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CRC for Sheep Industry Innovation

Project 2.2 Whiter lightfast wools

Milestone / Task	Description	Due Date
R4.2.3.3	Report on changes in wool colour and photostability during all stages of processing for a pilot-scale commercial trial.	31/03/10

Summary

This document reports the details of a pilot-scale commercial trial conducted with The Merino Company (TMC) which took two bales of white Tasmanian merino wool (scoured yellowness Y-Z=7.9) through an optimised processing chain to maintain maximum whiteness from fibre to fabric.

The CRC trial produced finished knitted fabric in the undyed shade used by TMC (Toi Toi) that was 30–40 CIE Ganz whiteness index points higher than the TMC standard commercial product, which is an exciting result for the first trial. Photostability of the CRC trial fabric was similar to the standard product.

Enough yarn is available from this trial to produce ~600m of knitted fabric. Some of this will be used to produce a range of trans-seasonal sample garments for assessment by commercial partners as potential new products.

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CSIRO Materials Science and Engineering, Belmont.

31 March 2010

Introduction

Traditionally wool has been regarded as a winter fibre and consequently most wool knitwear is still dyed to dark, conservative shades. One aim of the *CRC for Sheep Industry Innovation*, set up in July 2007, is to develop the know-how and technology to allow wool access to the rapidly growing market for trans-seasonal, fine gauge, next-to-skin knitwear, currently dominated by cotton and synthetic fibres. To enable wool to compete on a 'level playing field' with other fibres in this market, one significant challenge is to improve the brightness and photostability of whites and pastel shades on wool.

Table 1 The relative whiteness of wool, cotton and polyester

Condition	Fibre	Whiteness (CIE Ganz index)
Clean scoured	Wool	20-30
	Cotton	40-60
	Polyester	40-60
Bleached	Wool	30-40
	Cotton	80-90
	Polyester	90-100
Bleached, and treated with fluorescent whitener	Wool	70-120
	Cotton	120-150
	Polyester	Up to 180

Table 1 compares the whiteness of wool, cotton and polyester at different processing stages. Bleaching of wool is far less efficient than for other fibres, limiting its achievable whiteness. Our aspirational goal in this project is to improve the whiteness of wool close to that of bleached cotton.

Principal contributors to this project are The Merino Company (TMC), CSIRO Materials Science and Engineering, Australian Wool Testing Authority (AWTA) and Levana Textiles (NZ). Our plan was to source white fleece wool and to maintain its whiteness throughout processing from fleece to fabric by sampling and colour measurement at each stage.

Initially archival data from AWTA was consulted, analysing 250,000 colour measurements from pre-sale tests [1]. A clear distribution in wool yellowness was found (Figure 1), which supports previous research [2-4] and subsequent studies carried out on the CRC IN flocks [5,6] showing that scoured wool colour is a heritable trait.

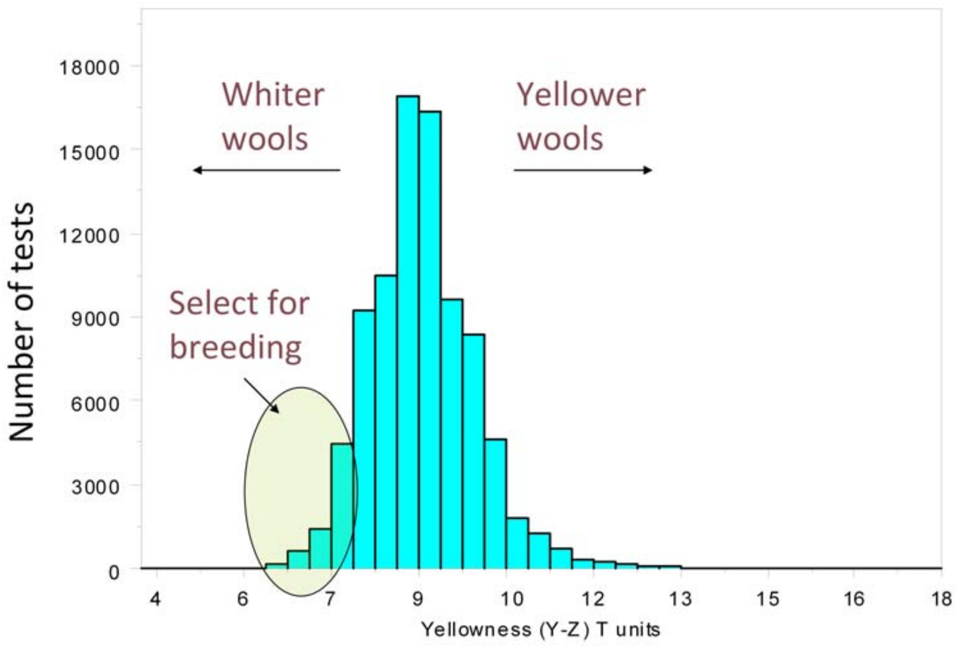

Figure 1 Histogram of measured wool yellowness (Y-Z) in colour testing carried out by AWTA (1997-2007)

If we wish to develop a supply chain for white fleece wools, we would select rams whose progeny show high wool whiteness (Y) and low yellowness (Y-Z) values and use these for breeding. There is no indication that low Y-Z is associated with any negative wool traits but it is strongly correlated to mean fibre diameter.

The CRC are strongly promoting the introduction of ASBVs for wool colour and are using the CRC information nucleus (IN) flocks to study genetic and environmental effects on wool colour and photostability. Environmental factors such as exposure to sunlight during growth and trace elemental contaminants from local soils can also affect wool colour and photostability. These are areas of ongoing research for the CRC.

The geographical distribution of the whitest wools in Australia in terms of wool statistical areas (WSAs) was also examined early in the project [1] and it was confirmed that Tasmanian and Victorian wools were amongst the whitest (Figure 2).

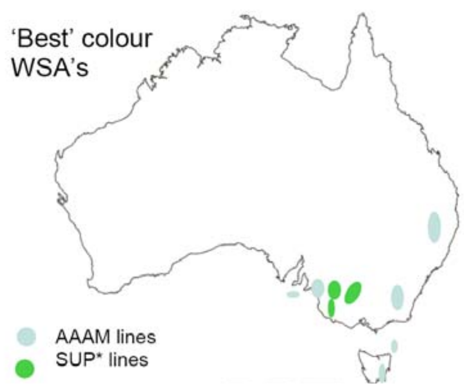

Figure 2 Wool statistical areas (WSAs) producing the whitest wools as determined from AWTA archive sale lot data 1997-2007

Analysis of the processing route suggested special care was required during scouring and shrink-resist (SR) treatment. Inefficient scouring is known to adversely affect wool colour significantly. The traditional route for commercial SR treatment of wool involves chlorination, which not only produces toxic effluent now regarded as a threat to the environment, but also causes significant yellowing of the wool. Because SR treatment is essential for next-to-skin products, we looked for alternative SR technologies and found a Chinese company in Shanghai (Shanghai Eco-life Textile Science & Technology Development Co Ltd) offering an alternative process called 3e. Not only is this process chlorine-free but it also uses hydrogen peroxide as the oxidant. Hydrogen peroxide is non-toxic and bleaches wool, improving its whiteness. The process is described in more detail below.

