

## Natural Fibre Blends of Cotton and Wool

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### Introduction

Blending of two or more different fibre types is of crucial significance to the textile industry. Shore [1] reports that several interrelated factors may contribute to the decision to replace a homogeneous textile material by a blend:

- Economy: The dilution of an expensive fibre by blending with a cheaper one.
- Durability: The incorporation of a more durable component to extend the useful life of a less durable fibre.
- Physical properties: A compromise to take advantage of desirable performance characteristics contributed by both fibre components.
- Colour: The ability to develop novel designs incorporating multi-colour effects.
- Appearance: The attainment of attractive appearance and tactile qualities using combinations of yarns with, for example, different lustre.

The blend of cotton with polyester represents one of the most important textile substrates, being widely used as a fabric for shirting. The *synthetic* fibre enhances the crease resistance, dimensional stability and easy-care properties of the blend, and the cotton component contributes comfort, especially important for products worn next to the skin.

In spite of the rapid growth in the use of synthetic fibres, *natural* fibre blends of, especially, cotton and wool have been of some importance over many years. Inclusion of wool in cotton products enhances properties such as appearance retention, bulk and comfort. Rocklea Spinning Mills has recently launched Colana<sup>®</sup> yarns, manufactured from 70% cotton and 30% wool. CSIRO Textile and Fibre Technology has provided scientific and technical support to Rocklea for this project, with funding provided by CSIRO, The Woolmark Company, and more recently, the Australian Cotton Cooperative Research Centre (Cotton CRC). This paper focuses attention on blends of cotton and wool, drawing on past and present experiences in the Colana<sup>®</sup> initiative.

### The Appeal of Cotton/Wool Blends

Natural fibres are characterised by their softness. Synthetic fibres, such as conventional polyester, can lead to products with a relatively harsh handle, and their incorporation into

blends with natural fibres leads to a trade off between handle and performance. In recent years, synthetic fibre manufacturers have made considerable progress in the development of their products, and so-called *microfibres* are becoming increasingly popular. These fibres are characterised by diameters considerably less than those of conventional fibres, generally resulting in softer and more lustrous products.

Natural fibres have one very clear advantage over synthetic fibres (such as polyester and nylon): their ability to absorb and desorb moisture vapour from the surrounding air as the conditions change. This property is often described as 'breathability'. The capacity for fibres to store up water vapour is indicated by the amount of swelling between dryness and saturation (Table 1); the higher the swelling, the greater the capacity.

**Table 1** Swelling of fibres in water [2]

Fibre	Swelling (%)
Cotton	44-49
Wool	32-38
Silk	30-41
Viscose	45-82
Nylon	2
Polyester	virtually nil
Acrylic	very slight

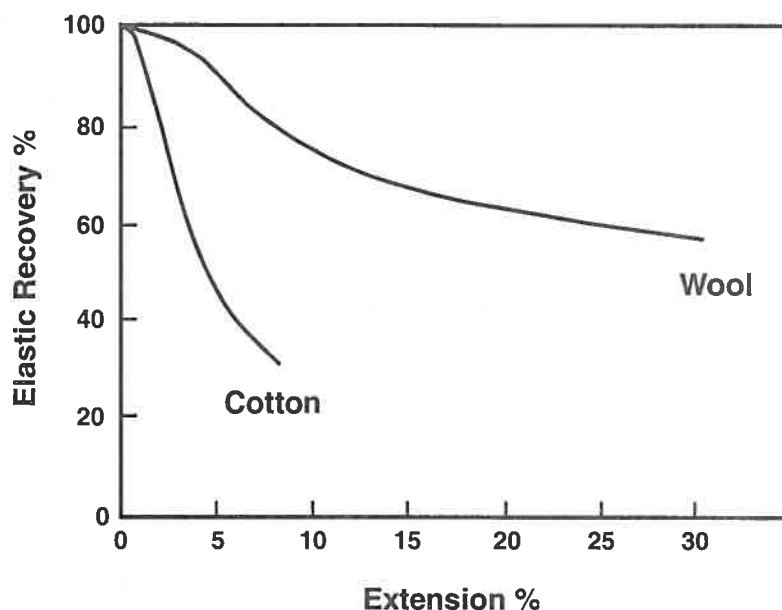
There are two important features associated with this moisture vapour absorption and desorption:

- The discomforting effects of rapid changes in humidity near the skin (of the garment wearer) are slowed down or 'buffered'.
- Large amounts of vapour can be stored inside the fibre without making the fabric feel wet.

