Assessing Yarns to Predict the Comfort Properties of Fabrics

Maryam Naebe[1], Bruce A. McGregor[1], David Tester[2] and Xungai Wang[1]
CRC for Sheep Industry Innovation and the University of New England, Armidale, NSW 2351
[1]Institute for Frontier Materials, Deakin University, Geelong, Australia
[2]CRC for Sheep Industry Innovation Ltd., CJ Hawkins Homestead, University of New England, Armidale, Australia
maryam.naebe@deakin.edu.au

OBJECTIVE
The feasibility of assessing yarns with the Wool ComfortMeter (WCM) to predict the comfort properties of the corresponding single jersey-knitted fabrics was examined. The relationship between WCM readings of wool knitting yarns and direction and frequency of yarns wound onto a test template were investigated. Using a notched template, yarn winding frequencies of 1, 3, 6, 12, 25 and 50 parallel yarns in two horizontal and vertical directions were tested on the WCM. Vertical windings produced significantly higher readings than horizontal windings. The best predictor of fabric WCM values was using 25 parallel yarns in horizontal direction.

INTRODUCTION
A faster and potentially cheaper method of evaluating the properties of knitted fabrics would be to assess the yarns prior to knitting thus avoiding manufacturing costs and delays.
The WCM instrument was developed as a fast and objective method of predicting the wearer comfort assessment of wool knitwear to replace subjective, lengthy and expensive wearer trials[1, 2].
The instrument uses a measurement wire mounted in a recording head, which scans the surface of the fabric interacting with fibres protruding from the fabric surface. The WCM reading provides a value that is related to the number and density of coarse fibres protruding from the fabric surface[1, 3]. The readings of the WCM have been shown to be strongly correlated with average prickle ratings assigned by wearers of the garments[1] where the changes in comfort affected by different treatments can be detected by the WCM[4].
The objective of this paper is to investigate a reliable predictor of knitted fabric comfort prior to knitting by testing yarns using WCM assessment.

APPROACH
To cover a large range of WCM values, seven pure wool (w) yarns and two 80/20 wool/nylon blends (w/n) with a mean fibre diameter (MFD) range between 16.5 and 24.9 µm were selected. Details are summarized in Table I. Single jersey fabrics were knitted with similar cover factor (CF), knitting gauge, and yarn plies[5].
Yarn testing templates were prepared from acrylic boards to enable the preparation of up to 50 windings of a yarn per test. On each side of the template and located centrally, 50 grooves were incised. For each yarn, six different winding frequencies were tested: 50, 25, 12, 6, 3 and 1per test. For each winding frequency, three separate templates were prepared and measured on the WCM device in a random order[5]. To investigate the effect of vertical direction, only 3 yarns with MFD of 18.5, 19.3 and 21.9 µm were prepared and tested. Yarn and corresponding fabric comfort evaluation was carried out at standard condition whereby each sample was subjected to 10 passes of the measurement device[6].

Table I. Specifications of yarns and their corresponding single jersey knitted fabrics[5]

Yarn ID	Fibre type	MFD (µm)	Fabric ID	Yarn count/ Nm	Gauge	CF
1	w/n	24.9	F1	1/23	14	1.32
2	w/n	22.6	F2	1/23	14	1.20
3	w	17.6	F3	1/40	24	1.28
4	w	18.5	F4	1/40	24	1.20
5	w	22.0	F5	1/40	24	1.20
6	w	19.3	F6	1/40	24	1.20
7	w	21.9	F7	1/40	24	1.28
8	w	24.3	F8	1/40	24	1.20
9	w	16.5	F9	2/72	24	1.28

RESULTS AND DISCUSSION
Effect of direction of winding
Analysis of variance (ANOVA) showed (Table II) a significant effect of yarn winding direction with vertical windings producing higher readings than horizontal windings ($P < 0.001$).

Table II. Effect of yarn winding direction on Wool ComfortMeter values

Winding direction	WCM	s.e.d.[a]	s.d.[b]	s.e.d.[c]
Vertical	842.5	70.28	148.6	18.22
Horizontal	408.7		99.3	

[a] standard error of difference between mean WCM values in different direction
[b] standard deviation
[c] standard error of difference between mean s.d. in different direction

It appeared that there was a mechanical interaction between the testing head and the space between the yarns, or perhaps the sides of the yarns, such that vertical readings were about twice that of horizontal readings. Since testing of yarns presented in the vertical direction is not recommended, further investigation was carried out with the horizontal direction and the corresponding fabrics.

