



Unpublished Report

Document ID:	SheepCRC_11_23
Title:	Determination of fleece wool colour and photostability on compressed discs of fibre snippets
Author:	Zhang, H.; Millington, K.' Wang, X.
Key words:	wool; colour; testing; compressed disk; fibre snippets

This report was prepared as part of the Sheep CRC Program 2007-2014. It is not a refereed publication. If the report is quoted it should be cited as:

Sheep CRC Report 11_23



Sheep CRC Colour Program – Deakin Component

**Determination of fleece wool colour and photostability on
compressed discs of fibre snippets**

March 2009

Hu Zhang¹, Keith R. Millington², and Xungai Wang¹

¹Centre for Material and Fibre Innovation, Deakin University

²CSIRO Materials Science and Engineering

Background

The use of small compressed discs of fibre snippets for measurement of wool colour and photostability before and after exposure to UV radiation and simulated sunlight has recently been demonstrated [1].

The current colour test for fleece wools recommended by International Wool Textile Organization requires about 5g minimum of clean wool (IWTO-56-03: Method for the measurement of colour of raw wool). This study describes an alternative method using a small amount of clean fibre (1-2g) from a midside sample converted into snippets and subsequently used to press a number of compressed discs for colour and photostability testing. A conventional textile reflectance spectrophotometer fitted with a small port can measure colour of wool discs directly, rather than through glass according to IWTO-56-03. Moreover, the pressed discs should be more robust than the fibre for photostability testing.

Objectives of the study

- 1) to determine fleece wool colour on compressed discs made by fibre snippets
- 2) to evaluate the photostability of different fleece wools under UVB irradiation

Experimental

Material

Ten samples of mid-side fleece wools were sourced from different sheep from SARDI Turretfield flocks and supplied with marked numbers shown in Table 1.

Table 1. SARDI fleece wool samples.

No.	Fleece wool sample	No.	Fleece wool sample
No.1	61928.6	No.11	61923.1
No.2	61930.1	No.12	61945.2
No.3	61917.2	No.13	61920.5
No.4	61910.2	No.14	62020.0
No.5	61915.0	No.15	61914.6
No.6	61942.6	No.16	62023.3
No.7	62022.2	No.17	62010.4
No.8	62000.1	No.18	62005.6
No.9	61979.1	No.19	61950.0
No.10	61933.4	No.20	61909.1

Disc preparation



Figure 1. Cutting machine used to obtain wool snippets.

Wool snippets were prepared by chopping loose scoured wool fibre into short snippets which varied in length from a few millimetres to several centimetres in length using an automated Fritsch Pulverisette 19 cutting machine (Figure 1). Visible foreign matter in the fibre snippets was manually removed. For colour measurement and photostability testing, wool snippets were pressed into solid discs (Figure 2) using a polished hardened stainless steel die designed for making halide discs for infrared spectroscopy (Specac, UK). Discs were compressed with a load equivalent to 5 tonnes resulting in circular discs weighing 0.1 ± 0.02 grams (13 mm diameter).



Figure 2. Pictures of wool discs.

UVB irradiation

Photostability studies on the colour stability of wool demonstrate that wool will be either yellowed by ultraviolet light or bleached by visible light [2-7]. A photostability test using visible light would be difficult to interpret as the result would depend on the original wool

colour. White wools tend to yellow at significantly faster rate than yellower wools due to the lower contribution of photobleaching [7]. However wools exposed to UVB or UVC do not undergo photobleaching due to the absence of wavelengths in the range 400-450 nm. As UVC is not present in natural sunlight, UVB irradiation was conducted on duplicate discs (A and B) made from each fleece wool sample for 4 hours.

Exposure to UVB wavelengths was carried out using a Philips tube with emission peaks at the specific wavelengths near 310 nm (Philips TL20W/12RS). The spectral irradiance of the source was measured with a spectral analyser (Sola-Scope 2000, Solatel, UK) and is shown in Figure 3.

For UV exposure experiments, discs were placed into individual compartments within two layers of polyethylene film and fastened around the tube circumference. UV-vis spectrophotometry showed that the absorption of the polyethylene film was relatively low in the UVB and UVA region (Figure 4) and did not change following irradiation.