Both of these aspects are important for the comfort of the wearer. Because synthetic fibres are unable to manage moisture as successfully as natural fibres, garments made solely from synthetic fibres can feel clammy, especially when worn in hot and humid conditions. On the other hand, garments made from natural fibres - having the ability to 'breathe' - feel more comfortable.

In comparison with the pure cotton article, cotton/wool knitted products generally have superior *appearance*. The wool fibre in the cotton/wool blend enhances the ability of the garment to retain its shape, especially after it has been worn and laundered a number of times. This can be explained in Figure 1, which shows that for a given extension, the elastic recovery properties of wool are superior to those of cotton. The *wrinkle recovery* of

cotton/wool woven products is improved through the presence of wool. The *bulk* of cotton/wool knitted products are generally greater than that of the corresponding cotton articles. Bulk contributes to the feeling of warmth - both to the touch as well as to the resistance to heat loss - and enhances the perception of a softer handle.



**Figure 1** Elastic recovery properties of cotton and wool [3]

## Market Potential for Cotton/Wool Blends

Competition in the global textile market is fierce. Profits margins in commodity markets are being eroded. Manufacturers are looking more to establish niche markets where differentiated products can capture consumer attention, and return a greater profit. Cotton/wool products fall into this niche category, but there is a major economic hurdle: cost. The presence of wool in a cotton blend will increase prices beyond those for pure cotton products. A typical cost for combed Australian cotton (sliver) is \$3.50/kg, whereas the cost of wool top appropriate for a blend yarn is \$10-15/kg [4]. The price of a cotton/wool yarn may be up to 2-3 times greater than the price of a cotton yarn. In order absorb this increased cost, products made from cotton/wool blends must have attributes that are:

- superior to those of pure cotton and other similar articles;
- recognised by the consumer as being superior; and
- worth paying for.

In what has been described as “a significant coup for the future of wool-cotton blends” [5], Rocklea Spinning Mills has won a \$500,000 contract to supply Colana<sup>®</sup> yarn into the

American market. Colana<sup>®</sup> is also being:

- tested by the Australian army in socks designed for tropical conditions;
- woven by Bruck Textiles for the Polo Ralph Lauren group to sell in European and US markets; and
- made up in Malaysia for China's Lion brand polo shirts.

Colana<sup>®</sup> will be used in the uniforms for the female athletes at the Sydney Olympics (an initiative sponsored by The Woolmark Company), and a number of major Italian processors have expressed a keen interest in the product.

With only a small percentage of Australia's wool and cotton processed in Australia before export, cotton/wool blends can lead to opportunities for Australian manufacturers to increase the level of value that is added in Australia to the locally grown fibres. New markets for Australian cotton and wool will also increase the demand - and price - for the fibres, returning greater profits to both the cotton and wool producers.

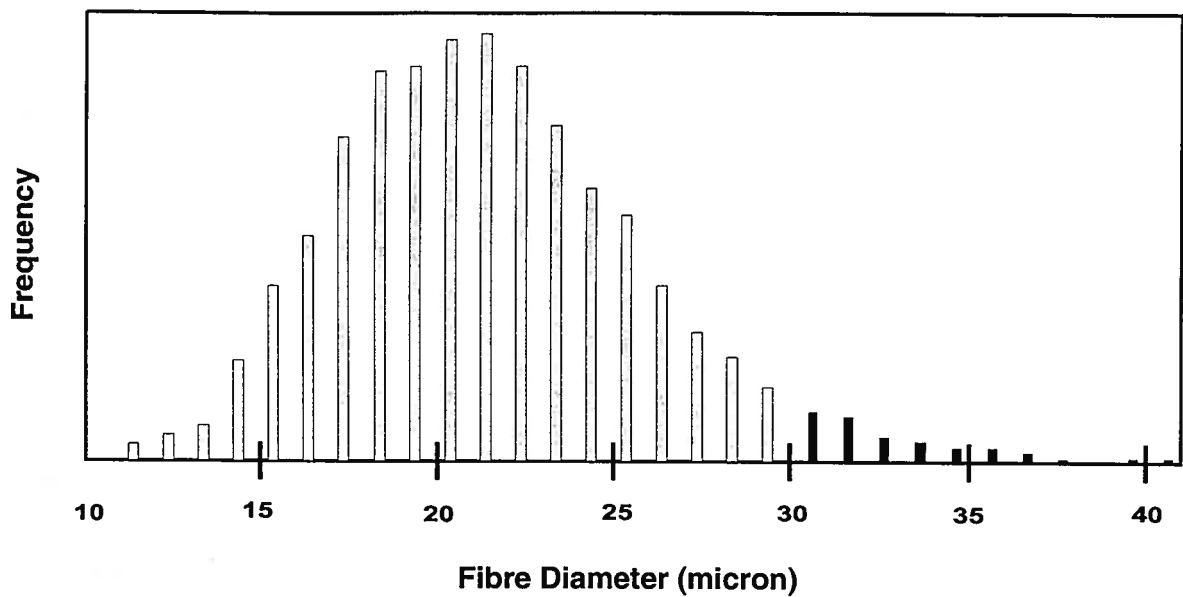
## Technical Issues for Cotton/Wool Blends

