimising damage such as fibre dehairing process.

(iii) **Process Development**

Almost all published information on processing and processes has emanated from the South African Wool & Textile Research Institute (SAWTRI). It is obvious that undisclosed knowledge is European and U.S. processing mills, but this knowledge is Australian processors, so there is an urgent need for proce
Can the industry afford to slow down (wool) processing machine specialty fibres?

Mohair and cashmere are smoother/more slippery than wool, and problems in early stage processing, particularly drawing and Development work on spin finishes, and methods to control fibre surface modification without detracting from the advantage properties of cashmere and mohair, are needed.

It is important to measure the relationship between drafting for slippage, as this controls (i) regularity, (ii) processing speed, finishes.

(iv) Product Development

"Conventional" uses for cashmere and mohair (e.g. hand-knits) has because these products can be created using "cottage industry Higher quality products are becoming available (e.g. fine hosiery woven worsted) by developing special processing techniques (in: house as closely-guarded secrets; or by blending with other fibres wool).

There is scope for a much wider range of products by extending referred to above (process development). Another very important objectively measure end-use and aesthetic properties of produc goat fibres e.g. wrinkle recovery, abrasion resistance, brightness of dyeing, pilling propensity, comfort and shrink resistance. W indications in this review that cashmere and mohair differ from particular properties, definitive studies have not yet been reported.

Objective measurements on blends of goat fibres with other fibr to define optimum blend ratios for various products. For example of wool and goat fibres be created to give washable knitwear? of wool and mohair exhibit improved wrinkle recovery? What otro to exploit softness and lustre? Can niche markets be co
- and, therefore, can we create a value-addition mohair/cashmere/specialty fibre industry complementary to the established wool industry? (It is outside the scope of this paper to authorise that an Australian specialty fibre industry could be superior to (but obviously much smaller than) the Alpaca processing industry!).

There is at present considerable excess wool processing capacity due to the negative effects of recent Government policy changes on industries. These facilities are adaptable for the processing of mohair. In fact, current work at TFRI on process and product development involves collaboration with the wool processing industry to produce woven products containing cashmere and mohair.

**Deharing** of cashmere in Australia is also essential for value development, and work is in progress on new approaches to fibres.
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Weideman, E., E. Gee, L. Hunter and D.W.F. Turpie


APPENDIX 1: SECONDARY REFERENCES

The following South African papers have been mentioned on reviews. All were published in 1982 or earlier. We have not examined the papers and do not know their authors or their lengths, only the titles. Technical Reports of SAWTRI.

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APPENDIX 2

"Luxury Fibres"
Alexandra Buxton

This article is appended because we consider it to be an essential technical overview of the appeal and potential of "specialty fibres" and therefore complementary to the current review, and provide additional perspective.
SUMMARY

The appeal of luxury fibres is their extreme softness and fineness: all their unalloyed status which derives partly from limited availab

ity. Mohair is the luxury fibre which faces the least luxurious fibres such as wool. Yet mohair production is less wooll. Production of angora rabbit hair is relatively large and on the market for cashmere fibre is characterised by tiny volumes which

of prestige and high prices. Other luxury fibres include cashmere.

The UK industry is a key consumer of luxury fibres which is specialist processing. Personal and family contacts, stretching

famour, remain a vital part of the business.

Knitwear and hand knitting look likely to remain key marke
cashmere, and offer the greatest scope for growth. Spinners, p the lead in using luxury fibres to produce "adventurous" blends: mohair and alpaca with acrylic.

Luxury fibres are insulated from competition from the more wi although research by the International Wool Secretariat (IWS) the yarns of increasing softness and lightness which may pose a

Continued prosperity for luxury fibres in the clothing sector def
fibe and brand conscious consumer willing to pay premium p been traditional because of the product's high price. It is now mainstream fashion changes. Sales, however, still depend on association with "the best".

INTRODUCTION

Cashmere sweaters sell for £100 upwards – roughly 10

what sheep equivalent. A tailor will pay £150 for a pure recent British Wool Textile Show, held at the Dorchester

buyer reported that pure vicuña cloth was changing hand

metre and guarnicion for £500 per metre. There is little d
the demand for such products is there. Why?
Softness, scarcity and status

The appeal of luxury fibres, called "precious fibres" in softness and fineness and their scarcity. Further, appearance, they have unique and practical characteristics, are extremely resilient yet light and fine. It does not crease easily – factors which have long given it East. Cashmere knitwear will last a lifetime.