3e shrink resist treatment

The most common commercial shrink-resist treatment for wool is the two-stage chlorine-Hercosett (CH) process. Initially, the wool is chlorinated (using chlorine gas or chlorine gas dissolved in water), which modifies the outer scales of the fibre. Secondly, the Hercosett polymer (a polyamino-amide-epichlorhydrin resin) is applied to the wool and is spread evenly along the fibre thanks to the chlorine pre-treatment. This gives a dimensionally stable wool fabric through crosslinks formed by the polymer. Up to 40,000 tonnes of wool sliver is treated this way each year and current processes are robust and capable of treating wool of any MFD range, making it virtually unshrinkable.

Currently chlorination and the CH process are widely used commercially for the shrinkproofing of wool, most of which is now carried out in China. However unreacted chlorine in discharged waste water from the process may react with trace organics to generate harmful adsorbable organohalogen (AOX) by–products. Smaller quantities of AOX are also produced from the chlorine-containing Hercosett polymer. Organic chlorine compounds are persistent environmental contaminants and can accumulate via the food chain from simple aquatic organisms through to fish and shellfish and ultimately to humans. Every year in China, approximately 40,000 tons of wool is processed by this method and 2 million tons of chlorine-containing waste water is discharged, which results in a serious environmental threat.

According to published studies organohalogens accumulate in human lipids and body fat [7]. The textile eco-labelling Oeko-Tex Standard 100 (http://www.oeko-tex.com) states that these compounds not only damage the environment, but are also detrimental to human and animal health though the generation of carcinogens. The upper limit of AOX residue in textile fabrics is 0.5 ppm [8], and in Germany and most other European countries, the limit of AOX in drinking water is set at 1 ppm. The US Environmental Protection Agency is even stricter. Epichlorohydrin which is used in CH SR treatment is classed as toxic and carcinogenic and is not permitted, even in trace amounts, in drinking water. Hence the CH process cannot be carried out in the US.

Several eco-friendly shrink-resist technologies for wool have been described, including treatment with gaseous fluorine, with liquid ammonia, with plasma, with ozone, with enzymes and “3e-wool” shrink-proof treatment.

“3e-wool” has recently been developed by Shanghai Eco-life Textile Science & Technology Development Co. Ltd. and claims to be a chlorine-free, AOX-free, and resin-free process, which confers felting shrinkage of less than 8%. It has received Oeko-Tex Standard 100 approval. The technology is based upon the so-called Vantean process, a metal-catalysed oxidative process developed in Japan in the 1980s [9,10] which included the following steps:

1. Pretreatment of wool fibre surface with heavy metal ions eg Ni(II)
2. Treatment with an oxidising agent (hydrogen peroxide) in a saturated, strongly acidic salt solution
3. Treatment with a reducing agent (sulphite)
4. Stabilization with formaldehyde

The process can remove the cuticle almost completely, and gives the wool a lustre resembling that of more expensive fine animal fibres such as cashmere, angora and mohair. Originally the Vantean process used hypochlorite as the oxidising agent and was not an AOX-free process [9].

Shanghai Eco-life Textile Science & Technology Development Co Ltd, an affiliated company of China Textile Resource Corporation, introduced 3e-wool shrink-resist technology from Japan to China in 2003. With sustained technology innovation keeping close pace with market demand, including conversion to a chlorine-free process by using hydrogen peroxide as the oxidant, they commercialised the new 3e technology and also claim to have improved performance by cutting production costs while stabilising the quality. Appendix 1 contains a brochure on the 3e-wool process.

The two-bale commercial trial

Following discussions with The Merino Company (TMC) in Melbourne in November 2008 the commercial trial was commenced in January 2009 and completed in January 2010, having been carried out in four countries and fitted in to the production schedules of five different companies in the TMC supply chain (Table 2).

Two bales of superfine wool (MFD 18.1 μm) were sourced from Henry Foster's Merton Vale flock at Campbell Town, Tasmania with a measured Y-Z of 7.9 for conversion to fine gauge next-to-skin knitwear. Fibre and colour properties of this wool are shown in Appendix 2.

The Merton Vale wool was scoured at CSIRO in Geelong and was then shipped to China for top-making (carding and combing) and SR treatment. The SR-treated top was next shipped to Indorama in Thailand and spun into 40 tex metric singles yarn before finishing its jouney at Levana Textiles in New Zealand for knitting and finishing.

Table 2 Companies (and their location) used in 2-bale trial

Process	Company	Location
woolgrowing	Merton Vale, Campbell Town (18.1 μm)	Tasmania
scouring	CSIRO, Belmont	Victoria
topmaking	Nanhai Pindar, Guangdong	China
combing	Nanhai Pindar, Guangdong	China
shrink-resist treatment (Cl_2-free)	Shanghai Eco-life, Shanghai	China
yarn spinning	Indorama	Thailand
knitting	Levana Textiles	New Zealand
finishing	Levana Textiles	New Zealand

Levana knitted up the CRC trial fabric and finished it in the same manner as for their standard commercial product in an undyed shade ('Toi Toi'). For this shade a double bleaching process is applied with an optical brightener (Uvitex NFW 0.5% owf) present in the reductive bleach bath.

Table 3 shows that the CRC trial fabric is significantly whiter than three batches of the standard commercial product. Here fabric colour was measured on a Gretag Macbeth Color-Eye 7000A spectrophotometer using the large 25 mm diameter aperture, two thicknesses of test fabric and a dense white backing fabric. The spectrophotometer was configured with a D65 light source and a 10^o collection angle with the spectral component included (SCI). The tristimulus values X, Y and Z were measured by averaging 2 reads and used to calculate the wool yellowness (Y-Z). The magnitude of the improvement is 30–40 CIE Ganz index points for fabric finished identically and 10–20 points for fabric where the oxidative bleaching stage during finishing was omitted.

Table 3 Colour measurements on finished Toi Toi knit fabric produced via standard commercial and CRC processing routes

Fabric	X	Y	Z	Y-Z	WI GANZ 82
unfinished 631655	65.3	69.6	59.9	9.7	-
standard route batch 631655	74.9	78.4	84.4	-6.1	80.6
standard route batch 849233	75.0	78.5	85.7	-7.2	89.7
standard route batch 839179	73.6	76.8	83.2	-6.4	82.3
unfinished CRC fabric	65.0	69.0	63.4	5.6	-
CRC route reductive bleach only	74.3	77.3	86.1	-8.8	101.1
CRC route double bleached	74.7	77.5	88.9	-11.4	120.0

Initially we were concerned that treating wool twice with hydrogen peroxide during processing (first in the 3e SR stage and secondly during fabric finishing) may cause fibre damage and hence affect handle, but the effects of two peroxide treatments on handle appear to be minimal. A 30–40 CIE Ganz index point improvement in colour for the CRC trial fabric over the standard commercial route for this shade is a very significant and exciting result from the first trial. It shows that large improvements in wool whiteness are possible by careful selection of the initial fleece wool and use of an optimised processing route with low impact on colour at every stage.

Yellowness and photostability through each stage of processing

It was of interest to determine the changes in wool colour through each stage of processing. Previous work by Cottle and Zhao followed colour changes in seven lots of Australian merino fleece wool through from greasy wool to top [11]. They found that although the brightness (Y) improved slightly during processing, yellowness (Y-Z) also slightly increased which is a negative outcome from our perspective. A similar study by Mahar and Osbourne [12] reported very similar brightness and yellowness values at the greasy and top stages. Nobody has yet reported colour data on the same fleece wool taken right through to fabric, and one of the reasons is that it is difficult to compare colour measurements taken on loose fibre to measurements taken on yarn and fabric due to the presence of a window material, differences in fibre packing density and possibly fibre alignment. Fibre packing density has a profound effect on the tristimulus values X, Y and Z [13].

