THE INFLUENCE OF DATE OF SHEARING ON THE PROCESSING PERFORMANCE TO TOP OF MINI-COMMERCIAL CONSIGNMENTS OF MERINO FLEECE WOOLS GROWN IN EITHER SOUTHWESTERN OR EASTERN AUSTRALIA – 2. IMPROVED PREDICTION FROM THE FD PROFILES OF STAPLES FROM COMPONENT SALE LOTS

Andrew D. Peterson* **and Chris M. Oldham**

Wool Program, Agriculture Western Australia, 3 Baron Hay Crt South Perth 6151.

An experiment is described in which sale lot display samples were used to build processing batches that mimicked standard commercial 20 tonne containers of Merino fleece wool. The wool classer's specification was used to assign each sale lot and consignment to a month of shearing within the 1997/98 wool selling year from wool either grown in South-Western Australia (Fremantle) or New South Wales (Sydney). Greasy staples were collected from each sale lot and the fibre diameter (FD) profiles were measured on the OFDA 2000. The mini-commercial-consignments were sent to CSIRO, Textiles and Fibre Technology, Geelong and processed through to top using recommended CSIRO settings for 21.5 micron wool. Utilising data from the FD profile, a fibre breakage model was developed which predicted the fibre length distribution of the top. The model was able to differentiate differences in hauteur between the consignments that otherwise were under-predicted using the TEAM equation (r^2 = 0.38). The model could predict over 73% of the variance in hauteur from 56 consignments. Furthermore, the model was able to predict short fibre content (% fibres < 25mm) of the resultant tops. The new model offers scope for better prediction of wool shorn at different times of the year and offers greater efficiency to topmakers as well as providing a fairer payment to growers who produce longer hauteur wool that otherwise would not be rewarded due to the anomalies of the TEAM equation.

The prediction of hauteur using the TEAM equation has been well adopted in the worsted topmaking industry since the equation became available in 1988 *(1).* The prediction system allows topmakers to easily predict hauteur from consignments with additional measurements to within ± 4 mm of the actual value, 80% of the time. Because of the simplicity of the TEAM equation, and the ability of mills to incorporate further refinements, the TEAM equation is well adopted throughout the world. As a result, staple length and strength is now tested on the majority of wool lots offered at auction in Australia.

Recent work by Oldham et al. *(2)* identified anomalies in the prediction of hauteur using the TEAM equation when consignments were acquired from sale lots that were shorn at different times of the year. Further work by Oldham and Peterson *(3)* identified a systematic error in TEAM predicted hauteur relating to the time of shearing of sale-lots that went into experimental consignments. Wool shorn in autumn, both on the Western and Eastern seaboard of Australia, processed to top with significantly longer hauteur than predicted. The reverse was true for wool shorn in spring. The wool was selected to process to the same specifications and the only major difference between consignments was the average FD profile of staples. The FD profile is a measurement of the changes in diameter along the

* apeterson@agric.wa.gov.au

length of a staple and this can be measured by conventional snippet technique *(4)* or using the newer OFDA 2000 technology *(5).* The shape of the FD profile of raw wool has also been shown to be important in determining hauteur to the extent that new prediction systems have been developed based on the FD profile *(6).* The FD profile was measured on a randomly selected population of staples from each sale lot used by Oldham et al. *(3).* This paper investigates a new model, which predicts the amount of fibre breakage during topmaking based on data from the FD profile. The ability of the model to predict hauteur was then tested on a number of consignments that were blends from sale-lots shorn in either spring or autumn.

Experimental

Measurement of Diameter Profiles. The preparation of experimental, mini-commercial topmaking consignments, is explained by Oldham (3). It was not possible to collect staples from 7 of the Sydney consignments hence the fibre breakage model was used on 56 of the 63 consignments described in *(3).* From the display sample of each sale-lot (3-7kg) that made up each consignment, 10 greasy staples were taken and measured on the OFDA 2000 *(5).* Staples were measured at standard laboratory conditions (20 C, 65% RH). The OFDA 2000 measured FD every 3.5 mm along the length of the staple. The average FD profile for each consignment was determined by expanding all staple profiles to 38 discrete sections along the staple and averaging values at each section.