But above all, what these fibres have is unrivalled status, which gives them a cachet and snob appeal which has not been matched by the man-made fibres industry.

Mohair is the most commercial

The industry considers that mohair is the most "cost-effective" and the one that faces the most competition from local fibres. Its production is based within the sophisticated sector of the industry, with the majority of the product in the luxury fibres category. It is estimated that the total wool production in the luxury fibres category is around 10% of the total wool production, representing less than 2% of total wool production.

Yet even mohair, the most significant of the high-quality fibres, is represented by 5x and growing – in comparison to the high degree of prestige and high prices commanded by the man-made fibres industry.

Cashmere, camel hair and alpaca are rarer

The small specialist industries based on cashmere, camel hair, and alpaca, for their raw materials on domesticated and semi-domesticated animals, in some of the world's most inhospitable and inaccessible rural areas, the collection of rare animal hair for the important part of the local economy and the country.

Table 1: Estimated world production of luxury fibres

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Source</th>
<th>Major producing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca and other llama</td>
<td>South American</td>
<td>Peru</td>
</tr>
<tr>
<td>Angora</td>
<td>Camelidés family</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td>Angorá rabbit</td>
<td>South American</td>
</tr>
<tr>
<td>Camel hair</td>
<td>Camelidés family</td>
<td>China</td>
</tr>
<tr>
<td>Cashgora</td>
<td>Angora goat</td>
<td>Mongolia</td>
</tr>
<tr>
<td></td>
<td>Feral crossbreed</td>
<td>New Zealand</td>
</tr>
<tr>
<td>Cashmere</td>
<td>Cashmere goat</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mongolia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iran</td>
</tr>
<tr>
<td>Mohair</td>
<td>Angora goat</td>
<td>Afghanistan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South Africa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Turkey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peru</td>
</tr>
<tr>
<td>Vicuña</td>
<td>South American</td>
<td>Peru</td>
</tr>
<tr>
<td></td>
<td>Camelidés family</td>
<td></td>
</tr>
<tr>
<td>Yak wool</td>
<td>Yak-Bovine family</td>
<td>Himalayan fagio</td>
</tr>
<tr>
<td>Wool (for comparison)</td>
<td>Sheep</td>
<td>Australia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Zealand</td>
</tr>
</tbody>
</table>

Notes: 1. Bechstein and Dromedary; 2. Fibre currently unavail but estimated to be 1,000 tons; 3. Clean weight
Supplies variable

Prices can fluctuate wildly

Production of luxury fibres has remained independent of the big specialist processors who make up the major export buyers. This is in political factors, the chief sources of luxury fibres being China, Mongolian countries like Peru and Argentina. With the exception of these volumes and sales are well documented, accurate production figures cannot be obtained and when sudden shortages occur, the reasons given are based more on guesswork and conflicting reports than hard fact. Exports of the approximate volumes produced vary widely.

The prices of mohair are partially regulated by the Mohair Board in Britain but for the other fibres, wild fluctuations are experienced. These are natural factors - floods, droughts, extremely severe winters - with escalating prices. Government agencies, too, are free to raise prices, if they have a virtual monopoly of supply.

Table 2: Prices to spinner of luxury fibres

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Average price (£/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca</td>
<td>10</td>
</tr>
<tr>
<td>Angora</td>
<td>30</td>
</tr>
<tr>
<td>Camel hair</td>
<td>13</td>
</tr>
<tr>
<td>Cashgora</td>
<td>30</td>
</tr>
<tr>
<td>Cashmere</td>
<td>60</td>
</tr>
<tr>
<td>Mohair</td>
<td>10</td>
</tr>
<tr>
<td>Yak wool</td>
<td>13</td>
</tr>
<tr>
<td>Lambswool (for comparison)</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Trade sources

The UK is a key consumer

The UK has long been a key consumer of luxury fibres which demand and specialist processing. This part of the industry has its roots in the British textile industry of the late 19th and early 20th centuries when Titus Salt discovered the potential of alpaca and Joseph Davis mechanised de-hairing process for cashmere and camel hair. Today, it is still a sector where personal and family contacts, stretching to highland farmers, remain a vital part of the business.