Cotton and wool fibres are physically and chemically different, posing some real challenges for the processing of cotton/wool blends. Technical issues exist not only for the yarn manufacturer, but also for downstream processing, especially in relation to bleaching and dyeing.

### Fibre selection

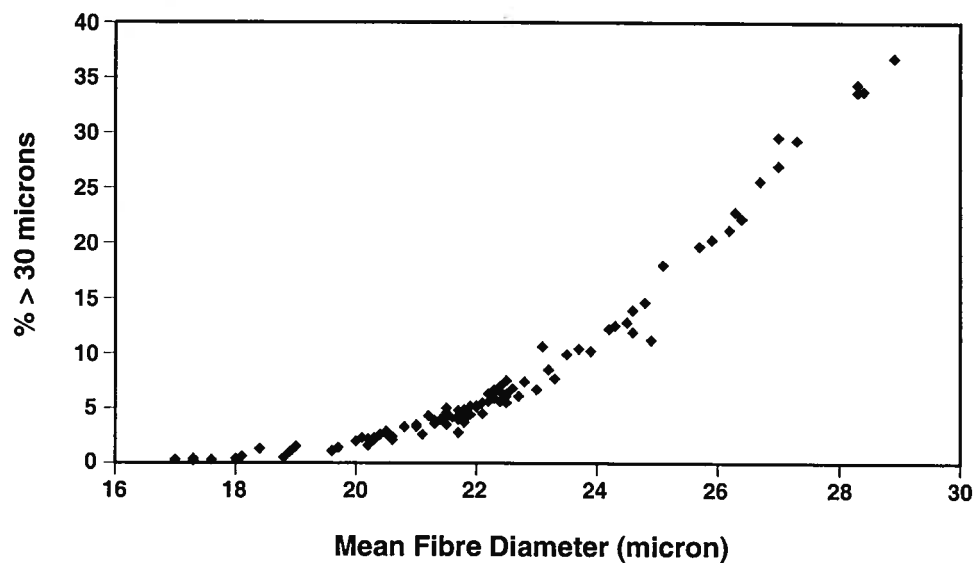
Fibre quality has a major impact on yarn and product quality. The high quality of Australian *cotton* is recognised globally, although local spinners are continually seeking further enhancements to yarn quality through reductions in short fibre and neps. The concept of quality in relation to *wool* has been recently summed up by Clark [6]: "The main accepted objective measurement for quality is micron, or the fineness of each fibre ..... fine wool is more comfortable and glamorous." The mean fibre diameter of wool varies significantly, being influenced by factors such as the breed of sheep and geographical location. Cotton fibres are somewhat finer than wool fibres.

As for cotton, many cotton/wool products are worn next to the skin. It is important that fine wool fibres are selected to maximise comfort. Naylor [7] has found that the percentage of wool fibres with diameters greater than 30 microns is an indicator of skin comfort: the lower the percentage, the greater the comfort. Figure 2 shows the distribution of fibre diameters for a wool lot that has a mean fibre diameter of 20.8 microns; fibres with diameters greater than 30 microns are indicated.