Figure 3 Small sample card at CSIRO

There were two potential methods to enable all colour measurements to be taken on the same playing field. Either loose fibre samples would have to be converted to yarn and fabric, or yarn and fabric would have to be somehow reverted to loose fibre. The latter option looked to be the more feasible since ragging machinery is known that can reclaim the fibre from used or waste textiles for recycling. We explored the use of a small sample card at CSIRO (Figure 3) on yarn and knitted fabric to regenerate loose fibre.

The procedure used small (approximately 2 x 2 cm) squares of knitted fabric and ~15cm lengths of cut yarn. The card was first cleared using undyed raw polyester fibre and then wool fabric or yarn was placed on the in-feed belt of the card and slowly fed in. A very loose mass of separated fibre mixed with starting materials was obtained near the doffer end of the card and this was put through the machine a number of times until sufficient loose fibre was obtained for colour and photostability testing. Clearly the fibre length would be significantly shorter after after several passes, but previous work has shown that fibre length has very little effect on tristimulus values [13]. Colour measurements were carried out using the CSIRO method for small fleece wool samples [14-16] since this method has the advantage that it requires only 0.5 g of fibre, and data are shown in Table 4.

Table 4 Colour measurements from 2-bale trial after each processing stage

Form	X	Y	Z	Y-Z
greasy wool	45.3	47.4	41.7	5.7
scoured wool	59.4	62.8	58.1	4.7
carded wool	61.1	64.5	59.2	5.4
combed wool	59.1	62.3	57.2	5.1
3e-treated wool top	65.6	69.5	66.4	3.0
yarn wrapped around card	72.4	76.6	69.6	7.0
yarn single length packed in cell	58.1	61.6	58.1	3.5
chopped yarn packed in cell	59.2	62.7	59.5	3.2
fibre from yarn carded 1 pass	64.5	68.4	64.5	3.9
fibre from yarn carded 2 passes	66.0	69.9	66.5	3.5
fibre from yarn carded 3 passes	64.7	68.5	65.5	3.1
fibre from yarn carded 4 passes	66.0	69.9	66.7	3.2
fibre from yarn carded 5 passes	67.2	71.2	67.6	3.6
fibre from yarn carded 6 passes	66.8	70.7	67.2	3.6
unfinished CRC fabric measured as fabric	70.8	75.0	66.1	8.9
unfinished CRC fabric carded 1 pass	64.8	68.6	65.4	3.3
unfinished CRC fabric carded 2 passes	66.7	70.7	67.4	3.2
toi toi CRC fabric measured as fabric	74.3	77.3	86.1	-8.8
toi toi CRC fabric carded 1 pass	69.1	71.7	82.3	-10.6
toi toi CRC fabric carded 2 passes	70.3	73.0	83.2	-10.2

It is clear that XYZ tristimulus values for colour measurements taken on wrapped yarn or fabrics are significantly higher than those taken on loose fibre packed into a spectrophotometer cell at constant density. Direct measurements of fabric and yarn are highlighted in yellow in Table 4. These also give much higher yellowness (Y-Z) values than loose fibre.

A plot showing yellowness at each stage from greasy wool through to finished fabric is shown in Figure 4. This shows a small increase in yellowness during carding and combing, possibly due to lubricants, followed by a large improvement in whiteness following 3e SR treatment as expected. The large decrease in Y-Z after finishing is due to the application of the OB (Uvitex NFW 0.5% owf).

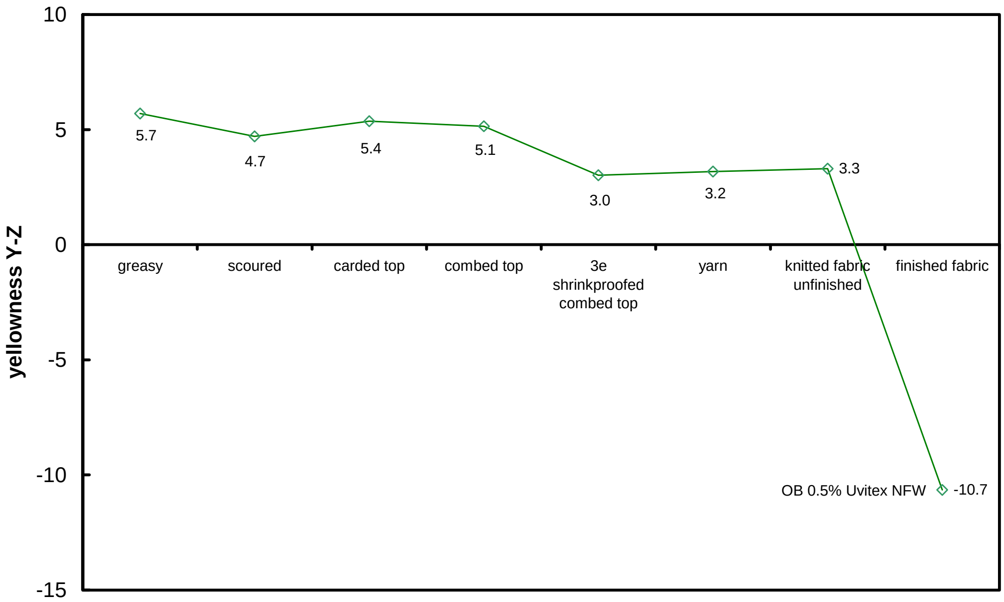

Figure 4 Changes in fibre yellowness (Y-Z) during processing measured using CSIRO small sample method

The corresponding plot of wool brightness Y against processing stage is shown in Figure 5.

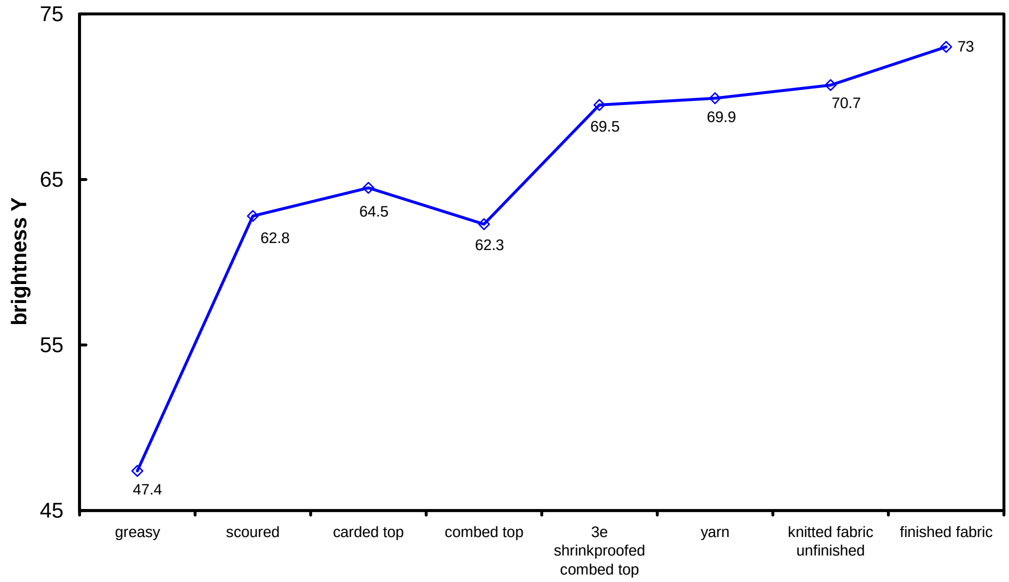

Figure 5 Changes in fibre brightness (Y) during processing measured using the CSIRO small sample method

We have also looked at the effects of each processing stage on photostability, shown in Figure 6. The application of an OB decreases the photostability of the CRC trial wool significantly as expected, but it is similar to that of other TMC batches of Toi Toi shade (see Figure 7).