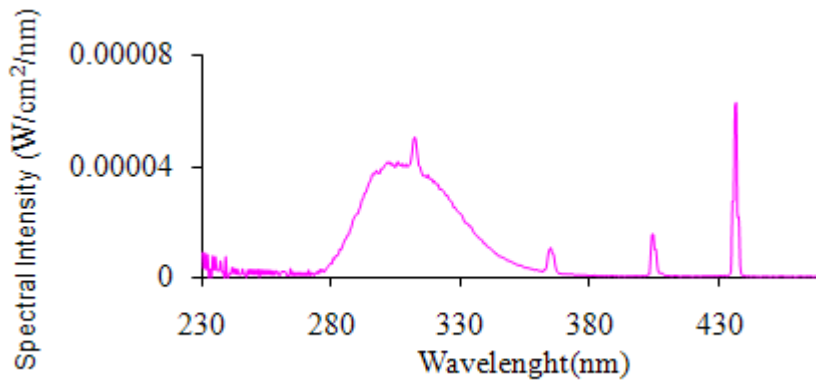


Figure 3. Spectrum of UVB source.

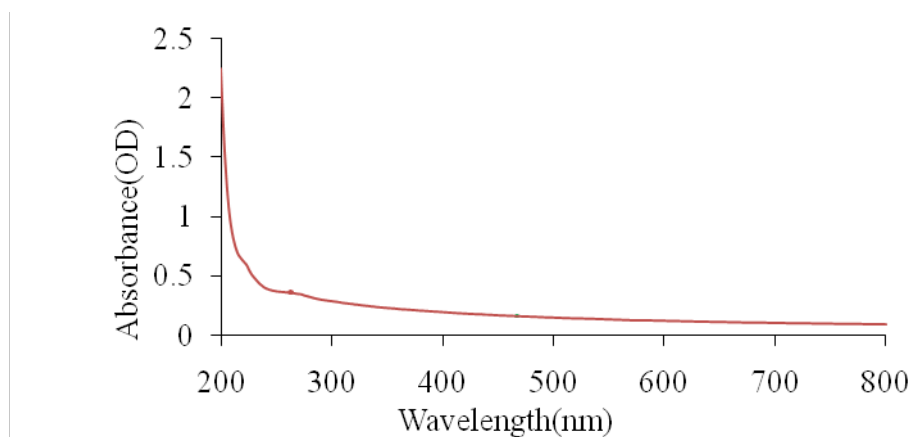


Figure 4. UV-visible spectrum of polyethylene film used as disc holder under UVB irradiation.

Colour measurements

A Gretag Macbeth Color-Eye 7000A spectrophotometer was used for colour measurements on the wool powder discs using a D65 source, 10° collection angle and a small area view (SAV) aperture (0.8 cm x 1.0 cm).

Five discs were made from each fleece wool sample for colour measurements. Three tristimulus values X, Y, Z and D1925 yellowness index were instrumentally obtained from spectrophotometer. Yellowness (Y-Z values) of each measurement was calculated.

Results

Original colour of fleece wool

Table 2 lists the mean values and standard deviations of tristimulus values X, Y, Z, Yellowness (Y-Z) and D1925 Yellowness Index (YI) measurements on both sides of five discs made by the fibre snippets of each fleece sample (ten readings for each sample). The colour measurement for each sample was shown in Appendix I. The colour comparisons between these twenty fleece wool samples are illustrated in Figures 5 and 6.

Table 2. Averages and standard deviations (STDEV) of colour parameters for each fleece sample.

	X		Y		Z		Y-Z		D1925 YI	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
61928.6	69.6	0.33	73.48	0.36	65.85	0.42	7.67	0.16	20.22	0.25
61930.1	71.58	0.33	75.57	0.37	68.75	0.39	6.79	0.05	18.65	0.24
61917.2	70.62	0.46	74.41	0.5	68.4	0.48	6.01	0.29	17.8	0.35
61910.2	70.27	0.44	74.18	0.49	67.12	0.42	6.88	0.05	19.09	0.3
61915.0	69.82	0.36	73.73	0.4	66.46	0.44	7.27	0.14	19.59	0.28
61942.6	70.58	0.49	74.62	0.53	67.45	0.43	7.17	0.12	19.15	0.24
62022.2	71.98	0.27	79.95	0.29	68.98	0.38	6.96	0.19	18.69	0.24
62000.1	70.04	0.49	73.82	0.53	66.49	0.54	7.35	0.15	19.92	0.3
61979.1	68.83	0.58	72.79	0.63	64.91	0.73	7.87	0.17	20.51	0.45
61933.4	68.83	0.55	72.67	0.6	64.91	0.84	7.31	0.34	20.56	0.58
61923.1	71.38	0.41	75.37	0.45	68.73	0.6	6.68	0.18	18.38	0.41
61945.2	67.07	0.47	70.69	0.49	62.76	0.55	7.93	0.12	21.39	0.29
61920.5	69.41	0.34	73.26	0.37	65.62	0.32	7.58	0.07	20.3	0.15
62020.0	70.26	0.64	74.25	0.7	66.82	0.8	9.37	0.14	19.67	0.33
61914.6	72.73	0.38	76.85	0.41	70.37	0.5	6.53	0.11	17.86	0.28
62023.3	71.35	0.6	75.43	0.63	68.5	0.72	6.91	0.18	18.67	0.29
62010.4	69.37	0.71	73.27	0.77	65.52	0.8	7.77	0.23	20.38	0.34