**Figure 2** Distribution of fibre diameter for a 20.8 micron wool [7]

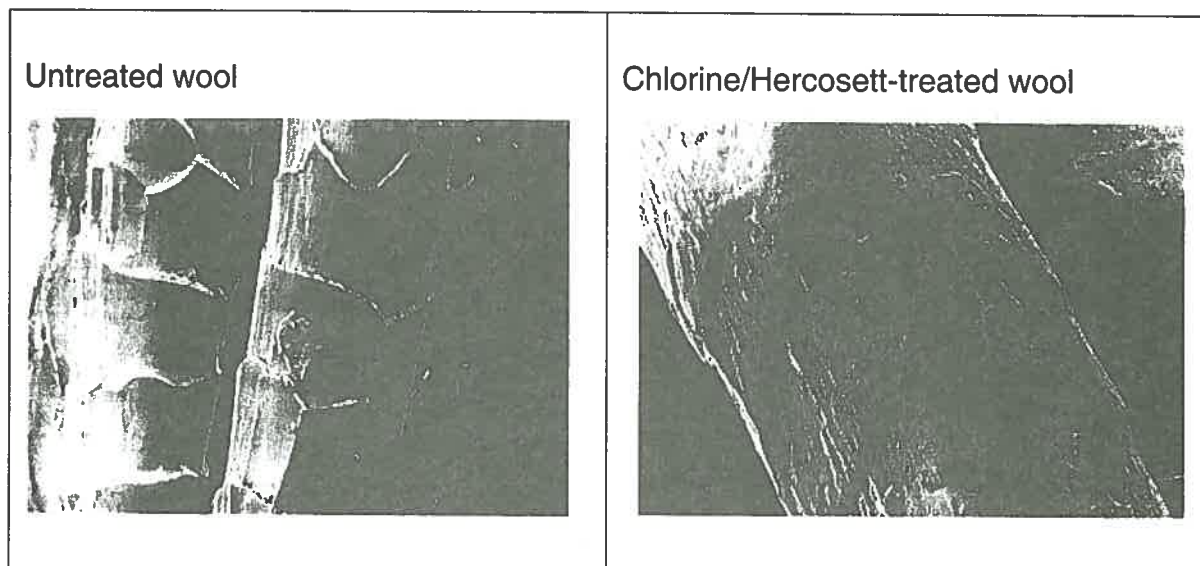
Figure 3 shows the percentage of coarse fibres (greater than 30 microns in diameter) as a function of mean fibre diameter for commercial wool tops. Below a mean fibre diameter of about 19 microns, the frequency of occurrence of coarse fibres is insufficient to cause discomfort. The choice of wool fibre will also be influenced by cost, with finer fibres considerably more expensive than coarser fibres [6]. In mid 1999, 19 micron wool was selling for about 850 cents/kg. Twelve months later, sales have seen the price at 1430 cents and higher. In contrast, 21 micron wool has been selling for 495-565 cents, with more recent sales rising to 640 cents, and 22 micron wool has been selling for around 545 cents. Australian A-index cotton has been selling recently for around 240 cents/kg.



**Figure 3** Percentage of coarse fibres as a function of mean fibre diameter [7]

### Shrink-resist treatment of wool

An important requirement for cotton/wool products is that they are machine washable. Wool fibres, because of their scale structure (Figure 4 - untreated wool), can felt when they are subjected to mechanical action in the presence of water. The exposed edges of the wool fibre point towards the fibre tip. There is a tendency for fibres to move preferentially in the direction of the root, because of the relatively low inter-fibre friction. Movement in the direction of the tip is somewhat restricted through interactions of the scale edges. This tendency towards unidirectional movement of fibres causes progressive entanglement of fibres and yarns, and irreversible shrinkage. The tendency for a cotton/wool fabric to felt will depend on the blend ratio - less felting with more cotton - and fabric structure. Wool fibres can be rendered shrink resistant by the chlorine/Hercosett process, which smoothes over the scale edges and encapsulates the fibres in polymer (Figure 4). Chlorine/Hercosett-treated wool top is commercially available. Shrink-resist treatments improve the after-wash appearance of a cotton/wool product, and also reduce the tendency for the wool fibre to pill.



**Figure 4** Scanning electron micrographs of untreated wool and shrink-resist treated wool

### Processing of fibre into yarn

The normal processing routes for wool and cotton are quite different. Cotton fibres, being relatively short, are processed on the *short-staple* system. Wool fibres are somewhat longer (Table 2), and are generally processed on the long-staple or *worsted* route. Woven blends can be made simply by weaving cotton yarn in one direction, and wool yarn in the other; *union* fabrics made from a cotton warp and a wool weft have enjoyed some popularity in the past [8]. *Intimately-blended* yarns (such as Colana<sup>®</sup>) where both fibres

are mixed together to form a uniform yarn will, however, generally produce a superior product that combines the best aspects of each fibre.

**Table 2** Approximate lengths of wool and cotton fibres [9]

Fibre	Diameter (micron)	Perimeter (micron)	Length (mm)
Fine Upland cotton	15 (micronaire 4.0)	50	26-28
Fine wool (top)	19	60	65

Cotton/wool yarns can be manufactured by cotton processors on the short-staple system by reducing the length of the wool fibres. This can be achieved by a process known as *stretch-breaking*. Alternatively, naturally shorter wool fibres that are compatible with the short staple system can be used. Although the production of a quality yarn is dependent on the quality of the input fibres, fibre quality alone is insufficient to achieve this. The skill of the spinner is paramount! The quality of the final product is affected greatly by yarn quality.