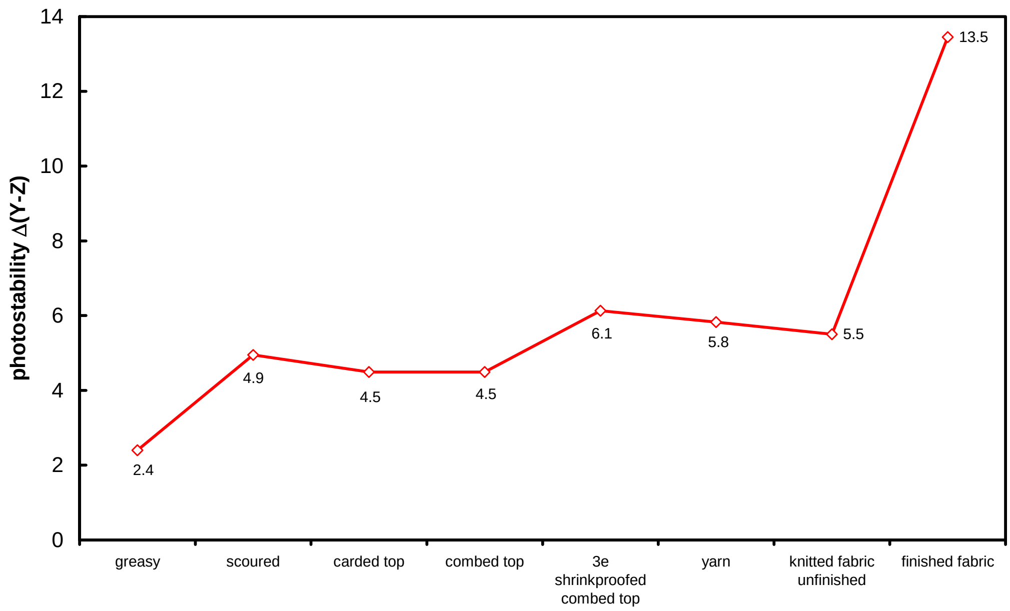

Figure 6 Changes in photostability Δ(Y-Z) during processing measured using the CSIRO small sample method

Future tasks include assessing the benefits of improved wool whiteness for achieving bright pastel shades on wool compared with cotton fabric. Also we are assessing any potential benefits of the optimised processing route on the comfort and handle properties of the fabric, and also pilling performance. A range of sample garments are also being produced for exhibition at textile and garment fairs and to generate commercial interest.

Photostability results on finished fabric

The photostability of finished Toi Toi fabric samples prepared via TMC's standard commercial route and the CRC colour-optimised processing route were compared. Fabric samples were irradiated in a Hereaus Suntest CPS accelerated weathering machine (xenon arc) fitted with a combination of quartz and dichroic filters to produce a spectral distribution similar to sunlight and a water-cooled sample stage to minimise thermal yellowing during exposure. Dry irradiation of wool samples was performed over 12 h (Fig. 7), while exposure of wet samples was carried out for 60 min in sealed polyethylene bags having negligible absorption >280 nm (Fig.8).

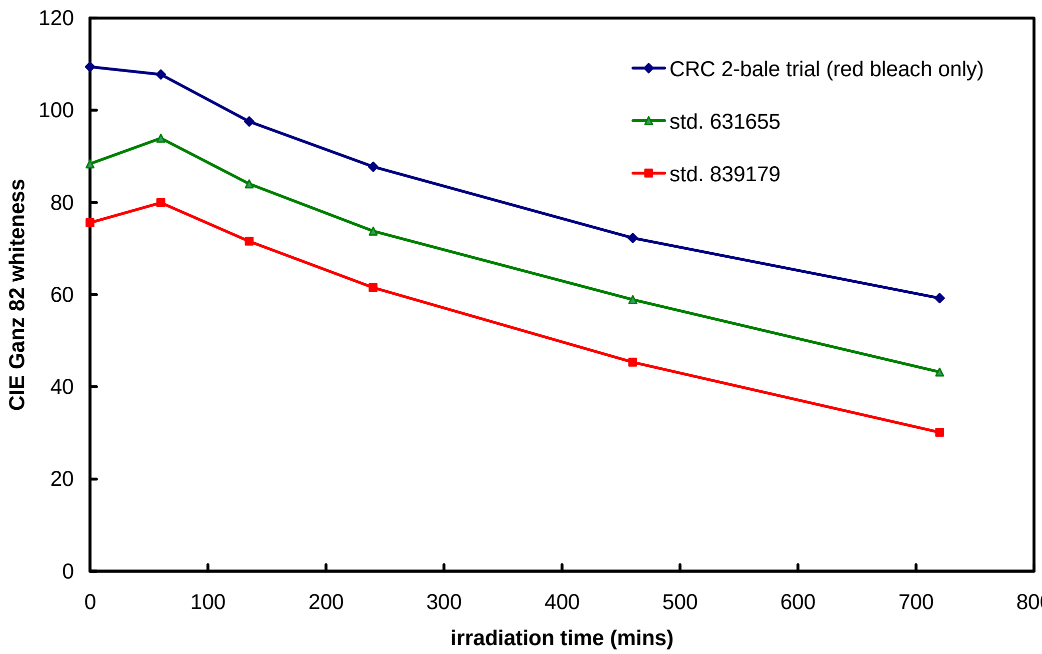

Figure 7 Dry photoyellowing of finished Toi Toi knitted fabrics with simulated sunlight

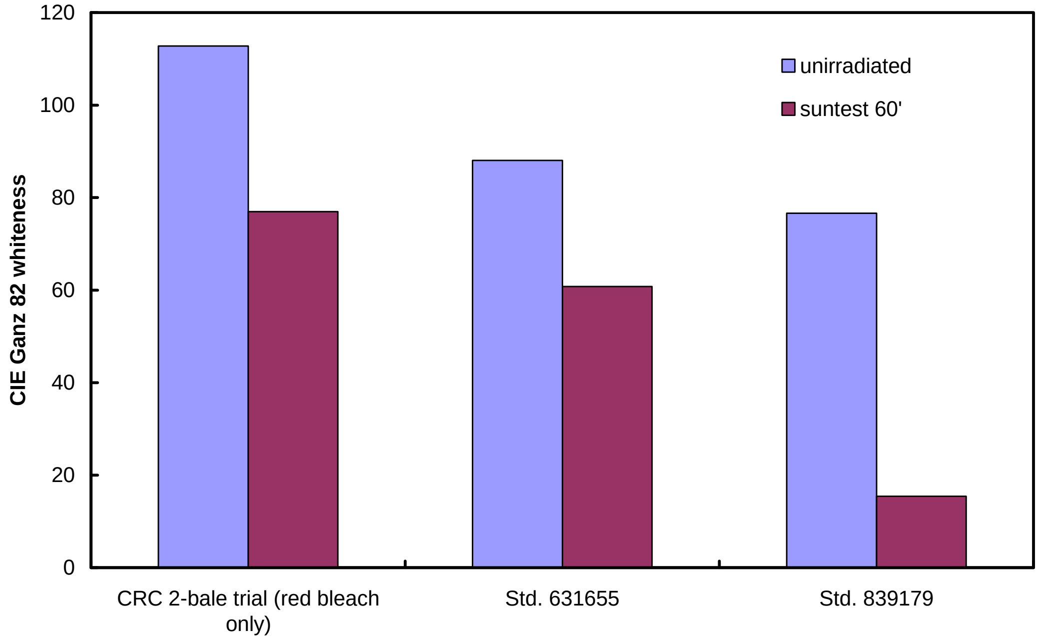

Figure 8 Wet photoyellowing of finished Toi Toi fabrics with simulated sunlight

Figure 7 shows that for t>60m the decrease of whiteness with time is very similar for the CRC trial fabric and the two fabrics prepared via the standard commercial route. This suggests that the dominant factor controlling the rate of photoyellowing for each of the fabrics is the presence of the optical brightener (OB), and any changes in photostability due to the different processing route are second order.