Prediction Model. A fibre breakage model was developed which utilised all the information from the FD profile. The model output predicted the distribution of fibre length for any given diameter profile. From this distribution, values for hauteur and CV of hauteur could be determined.

Assumptions. All fibres are broken in the model. Staple length (SL) was used to predict fibre length (FL), (FL = SL x 1.17). All fibres were considered to be the same length. The model does not attempt to balance the sum of broken fibre lengths, with the original sum of full-length fibres.

The simulation stepped through all the combinations of fibre lengths that were possible by breaking fibres at two points along the staple.

<u>Parameters</u>

S = Starting segment of fibre (1....38)
F = Finishing segment of fibre (1....38)
S_diam = diameter at S
F_diam = diameter at F
S_position = position of S as percentage distance along staple
F_position = position of F as percentage distance along staple
S_diam_prob = probability of fibre breaking at S based on diameter at S (Figure 1)
S_ position_prob = probability of fibre breaking at S based on S_position (Figure 2)
S_prob = S_diam_prob * S_position_prob
F_prob = as for S_prob but at F
Prob_total = S_prob * F_prob

The Prob_total was determined for every possible combination of fibre lengths with the smallest unit length being 1 segment (i.e. F - S = 1). For example, from a profile consisting of 38 segments (38 x 3.5 mm) there were 703 possible combinations of unique fibre lengths.

Segment lengths were converted to fibre lengths based on the staple length multiplied by 1.17. The mean fibre length, coefficient of variation of fibre length, and percentage of fibres less than 25 mm was calculated from the profile of each staple. These values were averaged for each consignment. No combing algorithm was used on the predicted fibre length distributions.

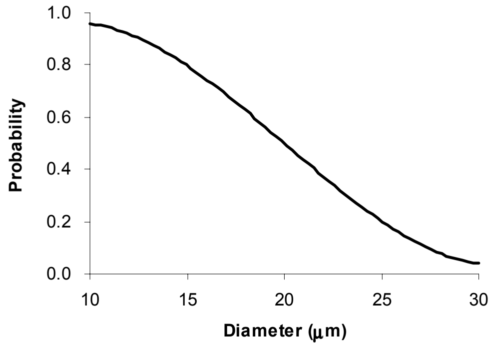

Figure 1 The probability of a fibre breaking for a given fibre diameter

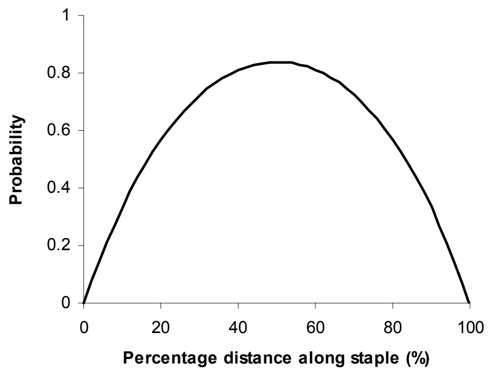

Figure 2 The probability of a fibre breaking at a given position along the staple

Preparation of blends. To test the prediction model, blends were prepared which consisted of different percentages of spring and autumn-shorn wool. Each mini-consignment consisted of varying proportions of wool from the display samples of the same 26 sale-lots. Half of the sale-lots were spring-shorn and the other half were autumn-shorn. Five 30 kg mini-consignments were created with mixtures of 100% spring, 75% spring: 25% autumn, 50% spring: 50% autumn, 25% spring: 75% autumn, and 100% autumn-shorn wool. FD profile was measured on ten staples from each sale-lot using the OFDA 2000.