Table 3: Sample prices of UK fabrics made from luxury fibres

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Price range (£/metre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vicuña</td>
<td>200*</td>
</tr>
<tr>
<td>Cashmere</td>
<td>50-70</td>
</tr>
<tr>
<td>Camel hair</td>
<td>40-50</td>
</tr>
<tr>
<td>Mohair/wool</td>
<td>70</td>
</tr>
<tr>
<td>Alpaca/wool</td>
<td>100</td>
</tr>
<tr>
<td>Lambswool</td>
<td>120</td>
</tr>
</tbody>
</table>

Notes: * for woollen-spun, women's wear coatings, etc.; + if available; text: ± £200 upwards
Source: Trade estimates

By virtue of their unique softness and their cachet, luxury fibres can be competitive with the more widely available natural fibres. International Wool Secretariat (IWS), however, is promoting it...
merino wool knitwear yarns of increasing softness and lightness may forecast a threat to cashmere and angora if the prices of their upward trend.

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Fibre diameter [microns]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca and other llama</td>
<td>22-34</td>
</tr>
<tr>
<td>Angora</td>
<td>11-12</td>
</tr>
<tr>
<td>Angora*</td>
<td>14-15</td>
</tr>
<tr>
<td>Camel hair</td>
<td>19-26</td>
</tr>
<tr>
<td>Cashgora</td>
<td>20-22</td>
</tr>
<tr>
<td>Cashmere</td>
<td>15-20</td>
</tr>
<tr>
<td>Mohair</td>
<td>24-40</td>
</tr>
<tr>
<td>Viscose</td>
<td>10-30</td>
</tr>
<tr>
<td>Yak wool</td>
<td>18-20</td>
</tr>
<tr>
<td>Finest sheep's wool</td>
<td>17-19</td>
</tr>
</tbody>
</table>

Notes: * 1 micron = 1 millionth of a metre;  † Chinese; ‡ South American. Source: trade sources.

**STYLE TRENDS**

**Strong upturn is forecast**

The autumn/winter 1987/88 yarn and fabric collections feature a light, soft handle. At the influential Italian yarn fair of lambswool with luxury fibres such as mohair, cashmere is the strong trend for the top end of the market. This is true of where a luxury look is providing a complete foil to the fashion washed and crumpled casualwear fabrics which predominated.

According to the London based fashion prediction company this reflects the overall return to femininity in the women'swear -"soft, subtle colours into focus, used for a silhouette which body". The emphasis at both Pitti Filati and the Leicester subdues, glowing appearance in fine mohair and alpaca spinners were even using "exotic" fibres such as reindeer to get a modern look.

Frank Monkman, a world specialist in exotic animal fibres, reports an upturn of interest in deer, sable, mink fibres, such as sable, have diameters as fine as 9.5 microns.

**ALPACA**

Alpaca fibre is valued for its natural sheen, its remarkable handle, also its colours. In the 19th century the term alpaca became attached to cloth in general, following Titus Salt's development of his "Salt's Alpaca" using a native llama and an alpaca suiting.
Alpaca fibre comes from the alpaca, a domesticated wild American camel family, farmed chiefly in Peru where a large rural population relies on alpaca for a livelihood. The term alpaca fibre describes fibres from other South American camelids including hybrids like the huacu. It was recently suggested that around 1 million alpacas are reared in Peru. Alpaca production is more professional. The Peruvian government is starting a collection in the more remote areas but otherwise all but merchants, the largest being Michell in Atequipa. Trade est of alpaca at around $4,000 tons.

An International Alpaca Association (IAA), based in Atequi 1983 to promote alpaca and protect its name. Members, who are entitled to use the IAA's certification trademark - a stylised variety denoting pure alpaca, a blend containing a mini alpaca, and one containing a minimum of 25% alpaca alpaca.

Alpaca is often used in blends with wool to contribute softness to some instances to add cachet to a label. The Biella mills in Italy also market for Peru, as is the UK. Alpaca is also beginning to gain in knitwear with spinners showing alpaca/wool blends for autumn.

All alpaca is processed into sliver or tops in Peru and the UK is gradually expanding its own exports of yarn, cloth and finished products. The biggest weaver in Peru, expects to export 1 million square metres of alpaca/wool cloth by the end of 1986.

ANGORA

The term angora, applied to a fibre, refers to the hair of the Angora goat which is mohair. This causes within the industry itself. With a diameter of 11-15 microns than cashmere. Its image, however, is more "commercial": describe angora as "downmarket".