Figure 8 shows the significant decrease in whiteness following wet exposure to simulated sunlight. Once again this poor photostability is mainly due to the presence of the optical brightener. It may be possible to improve the photostability of OB-treated wool by using an antioxidant-metal chelator rinse during the finishing process [17]. Although this is not a substantive permanent treatment, it is effective under both wet and dry conditions and can also further improve whiteness.

Comparison of photostability of different fibres

Is was of interest to measure the photostability of a range of raw fibres using the CSIRO small sample test method [16] and compare the data with wool from each stage of the trial. Data is shown in Figure 9. All of the fibres underwent photoyellowing following exposure to UVB radiation for 4h except for bleached cotton, which underwent slight photobleaching. Photobleaching of bleached cotton was confirmed in two repeat tests, showing that it has very high photostability to UVB. The presence of lignins in scoured cotton causes slight photoyellowing but these are very effectively removed during bleaching.

The plot confirms that wool has the worst photostability of all of the fibres tested as expected. Photostability will need to be monitored closely during the development of new bright wool products

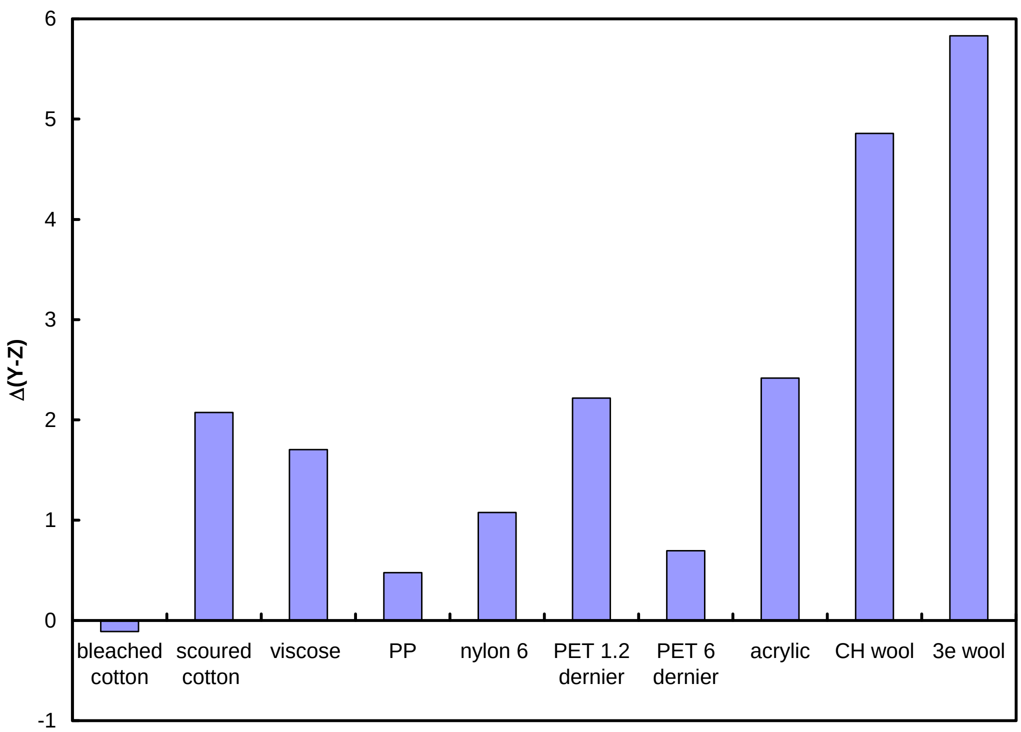

Figure 9 Photostability Δ(Y-Z) of different fibres measured using the CSIRO small sample method

Shrink resist testing

Samples of the three standard TMC fabrics and the CRC trial fabric, all finished to the toi toi shade, were assessed for relaxation and felting shrinkage according to IWS standard method TM31 involving one 7A and one 5A wash cycle. All of the fabrics performed satisfactorily, and data is shown in Appendix 3.

Pilling performance

Samples of the three standard TMC fabrics and the CRC trial fabric, all finished to the toi toi shade, were assessed for resistance to pilling. The Atlas random tumble pilling test (RTPT) was used (ASTM D-3512) and samples were rated from 1 to 5 after 30 minutes tumbling according to:-

5- no pilling
4- slight pilling
3- moderate pilling
2- severe pilling
1- very severe pilling

Table 5 Pilling performance of finished Toi Toi fabrics

Fabric	RTPT rating (30m)
standard batch 631655	4-5
standard batch 849233	4-5
standard batch 839179	3-4
CRC fabric reductive bleach only	4-5

Three out of the four fabrics performed well and rated 4-5, including the CRC trial fabric, which had a slightly cleaner surface after testing.

Colour stability to washing

Samples of the finished CRC fabric were washed at Levana Textiles according to their standard method using a 50°C machine wash on wool cycle using a wool-approved detergent followed by a tumble dry set to low heat setting. This process was repeated up to 4 times.

Colour measurements were made at CSIRO on the Gretag Macbeth Color-Eye 7000A spectrophotometer using the large 25 mm diameter aperture, two thicknesses of test fabric and a dense white backing fabric.

Table 6 Results of colour stability to washing test at Levana Textiles

Name	X	Y	Z	Y-Z	WI-GANZ
CRC fabric before wash	77.0	79.9	93.0	-13.2	132.5
CRC fabric after 1 wash	76.6	79.7	93.3	-13.6	135.7
CRC fabric after 2 washes	75.6	78.8	91.9	-13.1	132.5
CRC fabric after 3 washes	75.0	78.2	91.5	-13.3	133.6
CRC fabric after 4 washes	73.7	76.9	89.7	-12.8	130.8

Table 6 shows that the whiteness of the CRC fabric is highly stable to laundering under appropriate conditions.

Conclusions

Analysis of the results from the 2-bale trial so far has shown it to have been very successful.

- an improvement in whiteness of 30–40 CIE Ganz points was observed for the trial fabric finished in Toi Toi shade, compared to three different standard commercial batches. This is an exciting result for the first trial.
- the clean colour of the Merton Vale wool used in the trial (Y-Z=7.9) is whiter than average, but could certainly be improved on further.
- no significant negative effects (eg. poorer SR or pilling performance, coarser handle) of optimising the processing route for whiteness have been observed. Other fabric properties appear to be very similar.

From this trial we now have enough yarn available to produce ~600m of knitted fabric which is equivalent to >420 garments, depending on style and size.

Future studies will include:-

- dyeing trials to produce brightest possible pastel shades on wool to compare with knitted 100% cotton for the trans-seasonal market.
- handle assessment of knitted fabric prepared via the optimised CRC route compared with TMC standard route using Phabrometer.
- preparation of a range of trans-seasonal sample garments for assessment by commercial partners as potential new products.
- assessment and optimisation of photostability of bright shades on wool.

