Fabric Comfort: Prediction of the Fibre End Characteristics of Processed Wool from Currently Measured Raw Wool Parameters

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Summary
A Draft Test Method concerned with measurement of the Diameter of Fibre Ends (DFE) in Top was accepted recently by IWTO. This paper reports on the prediction of the fibre ends characteristics in 190 commercial Tops from the TEAM-3 project based on Raw Wool parameters of sale lots.

The DFE in a Top can be predicted from the Mean Fibre Diameter (MFD) of the Raw Wool with an r^2 of 0.96. However, the prediction is improved marginally (R^2 increases to 0.98; Standard Error (SE) of 0.3µm) with the inclusion of the Coefficient of Variation of Fibre Diameter (CVD), percentage of Tip-breaks (T) and the Mean Fibre Curvature (MFC). The Comfort Factor of fibre ends in a Top was best predicted by the Raw Wool Comfort Factor (R^2 = 0.93; SE: prediction 0.35%; validation 0.24%). The prediction relationships quoted in this report are for information only. Further work is required before any prediction relationships are recommended.

Introduction
Research by CSIRO (Garnsworthy *et al.* 1985) has shown that fibre ends protruding from the surface of a fabric can trigger nerve endings just below the skin surface, providing an irritating sensation. The paper highlighted the importance of both the diameter and the number of these fibre ends in determining the skin comfort of wool fabrics worn close to the skin. While this skin comfort can be largely independent of the handle and other comfort properties of a fabric, it can have a major impact on the desirability of a fabric or garment.

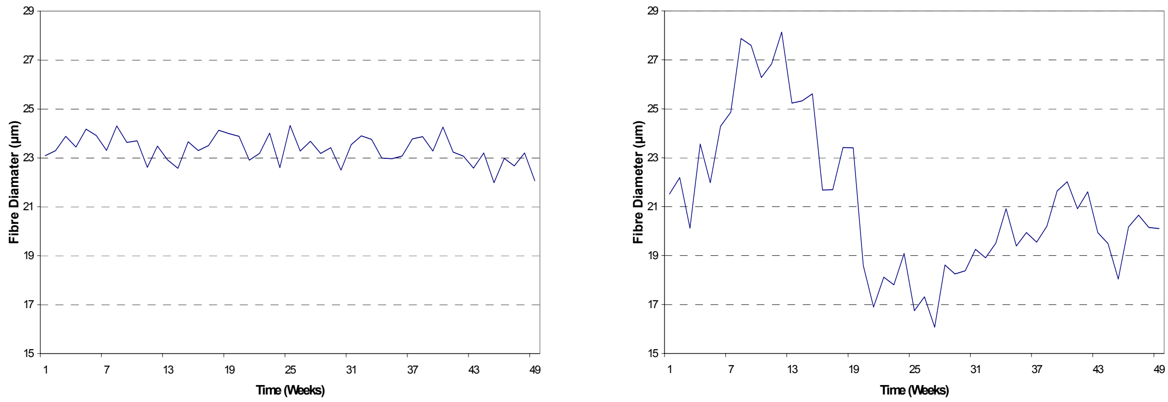
It is important for designers of wool fabrics that are worn next to the skin to have some indication of the diameter and number of fibre ends in the wools from which fabrics are to be constructed. The widespread use of LASERSCAN and OFDA instruments has provided a basis for reporting information about the proportion of coarse fibres in all sale lots of Australian Raw Wool, i.e. the Comfort Factor (CF) which is the percentage of snippets tested which have a diameter less than 30.5µm (IWTO-12-00).

There are factors other than the CF of Raw Wool that may influence the DFE in a fabric, particularly fibre breakage and fibre loss in processing. In processing from Raw Wool to Top, up to 50% of fibres are broken (Bownass 1984), tender fibres being more likely to break than sound fibres (Rottenbury *et al*. 1985), and a significant proportion of fibres are removed as noil and as card waste (Hunter, 1980). Much less fibre breakage is expected in processing from Top to a woven or a knitted fabric (Godard *et al.* 1975). The DFE in the Top is therefore likely to be similar to the diameter of fibre ends in the fabric manufactured from the Top. Yarn and fabric structural variables will also affect skin comfort, presumably by changing the number of fibre ends able to contact with the skin of the wearer. Indeed some knitted structures, especially single jersey, achieve the same level of assessed skin comfort as an equivalent plain woven fabric made from wool that is 3µm coarser (Naylor and Phillips 1996).

Individual wool fibres vary in diameter along their lengths as shown in Figure 1 (a, b). An instrument designed to measure diameter variation along a fibre, the SIFAN, was used to measure two fibres, one drawn from a sound wool (a), and the other drawn from a tender wool (b) (O'Keefe 2000). Tender fibres are characterised by larger variation in diameter along their lengths than the more even, sounder, fibres. And, these tender fibres may break preferentially at the lowest diameter along their lengths (Yu *et al.* 2001), resulting in the ends of these fibres being finer than the average diameter of the whole fibre.