Estimates suggest a total world production of 7,000 tons from China. Smaller volumes come from South America, Chile, and Western Europe. Characteristics vary according to fine quality. Chinese Angora gives knitwear the typical Angora look - a fine wool. This is due to the kempy fibre, a coarse component which does not take up the same proportion of dye as the other fine wools. South American Angora is softer but less kempy. A recent study in Medina, a West German underwear manufacturer, specifi

Recently, fibre prices have fluctuated dramatically. A peak coincided with a shortage of Chinese qualities. This led to $40 per kilo, with Monkman quoting French angora for £

Official figures for UK production of garments made from cashmere with "other fine animal hair" - there are no categories. The combined total shows a drop in the production of woollen and other fine animal hair. Most of this is by Angora, reflecting the fibre's unprecedented high price.
Table 5: UK production of women's fully fashioned knitwear

<table>
<thead>
<tr>
<th></th>
<th>Cashmere and other fine animal hair</th>
<th>Wool</th>
<th>Synthetic fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(000 dozen)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>80</td>
<td>867</td>
<td>618</td>
</tr>
<tr>
<td>(E mn)</td>
<td>21</td>
<td>61</td>
<td>25</td>
</tr>
<tr>
<td>1981</td>
<td>63</td>
<td>1,030</td>
<td>680</td>
</tr>
<tr>
<td>(E mn)</td>
<td>21</td>
<td>77</td>
<td>22</td>
</tr>
<tr>
<td>1982</td>
<td>52</td>
<td>832</td>
<td>427</td>
</tr>
<tr>
<td>(E mn)</td>
<td>18</td>
<td>73</td>
<td>25</td>
</tr>
<tr>
<td>1983</td>
<td>53</td>
<td>878</td>
<td>411</td>
</tr>
<tr>
<td>(E mn)</td>
<td>19</td>
<td>72</td>
<td>21</td>
</tr>
<tr>
<td>1984</td>
<td>62</td>
<td>819</td>
<td>331</td>
</tr>
<tr>
<td>(E mn)</td>
<td>25</td>
<td>72</td>
<td>18</td>
</tr>
<tr>
<td>1985</td>
<td>71</td>
<td>785</td>
<td>392</td>
</tr>
<tr>
<td>(E mn)</td>
<td>33</td>
<td>79</td>
<td>26</td>
</tr>
<tr>
<td>1986 1st quarter</td>
<td>9</td>
<td>132</td>
<td>66</td>
</tr>
<tr>
<td>(E mn)</td>
<td>5</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: *jumpers, pullovers, cardigans, twin sets and similar items*

Source: Business Monitor

Table 6: UK production of men's fully fashioned knitwear

<table>
<thead>
<tr>
<th></th>
<th>Cashmere and other fine animal hair</th>
<th>Wool</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(000 dozen)</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>91</td>
<td>967</td>
</tr>
<tr>
<td>(E mn)</td>
<td>21</td>
<td>79</td>
</tr>
<tr>
<td>1981</td>
<td>61</td>
<td>1,137</td>
</tr>
<tr>
<td>(E mn)</td>
<td>21</td>
<td>94</td>
</tr>
<tr>
<td>1982</td>
<td>58</td>
<td>1,090</td>
</tr>
<tr>
<td>(E mn)</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>1983</td>
<td>59</td>
<td>1,191</td>
</tr>
<tr>
<td>(E mn)</td>
<td>24</td>
<td>113</td>
</tr>
<tr>
<td>1984</td>
<td>64</td>
<td>1,274</td>
</tr>
<tr>
<td>(E mn)</td>
<td>25</td>
<td>128</td>
</tr>
<tr>
<td>1985</td>
<td>89</td>
<td>1,301</td>
</tr>
<tr>
<td>(E mn)</td>
<td>42</td>
<td>139</td>
</tr>
<tr>
<td>1986 1st quarter</td>
<td>41</td>
<td>226</td>
</tr>
<tr>
<td>(E mn)</td>
<td>8</td>
<td>28</td>
</tr>
</tbody>
</table>
The reasons given for the Chinese shortage differ considerably - rumours of widespread flooding decimating the rabbit population, animals being eaten in large numbers. A more official and deliberate policy of slaughter because of poor quality, the fibre becoming increasingly shorter and more liable to "dropping" (fat yarns).

Revival in knitwear forecast

Since 1984 the Chinese are reported to have been concentrating on improving supplies and improving the predominant strain. Prices have now dropped to a sensible level of £25-£35 but demand has not yet recovered. Angora/lambswool knitwear is predicted for autumn/winter 1987. Stores in the UK reported to be buying again. Prices for 20 per cent blend could be expected to retail at under £20 and 70 per cent blends for higher quality angora knitwear priced up to £80. Nevertheless, suppliers, some of which have halved their prices, say that they have been slow to respond to the renewed competitiveness of angora.