Effect of yarn winding frequency for horizontally wound yarns

The relationship between WCM value, over the range of values observed, and different yarn winding frequencies or yarns and their corresponding fabrics are shown in Figure 1. The logarithmic trend lines fitted to the WCM value vs. yarn winding frequency show the rapid increase in WCM value up to a winding frequency of 25. The WCM values increase proportionally less or remain almost constant between 25 and 50 yarn winding frequency.

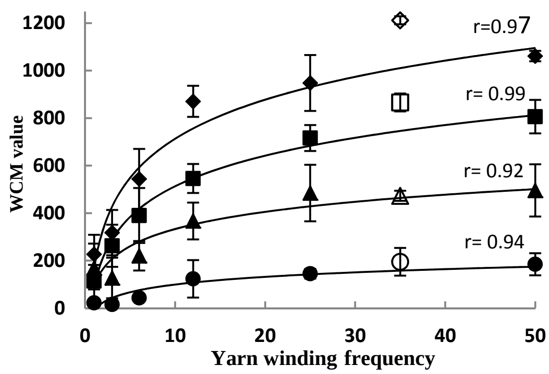

Figure 1. Wool ComfortMeter (WCM) value of selected yarns at different yarn winding frequencies and their corresponding fabrics. Error bars indicate standard deviation. The best line fitted (log) and the corresponding correlation coefficient (r) are shown. Symbols: ♦, yarn 8; ■, yarn 7; ▲, yarn 6; ●, yarn 9. Open symbols referred to the corresponding fabrics.

Yarn winding frequency significantly affected the WCM values (P = 8.5× 10^{-17}, s.e.d.= 1.69, least significant differences; L.S.D.5%=3.35; Table III). There was no difference in WCM values between winding frequencies of 50 and 25, but the values at winding frequencies of 50 and 12 were different These results suggest that a yarn winding frequency of 12 is insufficient to accurately reflect the true WCM values of a yarn but a winding frequency of 50 is probably too many. Therefore, if yarns are to be assessed on the WCM then the 25 windings may provide a compromise between detecting differences between yarns and reducing the time involved in preparing multiple samples with 50 windings[5, 7].

Table III. Effect of yarn winding frequency on Wool ComfortMeter values (WCM). Statistical significance determined after square root transformation. Values with different superscripts differ at P = 0.05.

Winding frequency	1	3	6	12	25	50
WCM	141^{d}	185^{d}	333^{c}	480^{b}	$569^{a,b}$	669^{a}

Models for predicting fabric WCM values

To estimate which yarn winding frequency can be used to predict the fabric WCM value, a regression model was applied to fabrics of similar attributes. This regression included all attributes of yarn and fabric along with the comfort value of six different yarn winding frequencies as independent variables. The final general multiple linear model included the WCM value for 25 windings (Yarn 25 WCM) and MFD, both attributes of the yarn (Table IV). No other physical attributes of fabric or yarn was significant in predicting yarn assessed WCM values. This model indicates that a yarn winding frequency of 25 provided a better prediction of fabric WCM values than yarn winding frequencies of 50, 12, 6, 3 or 1. The terms Yarn 25 WCM and its square explained 88.5% of the variation in fabric WCM values.

Table IV. A list of the statistical significance of included terms in the final model for fabric WCM values

Adjustment to final model	β	s.e.	P-value
$(\text{Yarn 25 WCM})^2$	0.0012	0.00029	< 0.001
MFD	84.0	23.6	0.002
Yarn 25 WCM	-0.94	0.459	0.042

CONCLUSIONS

The testing method of winding yarn around a notched template with a yarn frequency of 25 in horizontal direction provided the best precision for the prediction of fabric WCM evaluation. This indicates that evaluation at the yarn stage would be a reliable predictor of knitted fabric comfort, and thus yarn testing would avoid the time and expense of fabric construction.

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