62005.6	69.53	0.8	73.35	0.87	65.95	0.92	7.5	0.17	19.98	0.38
61950.0	67.55	0.69	71.23	0.75	62.87	0.9	8.42	0.25	21.93	0.5
61909.1	72.52	0.36	76.54	0.38	69.89	0.38	6.75	0.03	18.3	0.26

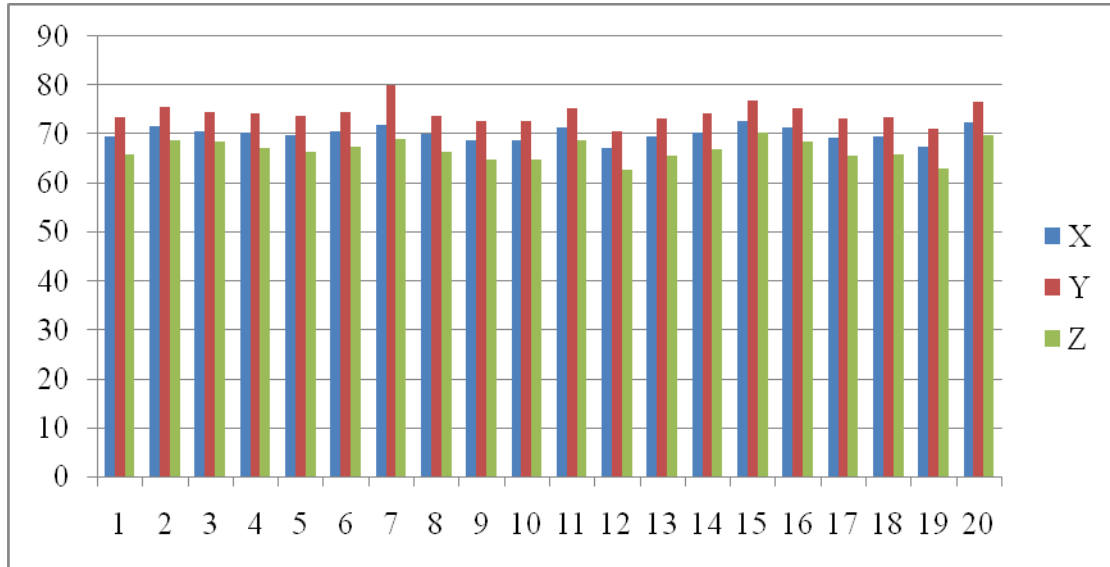


Figure 5. The mean values of colour tristimulus values X,Y and Z of each fleece wool (No. 1 denotes fleece sample 61928.6, as described in Table 1)