Italy is the main user

The biggest users of angora are spinners and knitters in the Veneto regions of Italy. All, however, remain cautious. A major in Belgium, J & J Petit, collapsed in September 1986 owing $8 mn basing forward selling prices on favourable Chinese contracts. Italian and UK spinners are already picking up the business.

CAMEL HAIR

Camel hair for use as a textile fibre is obtained from the underco As with cashmere, China and Mongolia are the chief sources. Bob, be as fine as 18 microns and fetches around £15 per kilo.

Declining volumes

The volume of camel hair produced is thought to be low, under diminishing as the camel gradually becomes less important as a beast. There are reports of camels being treated on a commercial scale for meat but these reports are doubted. The demand for camel has waned. In 1985, for example, Joseph Dawson processed only a volume which had processed five years earlier.

A number of reasons are given for the decline in popularity. A market, which was the chief use of camel hair, has declined. Can have become associated with a stuffy and even effeminate image. Furthermore, camel hair has become downgraded by the volume of wool or wool blend coatings on the market. Pure camel hair coverts fetches prices between £40 and £50 per metre - appreciably higher coating of a similar weight and quality selling for £20 to £30.

CASHMERE

One of the most luxurious fibres

Of all the animal fibres, with the possible exception of vicuña, it strongest associations with luxury, especially in the knitwear in average. A classic pure cashmere sweater sells for four times the quality lambswool. Cashmere also has the advantage of an exotic story, ideally suited to marketing a fibre which currently fetch
kilo for the best qualities. It starts life as the downy inner
coats herded by farmers and nomadic peoples in the North-
Mongolia, Afghanistan and Iran, where it forms extra prot
winter weather. In spring the coats moult, a natural proc-
exploited by hand combing. The combed hair is colle-
transported on the backs of porters, horses or yaks to cent-
China the grading, sales and pricing of cashmere is organise-
Animal Produce and By-Product Import and Export Corp
and Iran sales are handled by merchants.

The desirability of cashmere rests on its extreme softness
qualities have diameters of 15 and 15.5 microns. Cashmire
origin, strong hair content, micron, staple length and
Chinese/Mongolian superfine. Strong hair content def-
coarse guard hair in the fibre or top.

Availability
subject to
climatic
influences

China and Mongolia, known for the best qualities, repre-
cashmere, supplying roughly 80 per cent of world pro-
remainder comes from Iran and Afghanistan which are 1
qualities generally used in woven fabrics. Trade sources pu
supply at between 4,000 and 5,000 tons before processing,
be severely affected by natural factors such as sewer
which cause animals to die of cold and starvation.

Raw cashmere contains significant proportions of strong
hair from the goat’s outer coat, which must be separated
inner fibres by a specialist de-hairing process. This reduces
50 per cent in the case of Chinese cashmere and by up to 7
from Afghanistan and Iran.

Italy and UK
are the largest
users

Western Europe is the biggest market for cashmere, with
as the largest users, followed by the USA and Japan. Of
the group dominates. Dawson International, the Scottish-based
third of the world’s total cashmere production, represent
involvement with cashmere goes back to the turn of the
Dawson, now part of Dawson International, was the first
mechanised de-hairing system. This was kept a closely guar-
1901 and 1939 its plant in Bradford was the only one in the
fewer than 20 de-hairing plants worldwide.

Prices subject to
exchange rate
variations

The high prices commanded by cashmere reflect scarcity of
wastage from de-hairing. The prices are also largely in th
government which two years ago switched from selling fl
dollars, a result of which is that fluctuations in exchange rat
Prices of cashmere tops and de-hair ed fibre have fallen th
years as Table 7 shows.

<table>
<thead>
<tr>
<th></th>
<th>October 1978</th>
<th>October 1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese white</td>
<td>23.10</td>
<td>4.10</td>
</tr>
<tr>
<td>Iranian white</td>
<td>13.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Source: Joseph Dawson
Dramatic price fluctuations

An uncertain market, in terms of availability, has meant drastic fluctuations. One recent example occurred in the Afghani cashmere between December 1983 and October 1984. At the end of 1983 the price of brown cashmere was depressed, due to low demand, and merchants discounted prices. In the subsequent months prices more than doubled as Tabl Weavers who had put out ranges based on 1983 prices were hard-pressed to find top-quality suppliers. Some firms, however, did not survive the sharp increase.