Naylor (1992) developed a technique for the measurement of the DFE in Top. The technique was incorporated recently into an International Wool Textile Organisation (IWTO) Draft Test Method (Draft TM-60-01), providing a basis for specifying fibre end characteristics in wool trading contracts. If such a specification were used in contracts to supply Top, the purchasers of the Raw Wool used to produce the Top would require information about the predictability of fibre end characteristics in the Top based on available Raw Wool specifications. The availability of data from TEAM-3 provided an opportunity to develop predictions of the fibre ends characteristics of Tops based on Raw Wool measurements of sale lots.

This report examines the prediction of two parameters measured on the fibre ends of Tops based on measured Raw Wool characteristics of the wool used to produce the Tops. The two parameters are (i) the DFE, and (ii) the CF of fibre ends.



(a) **(b)**

Figure 1. Variation in fibre diameter of a typical sound (a) and tender (b) fibre.

Note that Draft TM-60-01 defines a Fibre Ends Fineness Index (FEFI) (Naylor 2001) which is related to the difference between the MFD of the Top and the DFE. The incorporation of results from further commercial consignments, and particularly from current sale lot processing trials, may lead to predictions of FEFI for both sale lots and consignments.

Materials and Methods

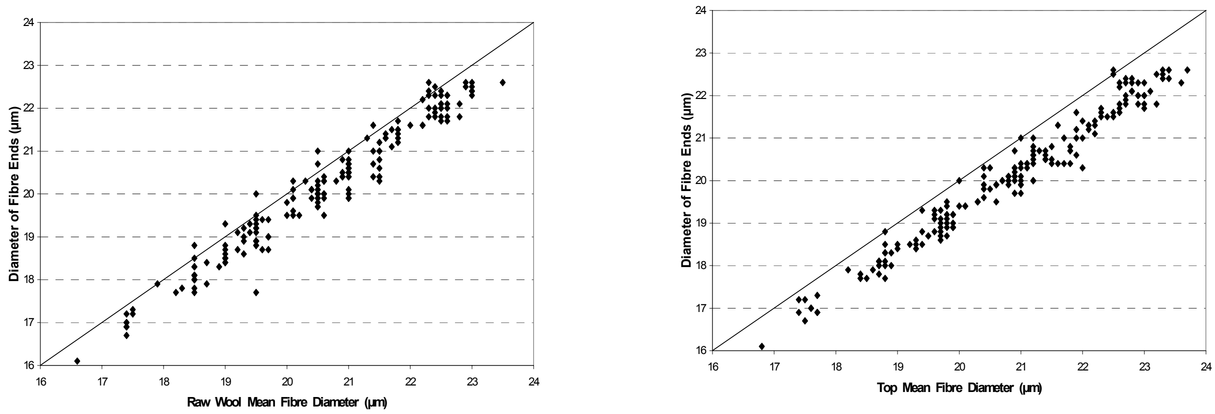
The data used for the following analyses were derived from 190 consignments from the TEAM-3 database (Lindsay *et al.* 2002). Raw Wool measurements were conducted at AWTA Ltd. following procedures defined in the relevant IWTO Standards (IWTO-12-00; IWTO-19-98; IWTO-30-98). All Tops were measured following IWTO-12-00 and DTM-60-01.

Equations to predict the DFE and the CF of fibre ends were derived using a subset of 95 consignments randomly selected from the 190 TEAM-3 consignments, and were validated with the remaining 95 consignments. The independent variables used initially in the predictions were: MFD, SD, CVD, CF, MFC, Staple Length (SL), Coefficient of Variation of SL (CVSL), Staple Strength (SS), T, and percentage of Mid Breaks (M). The data were analysed using the multiple linear regression function in Excel 2000; only those terms with a significant coefficient (5% level) are reported.

Results and Discussion

1. Diameter of Fibre Ends (DFE)

As noted in earlier work by Naylor (1995) the MFD of Raw Wool and Tops is consistently higher than the DFE, as shown for the TEAM-3 data in Figure 2 (a, b). For the 190 Tops in this investigation the DFE was, on average, 0.8µm finer than the MFD of the Top, compared with a 1.0µm difference in the earlier study.



(a) **(b)**

Figure 2. Relationship between Diameter of Fibre Ends (DFE) and Raw Wool (a) and Top (b) MFD.