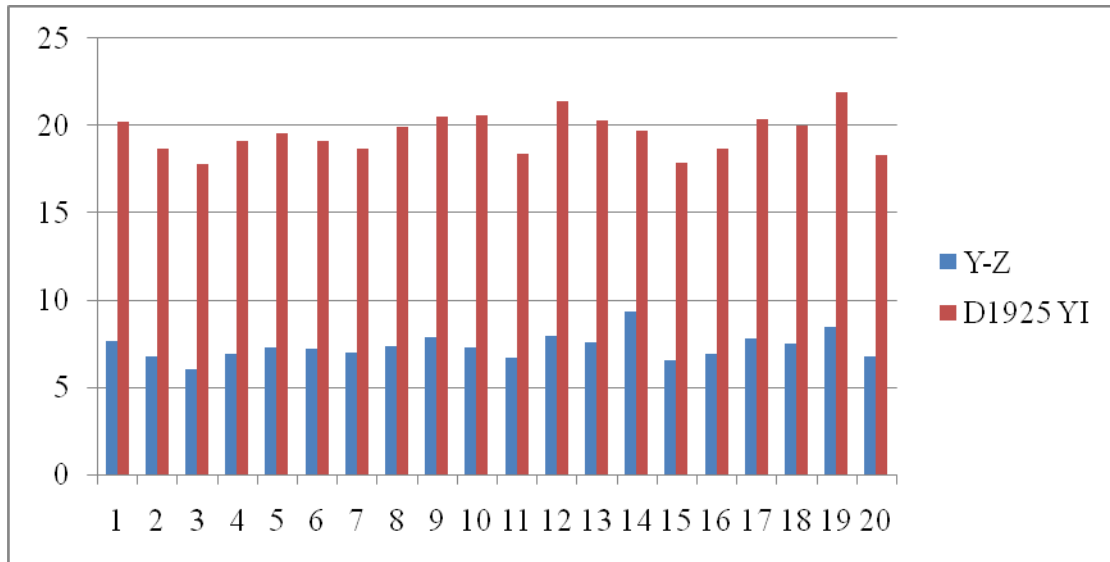


Figure 6. The mean values of yellowness Y-Z and D1925 yellowness measurements of each fleece wool (No. 1 denotes fleece sample 61928.6, as described in Table 1)

UVB irradiation

Table 3 shows the colour changes on irradiated wool discs, which are indicated by the changes of three tristimulus values, yellowness (Y-Z) and D 1925 Yellowness Index (YI). The colour measurements on discs before and after UVB irradiation are listed in Appendix II.

Table 3. Yellowness indices of fleece wool discs measured before and after UVB irradiation for 4 hours.

Fleece wool discs		Colour changes				
		ΔX	ΔY	ΔZ	$\Delta Y-Z$	$\Delta D1925 YI$
61928.6	A	2.258	2.186	6.697	-4.511	-7.45
	B	3.216	3.202	8.176	-4.965	-8.47
61930.1	A	2.865	2.804	7.21	-4.406	-6.95
	B	2.883	2.788	7.967	-5.179	-8.12
61917.2	A	2.075	1.994	5.739	-3.745	-5.94
	B	2.759	2.646	7.334	-4.688	-7.57
61910.2	A	2.13	2.03	6.348	-4.318	-6.83
	B	2.459	2.39	6.673	-4.283	-6.96
61915.0	A	2.073	1.995	6.094	-4.099	-6.56
	B	2.745	2.77	7.324	-4.554	-7.57
61942.6	A	2.49	2.416	7.033	-4.617	-7.44
	B	1.2	1.878	6.561	-4.683	-7.31
62022.2	A	3.161	3.105	8.079	-4.974	-7.77
	B	2.818	2.697	8.218	-5.521	-8.51
62000.1	A	2.749	2.652	7.634	-4.975	-8.07
	B	2.456	2.323	7.646	-5.323	-8.45
61979.1	A	2.245	2.155	6.545	-4.39	-7.19
	B	2.825	2.758	7.655	-4.897	-8.14
61933.4	A	2.616	2.598	7.049	-4.451	-7.46
	B	2.711	2.651	7.607	-4.956	-8.39
61923.1	A	2.766	2.706	7.255	-4.549	-7.24
	B	2.575	2.47	7.509	-5.039	-7.9
61945.2	A	2.784	2.735	7.085	-4.35	-7.52
	B	1.883	1.779	5.558	-3.779	-6.16
61920.5	A	2.365	2.301	6.571	-4.27	-6.96
	B	2.599	2.542	6.919	-4.377	-7.05
62020.0	A	2.135	2.023	6.905	-4.882	-7.67
	B	3.004	2.999	7.277	-4.278	-7.1
61914.6	A	2.025	1.886	6.373	-4.487	-6.68
	B	1.501	1.325	5.982	-4.657	-6.9
62023.3	A	1.65	1.476	6.119	-4.643	-7.06
	B	2.499	2.476	6.5	-4.024	-6.34
62010.4	A	1.641	1.56	5.151	-3.591	-5.72

	B	1.893	1.78	5.687	-3.907	-6.2
62005.6	A	1.842	1.724	6.078	-4.354	-6.88
	B	2.656	2.633	6.445	-3.812	-6.27
61950.0	A	1.329	1.222	4.438	-3.216	-5.2
	B	2.106	2.083	5.389	-3.306	-5.7
61909.1	A	2.083	1.984	6.36	-4.376	-6.7
	B	1.014	0.805	5.148	-4.343	-6.35

Summary

Powdering and disc compression techniques can be a suitable method to measure and compare the colour and photostability of different fleece wool. One solid disc made from fleece wool can provide two colour measurement spots from both sides of the disc which can be directly measured from commercial reflectance spectrophotometers designed for textile applications. For photostability studies, solid discs are robust to handling during experimental measurements. The surface of the disc is unaffected by handling and mounting on the spectrophotometer and the measured colour is independent of any variation in fibre density that may occur for webs and fabrics.