### Bleaching and dyeing

Procedures for bleaching and dyeing of cotton and wool are well documented. However, a number of processors have discovered to their dismay that bleaching a cotton/wool blend using a procedure developed for pure cotton will often dissolve the wool. Whereas the cotton fibre is a polymer made up of long chains of glucose units [10], the wool fibre is a protein, the building blocks of which are 18 different amino acids [11]. Under the harsh alkaline conditions often used for bleaching cotton, certain of the wool amino acids are destroyed [8,12]. Wool that has been chlorinated or chlorine/Hercosett-treated is even more susceptible to damage than untreated wool. Alkaline procedures are also recommended for the application of certain dyes to cotton.

Dyeing and bleaching problems can be overcome by treating the fibres *prior to* blending [8]. Dyeing of each component can be carried out under optimum conditions, and the dyes and dyeing procedures can be easily selected to give the required fastness properties and range of shades. Blending and carding can be used to correct problems regarding dye levelness and shade matching. Dyeing in *blend* form, however, is more the modern day norm, offering the following advantages:

- Spinning and other preparative processes are simplified because only undyed fibre is involved.
- The need to maintain stocks of coloured substrate is reduced.
  - If fashion demands change, the processor may be left with stocks of unsaleable product if it is already coloured.

- When making coloration decisions at a later stage, undyed product can be converted relatively quickly into the final product, and the processor is able to respond more quickly to market needs.

### **Bleaching**

The whiteness required for many cotton goods, such as underwear, is obtained by bleaching. Bleaching removes the creamy colour of natural cotton, and is also important to remove the cotton seed coat. Bleaching is often carried out prior to dyeing to enhance the brightness and colour purity of, especially, pale shades. Commercial methods for bleaching cotton/wool blends are based predominantly on the use of hydrogen peroxide. In order to minimise wool damage, mild conditions of pH and temperature are used, but this often leads to inadequate seed coat removal and whiteness. A new, improved procedure has been developed for cotton/wool *yarn*, which utilises the chemical activator, tetraacetyl ethylenediammine (TAED), in conjunction with hydrogen peroxide [13]. Under the Cotton Textile Research Program 5 of the Cotton CRC, different activator systems are being investigated to further enhance bleaching of cotton/wool blends, with particular attention being focussed on application to *fabric* using cotton processing equipment and operations.

### **Dyeing**

Dyeing of cotton/wool blends has created great a number challenges for the dyer [8,12]:

- Procedures that have been optimised for dyeing pure cotton are often inappropriate for dyeing the cotton portion of a blend because of wool's sensitivity to alkali.
- Although wool dyes have a low affinity for cotton, cotton dyes have a strong tendency to be taken up by wool.
- It is often difficult to get a uniform, matching shade on both fibres.
- Adequate build up of colour on the cotton, especially for heavy shades such as blacks and navies, can be difficult.

A recent study has established optimal procedures for the dyeing of Colana<sup>®</sup> [14]. These procedures relate to *exhaust* dyeing - for example yarn dyeing or fabric dyeing in jet machines - where conditions are such that the dye, which is dissolved in water, is allowed to exhaust from the liquor into the fibres. A technique used commonly in the cotton industry involves *pad* dyeing. Dye is applied to a fabric by passing it through a pad mangle where the nip is charged with dye liquor. After padding, migration of the dye from the surface to the interior of the fibre is achieved by storing the fabric on a roll for periods of up to 24 hours; this is referred to as a *pad-batch* operation. Excess dye is then removed

by washing, and the fabric dried. The use of a pad-batch (rather than exhaust) procedure to dye cotton leads to a more efficient reaction between dyestuff and fibre, and consequent savings in dye costs [8]. Pad dyeing also uses less water and energy. Pad dyeing is quite different from exhaust dyeing, and techniques appropriate to Colana<sup>®</sup> are being developed under the Cotton Textile Research Program 5 of the Cotton CRC.

## Conclusion

The development of the cotton/wool blend, Colana<sup>®</sup>, is an important initiative for the Australian cotton processing industry. It is laying the foundation for establishing higher value added markets for Australian cotton and wool. Considerable effort by Rocklea Spinning Mills has gone into developing a high quality yarn. It is important that optimal procedures are developed for, especially, bleaching and dyeing, and that customers are well informed of these developments. Work carried out in conjunction with Australian manufacturers, and jointly funded by the Cotton CRC and CSIRO, is aimed at developing these procedures using processing equipment and operations specific to the cotton industry. Previous work jointly funded by The Woolmark Company and CSIRO has focussed primarily on exhaust dyeing and bleaching.

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