Results

The greatest residual errors in TEAM predicted hauteur was seen in the Fremantle wool that also tended to have the greatest variation in FD between spring and autumn (Figure 3a & b). There was a linear increase in the error of predicting hauteur using TEAM as the actual hauteur of top increased (Figure 4). As a result, the TEAM equation was only able to predict 38% of the variance in actual hauteur. In contrast, the fibre breakage model explained 73% of the variance in hauteur of 56 mini-consignments of which 37 mini-consignments were from Fremantle and 19 from Sydney (Figure 5). Despite this good relationship there was an outlying group of 6 autumn-shorn, long hauteur tops that were still under-predicted by over 3 mm by the model (Figure 6). This indicates that there is still scope for improving the model. The 95% confidence limits for predicting hauteur using the model was ± 4.9 mm for a top with an actual hauteur of 76 mm. The 95% confidence limits for predicting hauteur from TEAM was ± 7.5 mm. There was no relationship between staple length (measured on the OFDA 2000) and actual hauteur. Hence, the prediction of hauteur by the fibre breakage model was not related to the staple length given in the FD profile.

The model was unable to predict the coefficient of variation in fibre length (CvH) but there was a relationship between the predicted value of short fibre content (%<25mm) and the actual short fibre content of tops (n=56; $r^2 = 0.58$). These values are not the same since the model predicts short fibre after carding whereas the measurement of short fibre in top is obviously after removal of short fibre after combing. The model was unable to predict romaine and there was no relationship between the model prediction of short fibre (%<25mm) and romaine. There was only a marginal improvement in prediction of hauteur when the model predicted value was added to the TEAM equation in a multiple regression ($r^2 = 0.75$).

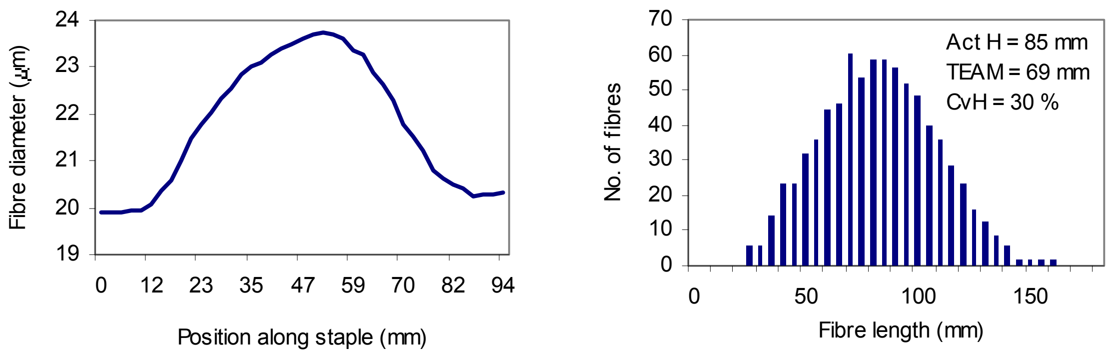

Figure 3a The fibre diameter profile and actual fibre length distribution of the top for an autumn-shorn consignment sold in Fremantle

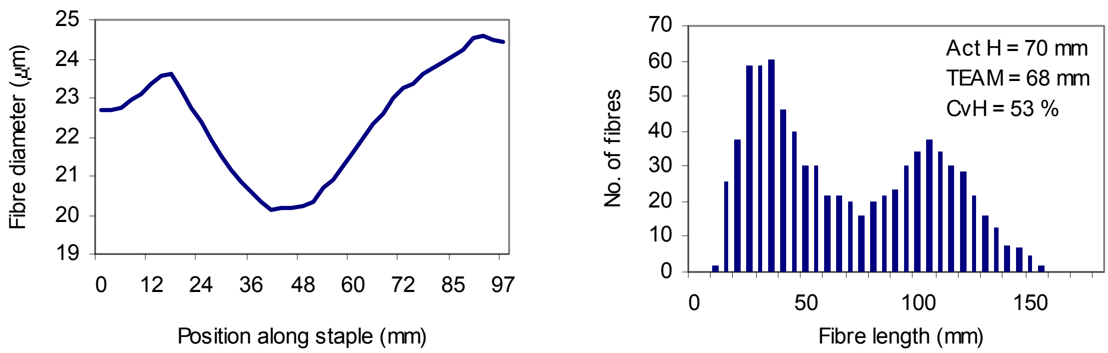

Figure 3b The fibre diameter profile and actual fibre length distribution of the top for an spring-shorn consignment sold in Fremantle