Reference

1. Zhang H, Millington KR, Wang X. A morphology-related study on photodegradation of protein fibres *Journal of Photochemistry and Photobiology B: Biology* 2008; 92: 135-143.
2. Millington KR. Photoyellowing of wool. Part 1: Factors affecting photoyellowing and experimental techniques. *Coloration Technology* 2006; 122: 169-186.
3. Launer HF. Effect of light upon wool Part V: Yellowing and Bleaching by ultraviolet and Visible Arc light. *Textile Research Journal* 1965; 35: 813-819.
4. Launer HF. Effect of light upon wool. part IV: Bleaching and yellowing by sunlight. *Textile Research Journal* 1965; 35: 395-400.
5. Lennox FG, Inglis AS, Holt LA. Studies in Wool Yellowing. Part XIII: Partial Bleaching With Visible light. *Textile Research Journal* 1966; 36: 837-843.
6. Milligan B, Tucker DJ. Studies on Wool Yellowing Part III: Sunlight Yellowing. *Textile Research Journal* 1962; 32: 634-640.
7. Lennox FG, King MG. Studies in wool yellowing: Part XXIII. UV Yellowing and blue-light bleaching of different wools. *Textile Research Journal* 1968; 38: 754-761.

Appendix I: Colour measurements on each wool fleece sample (10 readings)

61928.6	X	Y	Z	Y-Z	D1925 YI
1	69.891	73.769	66.14	7.629	20.2
2	69.775	73.667	66.167	7.5	19.98
3	69.296	73.167	65.235	7.932	20.73
4	69.391	73.277	65.395	7.882	20.62
5	69.18	72.99	65.541	7.449	20.09
6	69.435	73.278	65.782	7.496	20.09
7	69.215	73.083	65.442	7.641	20.28
8	70.064	73.976	66.423	7.553	20.01
9	69.88	73.773	66.204	7.569	20.08
10	69.92	73.842	66.195	7.647	20.15
Mean	69.6	73.48	65.85	7.67	20.22
STDEV	0.33	0.36	0.42	0.16	0.25

61930.1	X	Y	Z	Y-Z	YI-D1925
1	71.806	75.846	69.304	6.542	18.14
2	72.189	76.229	69.345	6.884	18.64
3	71.58	75.558	68.861	6.697	18.49
4	71.52	75.483	68.432	7.051	19.06
5	70.873	74.8	68.087	6.713	18.64
6	71.594	75.595	68.724	6.871	18.71
7	71.687	75.659	68.871	6.789	18.63
8	71.558	75.567	68.603	6.964	18.84
9	71.612	75.625	68.814	6.811	18.6
10	71.363	75.293	68.464	6.829	18.79
Mean	71.58	75.57	68.75	6.79	18.65
STDEV	0.33	0.37	0.39	0.05	0.24

61917.2	X	Y	Z	Y-Z	YI-D1925
1	70.868	74.693	68.806	5.887	17.55
2	70.848	74.666	68.406	6.26	18.13
3	69.645	73.336	67.345	5.991	17.99
4	70.318	74.104	68.049	6.055	17.9
5	70.159	73.877	68.4	5.477	17.13
6	71.063	74.876	68.843	6.033	17.79
7	70.775	74.615	68.555	6.06	17.79
8	70.677	74.44	68.049	6.391	18.44
9	71.152	74.966	68.959	6.007	17.74
10	70.708	74.481	68.632	5.849	17.59
Mean	70.62	74.41	68.4	6.01	17.8
STDEV	0.46	0.5	0.48	0.29	0.35

61910.2	X	Y	Z	Y-Z	D1925 YI
1	70.131	74.031	67.115	6.916	19.04
2	69.747	73.62	66.936	6.684	18.74
3	70.043	73.915	67.11	6.805	18.92
4	69.673	73.501	66.822	6.679	18.82
5	70.663	74.63	67.736	6.894	18.86
6	70.775	74.729	67.393	7.336	19.55
7	70.278	74.196	67.076	7.12	19.31
8	69.899	73.795	66.571	7.224	19.53
9	70.934	74.897	67.993	6.904	18.86
10	70.527	74.477	67.352	7.125	19.25
Mean	70.27	74.18	67.21	6.88	19.09
STDEV	0.44	0.49	0.42	0.05	0.3