Table 8: Sample prices of Afghan brown cashmere, December 1983-1984

| Month    | Price
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>£10.55</td>
</tr>
<tr>
<td>May</td>
<td>£21.50</td>
</tr>
<tr>
<td>July</td>
<td>£39.15</td>
</tr>
<tr>
<td>October</td>
<td>£43.95</td>
</tr>
</tbody>
</table>

Source: Joseph Dawson

Goat breeding in developed countries

Dawson International played no active role in cashmere production until that time Dawson was facing increasing competition from cashmere producers in Japan, Italy and the USA. Increasingly aware of the company’s debt to China and the inevitable growth of China’s own cashmere output, chairman Sir Alan Smith initiated a cashmere goat-breeding project. This has since been taken up in New Zealand and, even more lately, itself with a programme run by the Hill Farming Research Organisation.

Cashmere production in Australia and New Zealand is at an early stage and growing, is expected to remain small. Antipodean cashmere fibre is long and soft, as are goat fibres, but Chinese cashmere fibre, which is being developed in the UK, has the softness characteristic of cashmere. This is used for the manufacture of cashgora, a fabric made from cashmere and goat fibres.

Cashgora – from crossbreeding

One spin-off from the experimental cross-breeding taking place is cashgora, a fabric made from cashmere and goat fibres. This is the product of a cross between goats and Australian feral goats which have cashmere-like fibres. The softness characteristic of cashmere coupled with the lustre characteristic of wool.

In volume terms, cashgora, despite the “hype” that has surrounded it, is indeed a small quantity expected in 1986. Animal Fibres of Bradford sales which are currently confined to Weil der Stadt, a West German covering manufacturer, and Filatura di Cista, an Italian handknit future for cashgora depends on how the market reacts to a fibre spinner at £30 per kilo (mid-way between cashmere and mohair) for each animal for the farmer.

Chinese cashmere production more organised

In China, production of cashmere is reported to be becoming more systematic as the shift towards a more market-oriented economy is providing greater incentives for producers. Recent concern for declining supplies of one particular cashmere variety led the government to raise the selling price by 5 per cent to encourage supply.

Most directed at knitwear

Joseph Dawson’s cashmere sales divide by volume into 70 per cent catering for the knitwear industry, and 30 per cent to those selling in sectors, with the former gradually gaining ground. About 85 per cent of sales are aimed at the home market and the remaining 15 per cent is exported, for the larger proportion is exported indirectly by manufacturers for

...
Overall, Scottish knitters produce between 75 and 80 per cent of cashmere knitwear with Dawson group companies accounting for that share. These knitters, mostly based in Hawick, Cashmere Association (SCA) to defend the name of cashmere as its own trademark, carried as a twist ticket guaranteeing the cashmere spun and knitted in Scotland. The SCA also non-cashmere producers from adopting similar names. A producer Asahi, for instance, has capitalised on the favourable cashmere name by using the brand name Cashmilon for its $...

While some knitwear manufacturers such as Pringle have business many rely on sales in London, with its seasonal boutiques, leading stores such as Harrods, Simpsons and Selfridges, and such as N Peal. Other important centres are Edinburgh and the Highlands. Manufacturers catering for this business have a significant decline in the numbers of visitors to the UK and spending power of US tourists in particular. This has led to a cut in the shops as retailers attempt to shift their stock by cashmere processors who see it as detrimental to the far of cashmere in the public eye.

Overall, manufacturers are experiencing a levelling off in the in knitwear with West Germany, Japan, Italy and France export markets. One Dawson company, Barrie, reports a market in France where the "preppy" or college look is far back to classic styles. The high price of cashmere knitwear at around $100 - $140 - means classic styles represent a large part of the industry's output. Manufacturers have, however, found it increasingly import colour changes and trends in body shapes.

The indigenous Chinese cashmere knitwear industry is no threat at present. Quality and colour are not considered to standards for a highly discerning market, although some Chinese are known to be looking for West European partner presence in Western markets. So far Chinese exports have in USA, hitting the market for knitwear selling at under $100...

Guanaco

Guanaco is the soft hair of the semi-domesticated alpaca, another native of the South American camel family living in the Andes. This fibre, available in small and intermittent quan than vicuna although almost as fine and commands high pri...
Mohair is the name given to the hair of the Angora goat, a breed from Turkey. It is notable for its qualities of lustre, softness and shine. White is the most valued and predominant colour. The angora is thought to number 6.25 million and world Mohair production is about 21,000 tons expected in 1986.