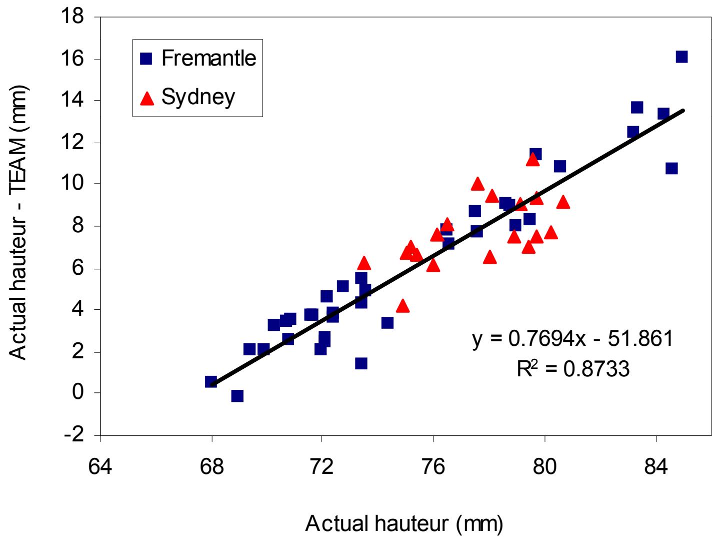

Figure 4 The residual error in predicting the actual hauteur of mini-consignments using the TEAM equation, plotted against actual hauteur

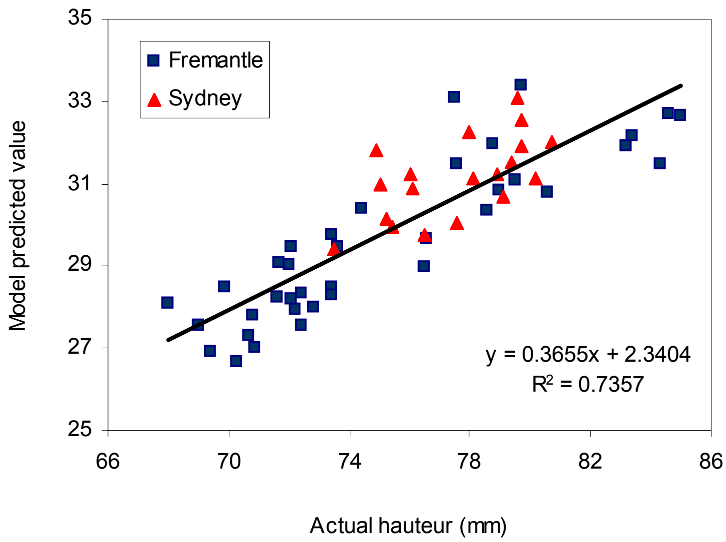

Figure 5 The relationship between actual hauteur and values predicted from the new breakage model, for 56 consignments acquired at different times of the year from Fremantle and Sydney