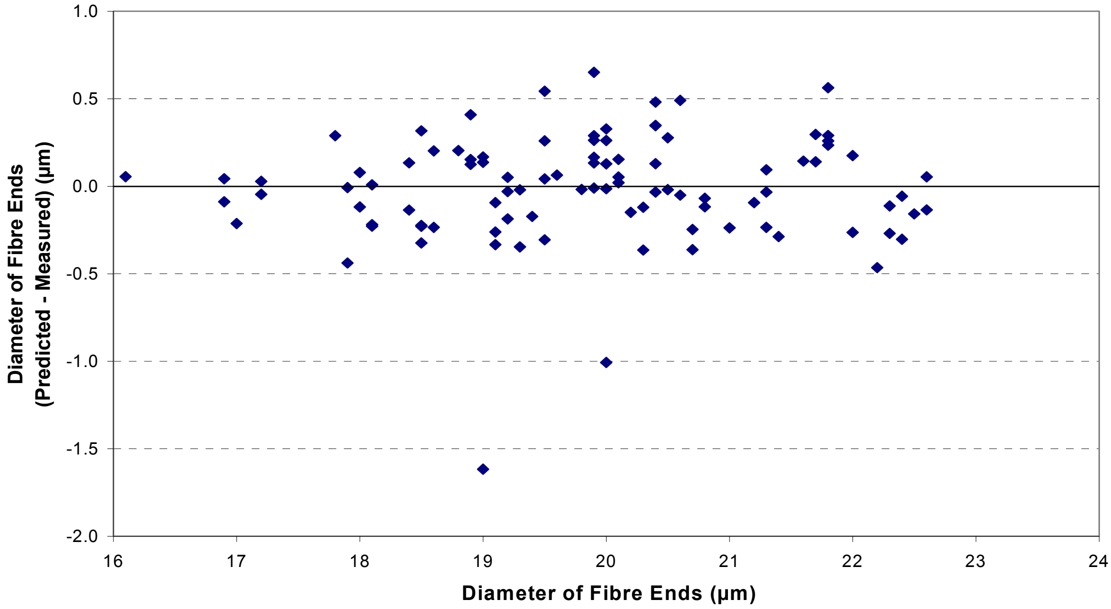


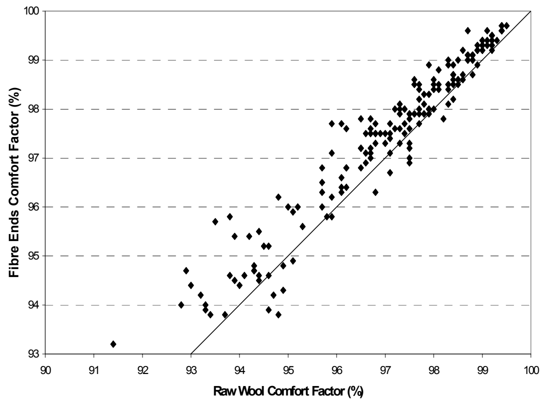
Figure 3. Prediction of Diameter of FibreEnds (DFE) from Raw Wool characteristics for 85 consignments.

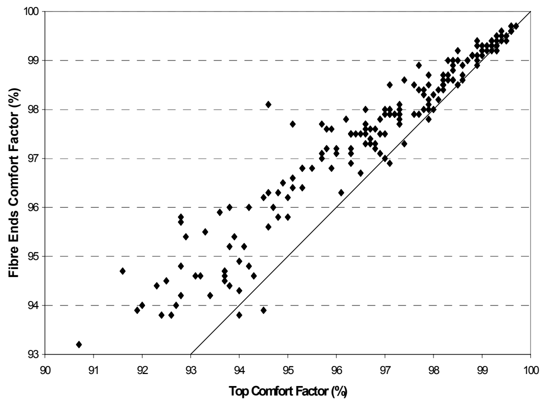
The DFE was predicted from four Raw Wool parameters: MFD, CVD, T and MFC (R^2 = 0.98; coefficients (SE's) 0.75(.0052), -0.12(0.048), -0.05(.010), -0.01(0.004) respectively, constant 12.1(2.7); SE 0.30µm for prediction and 0.31µm for the validation set). However, Raw Wool MFD alone accounts for 96% of the variation in DFE with only marginal additional information from the other three parameters. The errors in prediction for 85 consignments in the validation set are shown in Figure 3. The prediction errors were generally well within ±0.5µm, though there were two outliers. In one case the DFE was the same as the Top MFD; in the other case, the consignment had a high CVD and a high MFC for its MFD (MFD, 19.3µm; CVD, 22.9%; MFC, 124°/mm).