South African supply predominates

South Africa and Texas are leading producers, accounting for 40 and 30 percent of world volume respectively. South African wool between 1970 and 1985, overtook Texan volumes in 15 years. Mexico is the largest source, producing 17 percent, followed by Argentina. This is the largest customer for southern Africa and the USA, but second and third largest.

Mohair from Australia and New Zealand began to creep onto the scene two years ago. Users’ view this development positively, that the medullated fibre (kemp) content is causing problems with production.

The South African Mohair industry dominates. Cape Mohair reputation and prices fetched at the Mohair sales held at Cape Town the level worldwide. Cape Mohair is also a major market for greasy Mohair exports from the USA. In 1984 exports went to South Africa.

Cape Mohair production is largely regulated by the South African Mohair Board, which organises the collection, grading, sales and marketing of Mohair in South Africa. Lesotho Mohair is also sold by the Mohair Board to handle its marketing on an independent basis.

Organisation to promote Mohair

The 1974 saw the formation of the International Mohair Association, based in London. The IMA promotes Mohair and defends its interests. The IMA’s certification trade mark based on an Angora goat’s variations: gold, silver, and black and white, denoting different grades of Mohair.

The IMA’s activities are funded by its 165 or so member producers and product groups. Its limited budget means that activities are carefully targeted; for example, nearly all its budget is spent in Japan where the largest market lies.

The hand knitting sector is by far the biggest consumer of Mohair. In hand knitting, Mohair is associated with quality and design. A distinctive fashion focus and has been subject to swings to top makers. Demand for Mohair from handknit yarns has been depressed. The hand knitting sector has been experiencing a quiet year after several booms in recent years. Mohair has shifted towards cotton and cotton-linen blends.

**Table 9: World Mohair consumption by end-use**

<table>
<thead>
<tr>
<th>End-use</th>
<th>Mohair consumption (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand knitting</td>
<td>600</td>
</tr>
<tr>
<td>Other fabrics</td>
<td>100</td>
</tr>
</tbody>
</table>
**Increased competitiveness**

Falling demand over the past twelve months, coupled with higher prices of as much as 36 per cent in local currency, has resulted in the percentage of the offering sold at the Port Elizabeth sales. Another factor is a high incidence of seed contamination in the hair - the result (Table 10).

<table>
<thead>
<tr>
<th>Table 10: South African mohair prices*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(SA cents per kilo, greasy fleece)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>1985</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>June</td>
</tr>
<tr>
<td>Average adult</td>
</tr>
<tr>
<td>Good average adult</td>
</tr>
<tr>
<td>Fine adult</td>
</tr>
<tr>
<td>Average young goat</td>
</tr>
<tr>
<td>Good average young goat</td>
</tr>
<tr>
<td>Fine young goat</td>
</tr>
<tr>
<td>Average kid</td>
</tr>
<tr>
<td>Good average kid</td>
</tr>
<tr>
<td>Fine</td>
</tr>
</tbody>
</table>

*at sales in Port Elizabeth

**Note:**

**Source:** International Mohair Association

Nevertheless, the demand for kid and ewe hair (the finest quality) well, with prices just turning the corner, according to top makers. International. Kid mohair tops are selling for around £16 per lb. The general trend is softer, finer qualities whether in woven handknit yarns. Spinners are also taking advantage of competitiveness by using higher proportions of mohair in blends with acrylic. Leading UK spinners include British Mohair Spinners, Sirdar, William Hutchinson and Robins Wool.

**Men's Suiting - UK and Italy**

The menswear mohair suitng sector is small and specialist with worldwide concentrating on this market. The best known are John Foster of Bradford is the world's largest vertical produce suitngs. William Halstead is another British specialist. In Italy, Ermenegildo Zegna and Cerruti are among the most prestig.

**Japan is the main export market**

For both groups, Japan is the key market where mohair is established niche. Mohair is considered ideal for a hot, humid coolness and crispness. In the formal Japanese business scene, suits are tantamount to office uniform for those who can afford.

UK weavers are now experiencing a situation in which the highest prices for superior qualities. Top quality cloth will sell for £40 per yard a year ago £18 was the ceiling. Japanese clothes are the main purchases of mohair cloth which used to be confined to merh...
Decline in women's wear

In the women's wear sector, mohair coatings have declined along with the downward trend for conventional winter coats. This seems to be borne out by the figures showing a decrease in the volume of mohair consumed by woolen spinners from the Confederation of British Wool Textiles (CBWT). The December 1982 figure of 162,000 kg was down to 142,000 kg in December 1983. Some weavers are hoping for a revival for woolen spun coating fabrics, but it is doubtful whether this trend will be reversed.