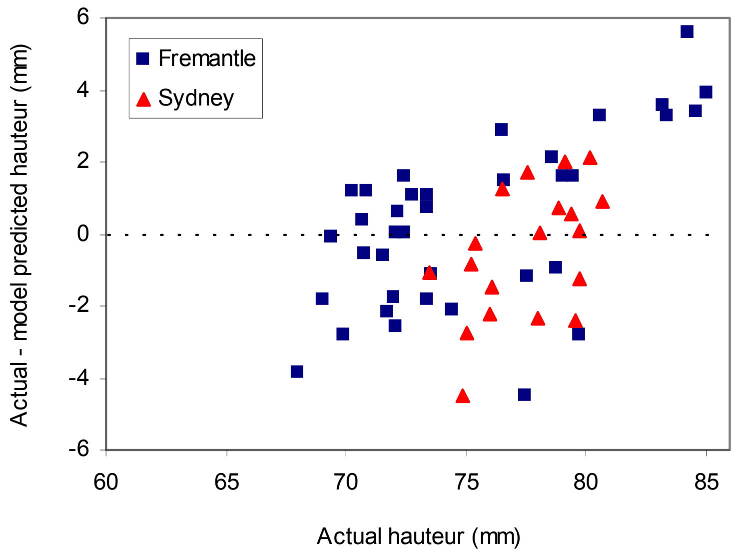

Figure 6 The residual error in predicting the hauteur of 56 mini-consignments using the fibre breakage model. Model predicted values are transformed using the regression equation; Actual H = Model H/ 0.365 - 2.3

The model was validated on five blends of varying percentages of spring and autumn-shorn wool. The FD profiles of these five blends (Figure 7) show the typical profile shape of spring and autumn-shorn wool as well as the flat profile of a 50:50 blend. Because the 50:50 blend is made up of equal amounts of both spring and autumn-shorn wool, the different shapes of these profiles cancel each other out so that the average profile appears flat.

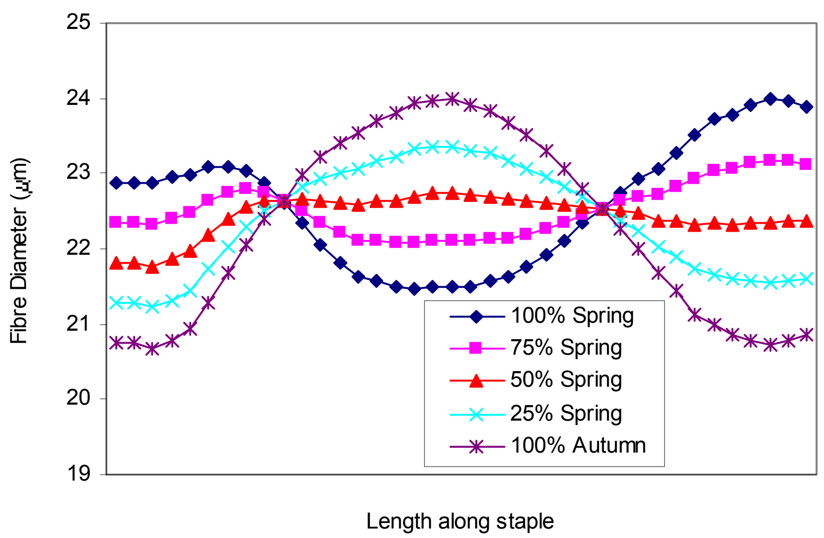

Figure 7 The FD profiles (raw wool) of blends containing varying percentages of spring and autumn-shorn wool

There was a strong relationship between actual hauteur and the model predicted hauteur, (Act H = 1.13 * model H - 9.6; $r^2 = 0.987$), (Figure 8). There was also a good relationship between TEAM and actual hauteur of blends (Act H = 3.41 * TEAM H - 163; $r^2 = 0.988$) but the range in TEAM values was only 3.3 mm when the actual hauteur varied by 11.1 mm (Table I). The change in the shape of FD profiles was well correlated with a shift in the fibre length distribution of the worsted tops (Figure 9).

Table I The raw wool properties of the 5 blends of autumn and spring shorn wool along with actual hauteur and TEAM predicted hauteur of the resultant tops

	Blend				
	100S	**75S:25A**	**50S:50A**	**25S:75A**	**100A**
Diameter (µm)	21.9	21.9	21.8	21.8	21.8
Staple length (mm)	91	91	90	90	89
Staple strength	34.6	35.6	36.7	37.7	38.7
Mid breaks (%)	62	56	51	45	40
TEAM hauteur (mm)	68.5	69.3	70.1	71.0	71.8
Actual hauteur (mm)	70.9	72.4	75.9	79.0	82.0
Act-TEAM hauteur (mm)	2.4	3.1	5.8	8.0	10.2