Acknowledgements

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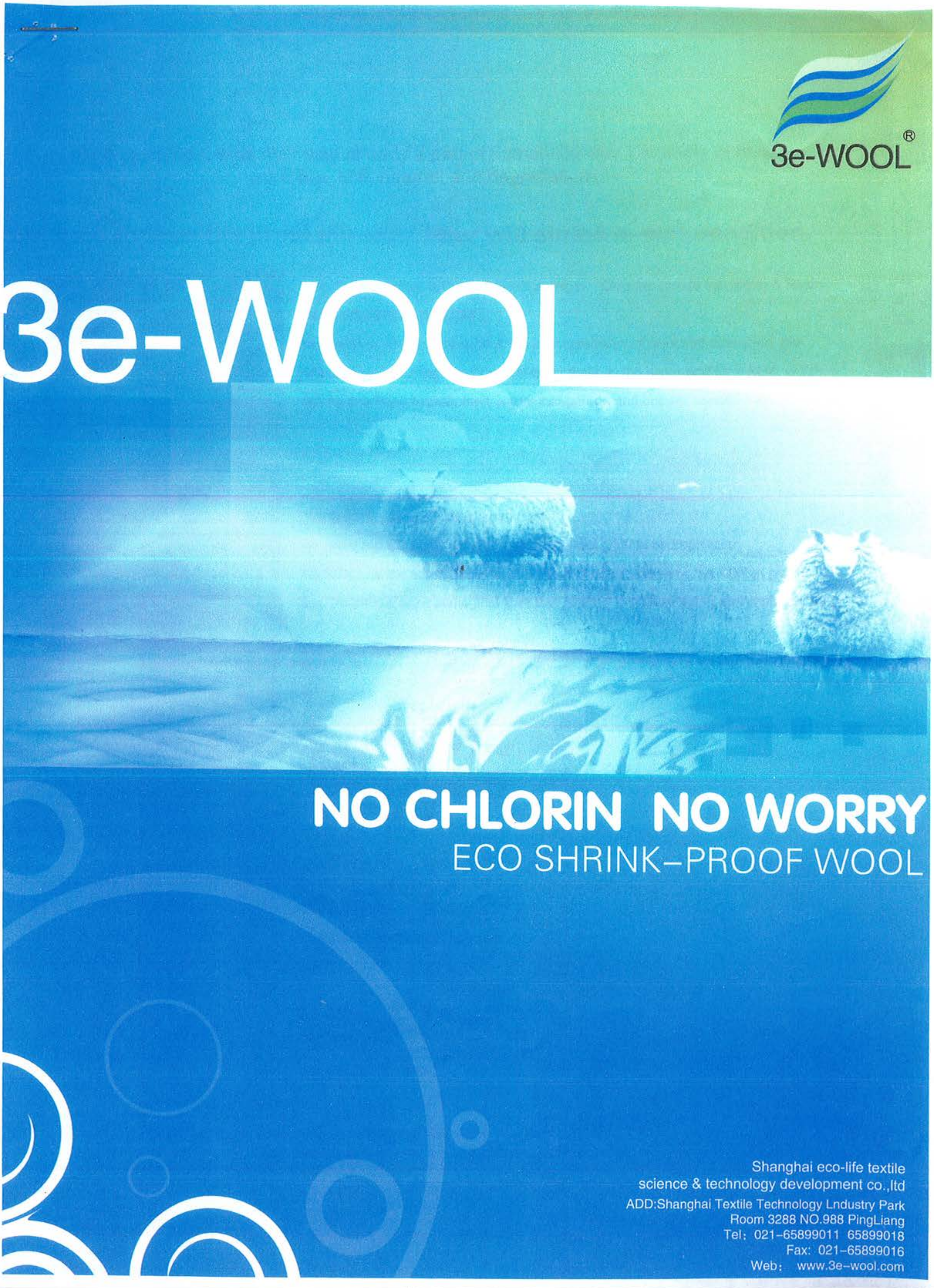
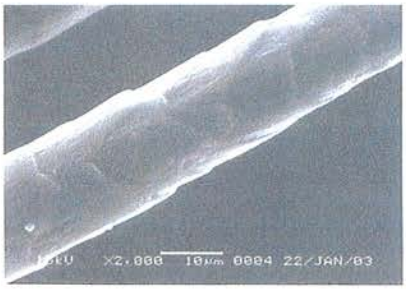
Appendix 1 Brochure on 3e-Wool


3e-WOOL®
3e-WOOL
NO CHLORIN NO WORRY
ECO SHRINK–PROOF WOOL
Shanghai eco-life textile
science & technology development co.,ltd
ADD:Shanghai Textile Technology Lndustry Park
Room 3288 NO.988 PingLiang
Tel: 021-65899011 65899018
Fax: 021-65899016
Web: www.3e-wool.com

2500 years ago, wool fiber was already a part of human life with it is ability of heat retention, soft, natural, and degradation.

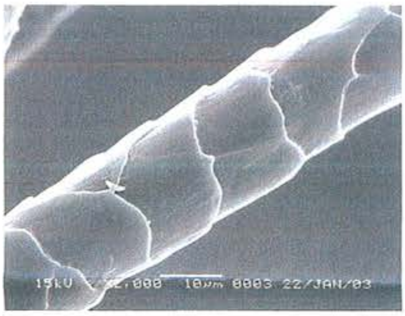
We have to face the problem: wool fiber will shrink in wet condition.



Traditional shrink-proof technology: Chlorine (erode the scale) & Resin

By hydrophobicity principle

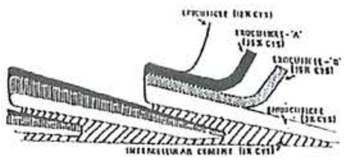
In traditional chlorine treatment, the characteristics of wool had damnified, the sewage has chemical reaction with the organic in the water and form AOX, which will be absorbed by fish, then enters into person and causes cancer.



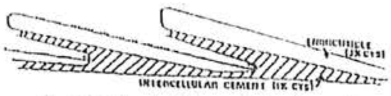
3e-WOOL: H2O2 & fiber movement

By changing the scale without damaging wool original hydrophilicity

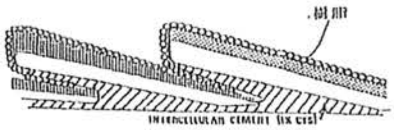
3e-WOOL is the shrink-proof wool without chlorine and resin, no AOX In processing. 3e-WOOL is an ecological fiber that is good to human being and environment.



wool fiber



3e-WOOL shrink proof treatment



chlorin and resin shrink proof treatment

After scale surface analysis, 3e-wool fiber shows better properties than the fiber treated by chlorin and resin

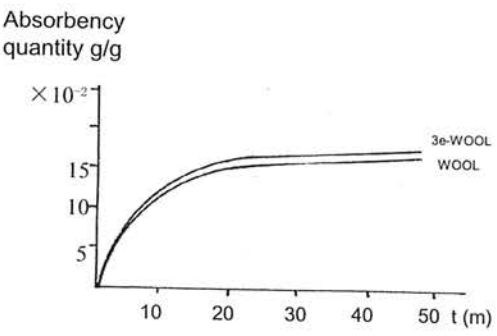
3e-WOOL products meet IWS TM 31 standard, making the products easier care.