In contrast, the CBWT figures showing mohair consumption in top hand knit yarns and men's suitings have increased over the same period. In 1981, 216,000 kg was consumed; by December 1985, consumption had increased to 249,000 kg. Accessories, rugs and blankets, which are produced in the UK tourist centres as part of a classic English look, have suffered a fall in sales as other merchandise aimed at this market. Mohair, manufactured by weavers in the Netherlands and West Germany and exported to the UK, is of a resilient quality, well suited to the top end of the furnishing sector and the contract market.

Threat from trade sanctions

Trade sanctions against South Africa would clearly pose a threat to the mohair industry as a whole. Not surprisingly, users and the INSA itself play down any political overtones which might be read into their dependence on South African supplies.

VICUNA

The rarest and most luxurious of all fibres, vicuna is a creature that produces it. Its attraction relies on its extreme fineness and its beautiful reddish-brown colouration, as well as its scarcity.

The vicuna, a shy, wild member of the South American camel family, was hunted almost to extinction a few years ago when the World Wildlife Fund stepped in to impose a complete ban. The Peruvian government stepped in to impose a complete ban. The measures worked and the vicuna population is recovering and was said to have increased to 10 million in 1979. The fibre is still unavailable, although previous users hope that it will soon be available. In the meantime, small amounts of vicuna fibre are available, and help to justify prices.

When, and if, this happens, prices will reflect vicuna's extreme scarcity. One UK mill, a past consumer, suggested a selling price of £15,000 per ton to London merchants who would pass it on to tailors at a profit. Meanwhile, small amounts of vicuna fibre are available. The fibre is still unavailable, although previous users hope that it will soon be available. In the meantime, small amounts of vicuna fibre are available, and help to justify prices.

YAK

The coarse outer hair of the yak, still an important part of the Lao Asian highlands, is generally termed yak hair and its finer, softer inner wool. No estimate is available of the production of either, but processors suggest that more yak wool is produced than is real.
Although yak is used in tiny percentages as a “novelty” fibre, to have negative associations and to lack the glamour and status, some top makers use other descriptions such as Mongol Satin.

**OUTLOOK**

**Re-emergence in fashion markets**

Knitwear and hand knitting look likely to remain key markets and cashmere, the three most significant luxury animal fibres, continue to enjoy scope for growth. Spinners, particularly in Italy, are taking the fibres to produce “adventurous” blends, thereby widening the range of fibre stereotypes. For example, silk is being blended with alpaca and acrylic.

The mohair industry is dependent on the hand knitting sector and, in the last six years, has re-emerged as a young fashionable area. This highly imaginative approach of designers, retailers and producers is now being extended to woven goods, where creative hand knitting books on the subject have recently been published. The mohair industry is dependent on the hand knitting sector and, in the last six years, has re-emerged as a young fashionable area. This highly imaginative approach of designers, retailers and producers is now being extended to woven goods, where creative hand knitting books on the subject have recently been published. The increasing uncertainty of the tourist trade may well erode the growth of cashmere knitwear and accessories to look increasingly at tourist centres by expanding their direct exports and direct mail outlets, for example in cruise lines.

**Woven accessories offer an introduction**

In woven goods, while cashmere prices are prohibitive for cashmere, accessories such as shawls and scarves provide an opportunity to reach a wider public, thereby introducing the fibre and its possibilities. They may not be able to afford complete garments, but they can afford the emphasis on colour coordination and the increasing involvement of the UK’s Marks and Spencer in the accessories market, which look good.

**Market reliant on status seeking consumers**

Continued prosperity in the clothing sector relies on a high street that is not becoming more affluent and more sophisticated. The emphasis is on status and association with “the best.” Japan, for example, report an upturn for a classic English cashmere cloth following the visit of the Prince of Wales to the country.

**No significant growth in supply forecast**

Significant growth in the volume of luxury fibres is improbable. In fact, the gradual urbanisation of rural areas is likely to lead to a decrease in fibre like cashmere, camel hair and alpaca production, whether for mohair or cashmere. In New Zealand and Australia, there are pressures on farmers to venture into alternative crops, but the high market continues to tempt and offer genuine possibilities.