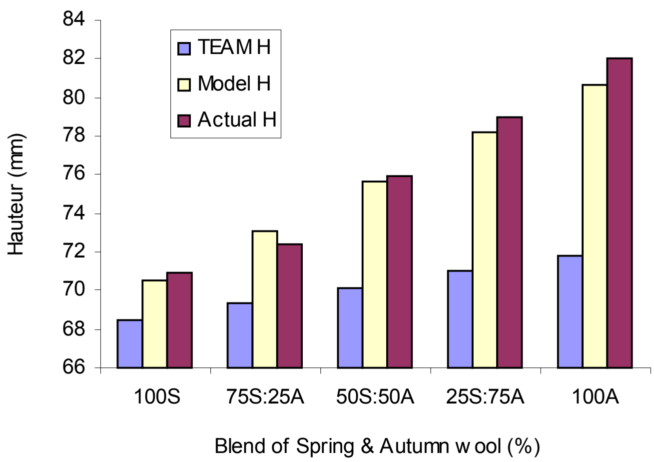

Figure 8 The actual hauteur, TEAM predicted hauteur and model predicted hauteur for blends containing varying percentages of spring and autumn-shorn wool.

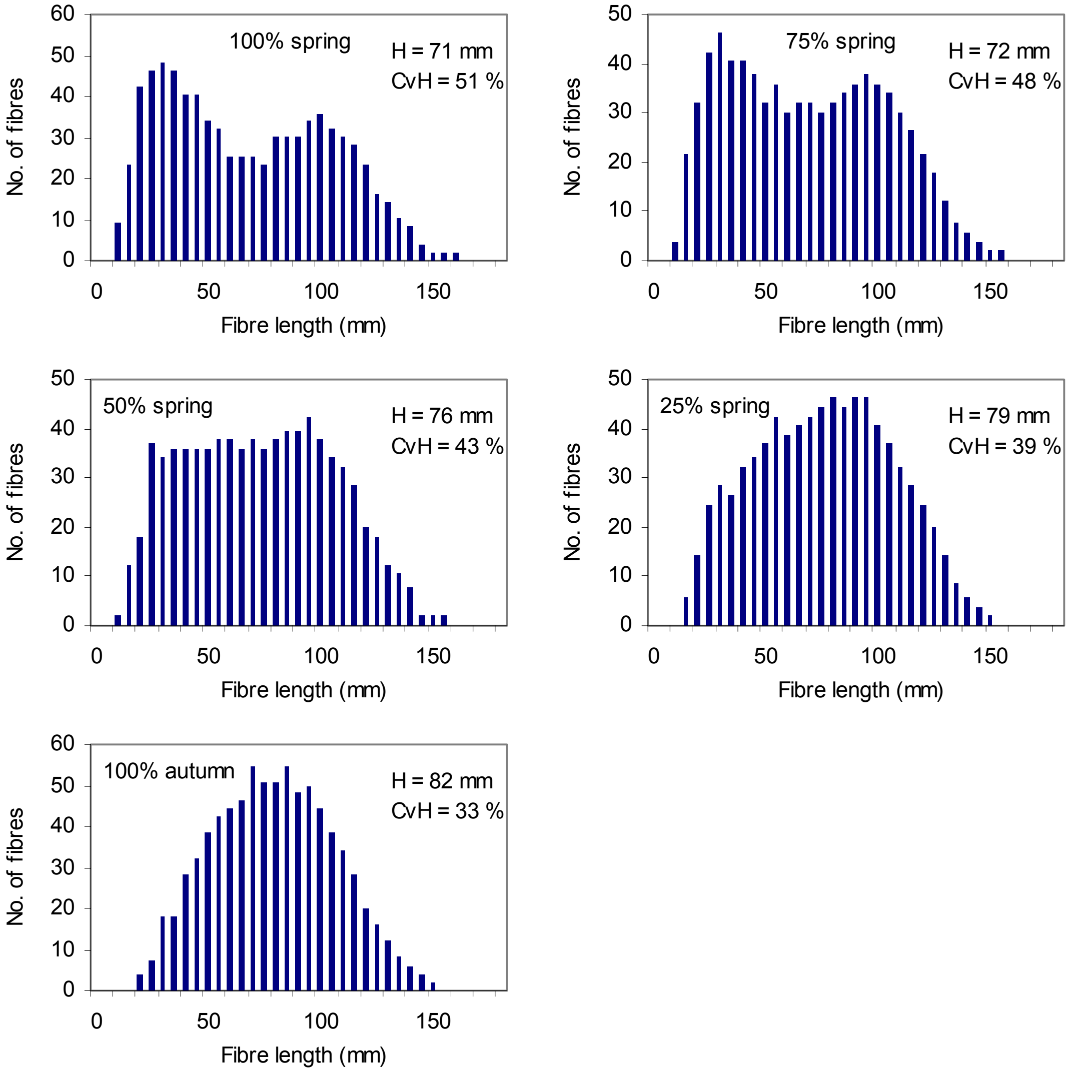

Figure 9 The fibre length distributions of top from the 5 blends of autumn and spring shorn wool

Discussion

This paper demonstrates that a new raw wool attribute, FD profile, can be used to predict differences in hauteur that would otherwise be poorly predicted using TEAM. This is particularly evident in wool that varies greatly in FD profile as a result of different times of shearing. However, the model in its present form is not suitable as a replacement for the TEAM equation due to the false assumptions that are made (i.e. all fibres break during topmaking). Previous work *(7)* has shown that between 30 and 40% of fibres break during carding yet our model simulates breakage of all fibres. This may explain why the model is unable to predict the CvH of consignments which is typically a measure of the spread of broken and unbroken fibre lengths. As the FD profile shifts from an autumn-shorn profile to a spring-shorn profile, two distinct fibre length distributions begin to appear (see Figure 9). The result is a reduction in average fibre length and a greater variability in fibre length (CvH). The model primarily explains the probability of fibre breakage at positions along the fibre and this parameter manages to explain the differences in hauteur between wool with different FD profiles. It must be noted that the model was not created to specifically fit the data, but rather mimic the fibre breakage that is theoretically expected during carding and gilling. Therefore, it is surprising how well the model was able to differentiate the hauteur of consignments despite only small differences in TEAM hauteur. There are advantages in developing a fibre breakage model rather than using a multiple regression approach like TEAM. If fibre breakage can be simulated, then a fibre length distribution can be generated