2. Comfort Factor of Fibre Ends

The CF is 0.4% and 0.7% higher, on average, in the fibre ends (97.5%) than in the Raw Wool (97.1%) and Top (96.8%), respectively. As shown in Figures 4a and 4b the fibre ends in a top have greater "skin comfort" than the raw wool from which the top was made. The higher CF in the Raw Wool compared to the Top may be due to the loss of fine fibre as noil in processing resulting in a higher proportion of coarse fibre in the Top. The higher CF for fibre ends than for Top may be related to fibre breakage occurring selectively at fine points in the fibre. It is interesting to note that the difference between both the Raw Wool and Top CF's and the fibre ends CF reduces with increasing CF. This reduction in CF difference is difficult to explain, but may mean that the positive relationship between fibre diameter and fibre length within a wool (Ford 1990) is stronger in coarser wools than in finer wools.

The only significant Raw Wool parameter in the prediction of fibre ends CF was the Raw Wool CF (R^2 = 0.93; coefficient (SE) 0.896(0.026), constant 10.49(2.50); SE prediction 0.45%; validation 0.42%). Note that the SE (approx. 0.44%) is of the same order as the difference (0.4%) between the Raw Wool and fibre ends CF's.





(a) **(b)**

Figure 4. Relationship between Comfort Factor (CF) of Fibre Ends and Raw Wool (a) and Top (b) Comfort Factors (CF's).

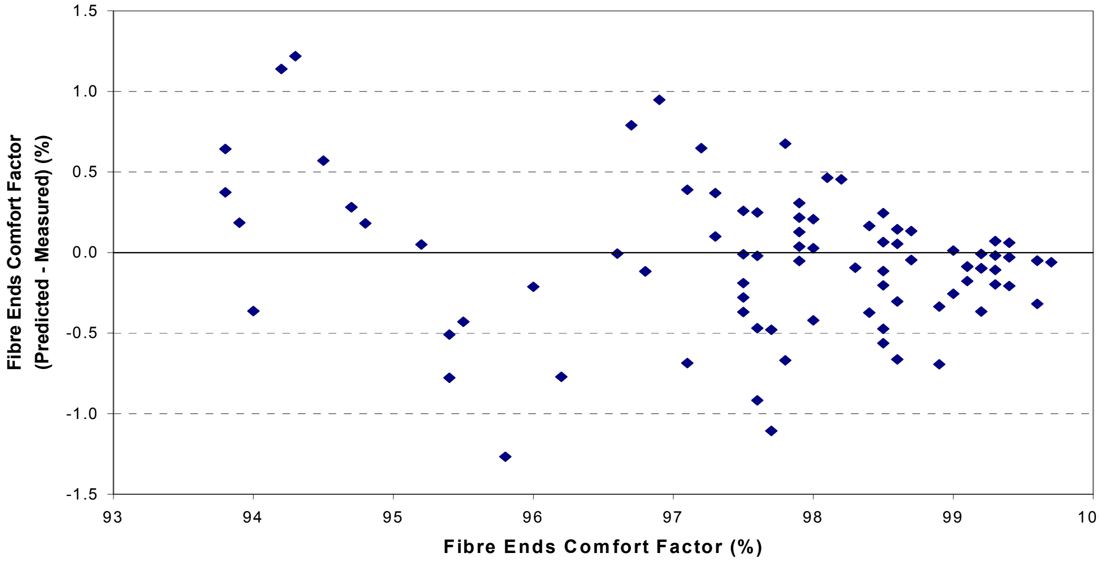


Figure 5. Prediction of Comfort Factor (CF) of Fibre Ends from Raw Wool characteristics for 85 consignments.

As can be seen in Figure 5, the error of the prediction is relatively low for values of CF greater than 98%, meaning that the absolute value of the error in the prediction of fibre ends CF is less than 0.35% in the region where CF would be of the most commercial interest, i.e. where the wool is likely to be worn next to the skin.

Conclusions

This report demonstrates that the fibre ends characteristics in Top can be predicted from Raw Wool measurements: DFE was predicted with an SE of 0.3µm; and, CF of fibre ends with an SE 0.4%. In both cases (DFE and CF of fibre ends), prediction of fibre ends characteristics was primarily determined by the corresponding Raw Wool parameter. This means that, on the basis of this analysis, the prediction of fibre end parameters can be based, simply on only one Raw Wool parameter in each case, viz. MFD for predicting DFE, and CF for predicting fibre end CF.

Future Work

AWTA Ltd. and The Woolmark Company plan further work on a larger set of data, including further lots from TEAM-3 and up to 250 sale lot grab samples that are being processed for AWTA Ltd. These sale lots contain a wider range of values of some Raw Wool parameters, especially Staple Strength and % Mid-breaks, than do the currently available TEAM-3 data set. The expansion of these ranges provides an opportunity to determine if prediction accuracy can be improved by incorporation of further Raw Wool parameters, other than the single parameter corresponding most directly to the fibre ends parameter being predicted. The incorporation of results from the current sale lot processing trials may also lead to predictions of FEFI for both sale lots and consignments.

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