		2/30	2/32	2/48	2/48
		3e-WOOL	Common	3e-WOOL	Common
Relaxation shrinkage (%) 7A×1	T	1.6	4.9	2.9	3.7
	F	0.9	4.0	2.4	3.4
	area.	2.5	8.9	5.3	7.1
Felting shrinkage (%) 5A×3	T	-1.0	45.5	-2.0	40.6
	F	-0.1	34.3	-1.8	29.1
	area.	-1.1	79.8	-3.8	69.7
Felting shrinkage (%) 5A×5	T	3.7	48.1	-1.1	45.0
	F	-2.2	36.5	-1.6	32.6
	area.	1.5	84.6	-2.7	77.6

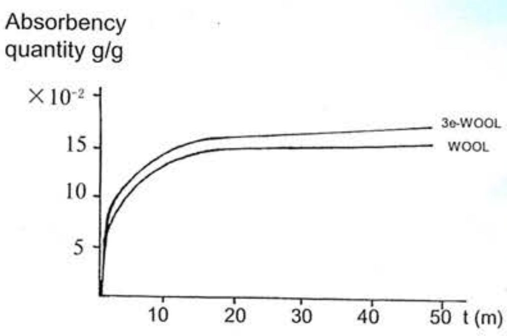
From the test, 3e-WOOL anti-pilling ability is the best comparing common wool and other shrink-proof wool.

		Common wool	Chlorinated treatment	3e-WOOL
count		2/48	2/48	2/48
twist		530	526	526
Anti-pilling	1	1-2	2	3-4
	2	1-2	2-3	4

From the test, the hygroscopicity of 3e-WOOL is better than that of common wool in different humidity, which means that 3e-WOOL treatment not only does not damage wool original hydrophilicity,but also keep and strengthen wool natural characteristics.



Humidity 22.8 % · Temperature 20 ℃



Humidity 75.4 % · Temperature 20 ℃

ecological essential easy care

3e-WOOL®

3e-WOOL Oeko- Tex Standard 100 Certificate

3e-WOOL treatment is the unique technology in the world, which has applied patent in America, Australia , China, China(Taiwan), Japan, Korea, New Zealand, South Asia and and is applying patent in Canada, England, Europe.

3e-WOOL characteristic

No chlorine and resin

Machine washable

Anti-pilling

Anti-bacterial and odor destroying

No skin scratchiness

Heat preservation and hygroscopicityMore comfortable

3e-WOOL®

Appendix 2   AWTA data on Merton Vale wool

AUSTRALIAN WOOL TESTING AUTHORITY LTD

Reg'd. Office: 70 Robertson Street, Kensington, Victoria 3031 P.O. Box 240, North Melbourne 3051 Tel: (03) 9371 4100 Fax: (03) 9371 4191

A.B.N. 43 006 014 106

COLOUR TEST CERTIFICATE

ORIGINAL

3-08849915-C1

TEST METHOD IWTO-56

PAGE 1

7 BALES

REF. W L 524 *HF/MERTON VALE *AAA M

246177

TOTAL BALE WEIGHTS:

TEST HOUSE GROSS 1 213 KG TARE 14 KG NETT 1 199 KG

*HF/MERTON VALE *AAA M

BALE NO.	GROSS	*TARE	NETT	BALE NO.	GROSS	*TARE	NETT
783	149	2	147	806	175	2	173
789	201	2	199	811	184	2	182
797	193	2	191	827	135	2	133
801	176	2	174				

GROSS 1 213 KG TARE 14 KG NETT 1 199 KG

IWTO Licensed Nº 7

I.W.T.O.

ILRT MEMBER

TEST RESULTS:

			C/2	D65/10
			======	======
1.	COLOUR	(X) :	63.4	68.2
2.	COLOUR	(Y) :	65.1	72.1
3.	COLOUR	(Z) :	65.3	64.2
4.	YELLOWNESS	(Y-Z) :	- 0.2	7.9

ADDITIONAL INFORMATION:

CHARGE: $ 17.61 GST @ 10% : $ 1.76 TOTAL CHARGE: $ 19.37

NO FURTHER PAGES

TEST CONDUCTED AT MELBOURNE LABORATORY

NATA

Accreditation No. 2859

This document is issued in accordance with NATA's accreditation requirements

08.2479 08 31296 0111 68.2 72.1 64.2 308756613 35048942 35012451 ISSUED ON 07.01.2009, PRINTED ON 07.01.2009 TMCM 5

For and on behalf of Australian Wool Testing Authority Ltd

MICHAEL A. JACKSON B.Sc.(Hons)
MANAGING DIRECTOR

Ian Ashman

IAN A ASHMAN B.Sc
GENERAL MANAGER – RAW WOOL

AUSTRALIAN WOOL TESTING AUTHORITY LTD A.C.N. 006 014 106 COMMON SEAL

CLIENT USE ONLY

7343

IWTO TEST CERTIFICATE

3-08883363-P1 *CLASSED GROWER LOT — TEST METHODS IWTO-19,12 — PAGE 1

ROBERTS WOOL - TASMANIA LAUNCESTON 2 BALES

REF. L99L 1880 *HF/MERTON VALE *AAA M 253723

TOTAL BALE WEIGHTS:

TEST HOUSE GROSS 348 KG TARE 4 KG NETT 344 KG

*HF/MERTON VALE *AAA M

BALE NO.	GROSS	*TARE	NETT	BALE NO.	GROSS	*TARE	NETT
801	174	2	172	806	174	2	172

GROSS 348 KG TARE 4 KG NETT 344 KG

TEST RESULTS:

1. WOOL BASE - 2 SUBSAMPLES 61.82 %
2. MEAN FIBRE DIAMETER - 4 SPECIMENS 18.1 MICRONS
3. COEFFICIENT OF VARIATION OF DIAMETER 22.1 %
4. VEGETABLE MATTER BASE 0.8 %
   INCLUDING **** % HARD HEADS-TWIGS

CALCULATED COMMERCIAL YIELDS & CLEAN MASSES:

5. IWTO SCHLUM DRY T&N YIELD (1.0%TFM) 71.6 % 246 KG
6. IWTO SCOURED YIELD at 17% REGAIN 75.0 % 258 KG
7. JAPANESE CLEAN SCOURED YIELD 72.8 % 250 KG
8. AUSTRALIAN CARBONISING YIELD 69.0 % 237 KG

ADDITIONAL INFORMATION:

9. MEAN FIBRE CURVATURE 66 DEG/MM
10. COMFORT FACTOR 99.6 %
11. VEGETABLE MATTER COMPOSITION
    (B) 0.1 (S) 0.7 (H) 0.0

DECLARED INFORMATION:

12. *DARK & MEDULLATED FIBRE RISK ND
13. *MULESING STATUS ND

CHARGE: $ 39.45 GST @ 10% : $ 3.94 TOTAL CHARGE: $ 43.39

CONTINUED ON NEXT PAGE

TEST CONDUCTED AT MELBOURNE LABORATORY
BALES SAMPLED AT LAUNCESTON ON 09.02.2009
AWTA LTD SERVICE TIME 2.3 DAYS

12.0036 12 32387 0010 35130167 35090830 ISSUED ON 11.02.2009, PRINTED ON 16.02.2009 ROBL 2

INTO STAPLE TEST CERTIFICATE

3-08883542-LO

TEST METHODS IWTO-7,30

PAGE 1

ROBERTS WOOL - TASMANIA LAUNCESTON 2 BALES

REF. L99L 1880 *HF/MERTON VALE *AAA M

253723

TOTAL BALE WEIGHTS:

TEST HOUSE GROSS 348 KG TARE 4 KG NETT 344 KG

*HF/MERTON VALE *AAA M

BALE NO.	GROSS	*TARE	NETT	BALE NO.	GROSS	*TARE	NETT
801	174	2	172	806	174	2	172

GROSS 348 KG TARE 4 KG NETT 344 KG

TEST RESULTS:

1. MEAN STAPLE LENGTH - 64 STAPLES 94 MM
2. COEFFICIENT OF VARIATION OF STAPLE LENGTH 12 %
3. MEAN STAPLE STRENGTH - 62 STAPLES 37 NEWTONS/KTEX
4. DISTRIBUTION OF POSITION OF BREAK:
   - BROKE IN THE TIP REGION 2 %
   - BROKE IN THE MIDDLE REGION 4 %
   - BROKE IN THE BASE REGION 94 %

ADDITIONAL INFORMATION:

CHARGE: $ 20.09 GST @ 10% : $ 2.00 TOTAL CHARGE: $ 22.09

NO FURTHER PAGES
TEST CONDUCTED AT MELBOURNE LABORATORY

12.003612 15554 0109 61.82 .80 308883363 35107038 35090830 ISSUED ON 11.02.2009, PRINTED ON 16.02.2009 ROBL 4

COLOUR TEST CERTIFICATE

3-08884041-C2 TEST METHOD IWTO-56

PAGE 1

ROBERTS WOOL - TASMANIA LAUNCESTON 2 BALES *HF/MERTON VALE *AAA M

REF. L99L 1880 *HF/MERTON VALE *AAA M

253723

BALE NO.	GROSS	*TARE	NETT	BALE NO.	GROSS	*TARE	NETT
801	174	2	172	806	174	2	172

GROSS 348 KG TARE 4 KG NETT 344 KG

TOTAL BALE WEIGHTS:

TEST HOUSE GROSS 348 KG TARE 4 KG NETT 344 KG

TEST RESULTS:

			C/2	D65/10
1. COLOUR	(X)	:	58.9	63.7
2. COLOUR	(Y)	:	60.7	67.4
3. COLOUR	(Z)	:	60.9	59.9
4. YELLOWNESS	(Y-Z)	:	- 0.2	7.5

ADDITIONAL INFORMATION:

CHARGE: $ 8.24 GST @ 10% : $ 0.82 TOTAL CHARGE: $ 9.06

NO FURTHER PAGES
TEST CONDUCTED AT MELBOURNE LABORATORY

12.0036 12 32387 0147 63.7 67.4 59.9 308883363 35125039 35090830 ISSUED ON 11.02.2009, PRINTED ON 16.02.2009 ROBL 5

Received Time 16. Feb. 2009 15:11 No. 5931

Appendix 3 IWS TM31 Shrinkage Test Data

CSIRO

CSIRO- Materials Science & Engineering (ABN: 41 687 119 230)
Henry St, Belmont, Victoria 3216, Australia.
Telephone: (03) 52464000 Fax: (03) 52464057
Email: texlab@csiro.au Web: http://www.tft.csiro.au

Textile Testing Laboratory

TEST REPORT

Report Number: 10-0147 **Date Issued:** 11/03/10
Client: Michael Jones

Sample Description: 4 x knitted samples
Sample Reference: 839179; 849233; 631655; CSIRO

Test Method	Result	Unit
IWS TM 31- 2000		
Washing of Wool Textile Products		
839179		
Relaxation Shrinkage		
Length	-1.8	%
Width	-0.5	%
Felting Shrinkage		
Length	-1.6	%
Width	-1.1	%
Total Shrinkage		
Length	-3.4	%
Width	+0.6	%
849233		
Relaxation Shrinkage		
Length	+1.5	%
Width	-4.6	%
Felting Shrinkage		
Length	+0.1	%
Width	-0.2	%
Total Shrinkage		
Length	+1.7	%
Width	-4.8	%

Note: Relaxation Shrinkage measured after 1 x ISO 6330 7A cycle + line dry.
Felting Shrinkage measured after 1 x ISO 6330 5a cycle + line dry.

Approved by: **D.R. Carroll - Laboratory Manager**

CSIRO- Materials Science & Engineering **(ABN: 41 687 119 230)**
Henry St, Belmont, Victoria 3216, Australia.
Telephone: (03) 52464000 Fax: (03) 52464057
Email: texlab@csiro.au Web: http://www.tft.csiro.au

CSIRO

Textile Testing Laboratory

TEST REPORT

Report Number: 10-0147 **Date Issued:** 11/03/10
Client: Michael Jones

Sample Description: 4 x knitted samples
Sample Reference: 839179; 849233; 631655; CSIRO

Test Method		Result	Unit
IWS TM 31- 2000			
Washing of Wool Textile Products			
631655			
Relaxation Shrinkage			
	Length	+3.5	%
	Width	-0.8	%
Felting Shrinkage			
	Length	-0.7	%
	Width	+0.2	%
Total Shrinkage			
	Length	+2.7	%
	Width	-0.6	%
CSIRO			
Relaxation Shrinkage			
	Length	-0.8	%
	Width	-1.6	%
Felting Shrinkage			
	Length	-0.5	%
	Width	+0.3	%
Total Shrinkage			
	Length	-1.2	%
	Width	-1.3	%

Note: Relaxation Shrinkage measured after 1 x ISO 6330 7A cycle + line dry.
Felting Shrinkage measured after 1 x ISO 6330 5a cycle + line dry.

Approved by: **D.R. Carroll - Laboratory Manager**

Formulas checked MS 3/7/02								**Project No:.**		10-0141
								Date:		10/03/2010
								Operator:		KW

Relaxation and Felting Shrinkage (TM31)

Measurements

839179	**Original**				**7A**				**5A**	
	L(mm)	**W(mm)**			**L(mm)**	**W(mm)**			**L(mm)**	**W(mm)**
	257.00	179.00			250.00	180.00			245.00	181.00
	255.00	181.00			250.00	179.00			247.50	180.00
	255.00	180.00			253.00	178.50			248.50	182.50
Av	**255.67**	**180.00**			**251.00**	**179.17**			**247.00**	**181.17**
				RS %	-1.83	-0.46		FS%	-1.59	1.12
								TS%	-3.39	0.65
849233	**Original**				**7A**				**5A**	
	L(mm)	**W(mm)**			**L(mm)**	**W(mm)**			**L(mm)**	**W(mm)**
	240.50	170.00			245.00	165.00			245.00	163.50
	239.00	168.50			240.00	160.50			241.50	160.50
	238.50	170.00			244.00	159.50			243.50	160.00
Av	**239.33**	**169.50**			**243.00**	**161.67**			**243.33**	**161.33**
				RS %	1.53	-4.62		FS%	0.14	-0.21
								TS%	1.67	-4.82
631655	**Original**				**7A**				**5A**	
	L(mm)	**W(mm)**			**L(mm)**	**W(mm)**			**L(mm)**	**W(mm)**
	237.50	170.00			247.00	168.50			244.50	171.00
	237.50	170.50			245.00	168.00			244.00	165.50
	240.00	170.00			248.00	170.00			246.00	171.00
Av	**238.33**	**170.17**			**246.67**	**168.83**			**244.83**	**169.17**
				RS %	3.50	-0.78		FS%	-0.74	0.20
								TS%	2.73	-0.59
CSIRO	**Original**				**7A**				**5A**	
	L(mm)	**W(mm)**			**L(mm)**	**W(mm)**			**L(mm)**	**W(mm)**
	241.00	173.50			241.00	173.50			239.00	173.00
	239.50	171.50			237.50	167.00			235.00	167.50
	240.00	169.00			236.50	165.50			237.50	167.00
Av	**240.17**	**171.33**			**238.33**	**168.67**			**237.17**	**169.17**
				RS %	-0.76	-1.56		FS%	-0.49	0.30
								TS%	-1.25	-1.26