for a given FD profile of the raw wool (i.e. almeter diagram). This could then provide estimates of CvH, noil, short and long fibre content which are all considered important attributes of top. Further work is continuing to improve the fibre breakage model and/or investigate alternative techniques for predicting the fibre length distribution of top for any given FD profile of raw wool.

Considerable savings could be made by top-makers if they could reliably source autumn-shorn wool which currently does not extract a price premium in the marketplace, even after considering higher staple strength and less mid-breaks. Measurements of FD profile will be available on sale-lots through the measurement of fleeces on farms using the OFDA 2000. This study also shows that the measurement of FD profiles on grab samples from sale-lots can be both rapid and cheap. This initial research, along with the work of Hansford *(6)* strongly suggests that FD profiles can be used as an alternative predictor of early stage processing. A further advantage is that woolgrowers will find it easier to produce wool which will process to a certain specification since the FD profile is easier to manage than trying to simultaneously manage staple strength, length, mid-breaks and fibre diameter.

Acknowledgements

The authors would like to thank John Davies and John O'Sullivan for collecting shearing dates and staples; to Lindy Coss, Robyn Pitman, Robyn Bradley and John Vayler of the Wool Testing Laboratory (AgWA) for measurement of the many FD profiles; to Kimbal Curtis (AgWA), Peter Baxter (SGS, NZ), David Scobie (AgResearch, NZ), Peter Lamb (CSIRO) and Mark Brims (BSC Electronics) for guidance on development of the prediction model; and to Gary Robinson and wool processing staff at the CSIRO Textiles and Fibre Technology. Australian woolgrowers and the Australian Government through the International Wool Secretariat, CSIRO and the Cooperative Research Centre for Premium Quality Wool provided support for this work.

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