61915.0	X	Y	Z	Y-Z	D1925 YI
1	69.503	73.355	66.305	7.05	19.37
2	70.047	73.956	66.875	7.081	19.28
3	70.331	74.302	67.169	7.133	19.23
4	69.453	73.353	65.906	7.447	19.9
5	69.899	73.807	66.624	7.183	19.45
6	70.484	74.469	67.02	7.449	19.69
7	69.652	73.53	66.443	7.087	19.37
8	69.581	73.468	66.015	7.453	19.93
9	69.519	73.38	66.063	7.317	19.77
10	69.743	73.64	66.196	7.444	19.89
Mean	69.82	73.73	66.46	7.27	19.59
STDEV	0.36	0.4	0.44	0.14	0.28

61942.6	X	Y	Z	Y-Z	D1925 YI
1	70.423	74.463	67.354	7.109	19.07
2	70.908	74.958	67.701	7.257	19.25
3	70.301	74.325	67.198	7.127	19.13
4	70.73	74.8	67.834	6.966	18.78
5	69.955	73.928	67.064	6.864	18.83
6	70.645	74.685	67.529	7.156	19.13
7	71.477	75.605	68.288	7.317	19.17
8	71.06	75.169	67.603	7.566	19.61
9	70.169	74.166	67.03	7.136	19.2
10	70.1	74.099	66.856	7.243	19.37
Mean	70.58	74.62	67.45	7.17	19.15
STDEV	0.49	0.53	0.43	0.12	0.24

62022.2	X	Y	Z	Y-Z	D1925 YI
1	71.451	75.529	68.523	7.006	18.79
2	71.582	75.641	68.59	7.051	18.88
3	71.771	75.832	68.676	7.156	19.03
4	72.122	76.24	69.184	7.056	18.76
5	72.164	76.251	69.538	6.713	18.3
6	71.626	75.725	68.667	7.058	18.82
7	72.111	76.236	69.182	7.054	18.75
8	72.076	76.177	69.265	6.912	18.58
9	71.628	75.69	68.728	6.962	18.74
10	72.071	76.179	69.468	6.711	18.26
Mean	71.86	75.95	68.98	6.96	18.69
SD	0.27	0.29	0.38	0.19	0.24

62000.1	X	Y	Z	Y-Z	YI-D1925
1	70.45	74.298	66.662	7.636	20.23
2	70.045	73.834	66.397	7.437	20.05
3	69.719	73.473	66.019	7.454	20.17
4	69.975	73.755	66.517	7.238	19.76
5	70.504	74.312	67.223	7.089	19.45
6	69.504	73.269	65.733	7.536	20.29
7	70.567	74.356	67.108	7.248	19.73
8	69.108	72.777	65.635	7.142	19.87
9	70.492	74.31	66.768	7.542	20.13
10	70.076	73.855	66.793	7.062	19.49
Mean	70.04	73.82	66.49	7.35	19.92
STDEV	0.49	0.53	0.54	0.15	0.3

61917.1	X	Y	Z	Y-Z	YI-D1925
1	68.593	72.412	65.435	6.977	19.37
2	69.319	73.24	65.727	7.513	19.98
3	69.023	72.905	65.523	7.382	19.86
4	68.923	72.862	65.259	7.603	20.11
5	68.862	72.72	65.643	7.077	19.44
6	68.941	72.874	65.173	7.701	20.28
7	69.591	73.542	66.143	7.399	19.73
8	68.825	72.786	64.912	7.874	20.51
9	70.535	74.588	67.313	7.275	19.29
10	68.617	72.576	64.701	7.875	20.53
Mean	68.83	72.79	64.91	7.87	20.51
STDEV	0.58	0.63	0.73	0.17	0.45

61933.4	X	Y	Z	Y-Z	D1925 YI
1	68.877	72.696	65.144	7.552	20.26
2	69.473	73.354	66.284	7.07	19.35
3	68.379	72.232	64.351	7.881	20.75
4	69.948	73.898	66.214	7.684	20.15
5	68.71	72.526	64.684	7.842	20.74
6	68.761	72.583	64.582	8.001	20.97
7	68.584	72.4	64.37	8.03	21.04
8	68.091	71.854	63.684	8.17	21.41
9	69.071	72.956	65.349	7.607	20.21
10	68.392	72.23	64.4	7.83	20.7
Mean	68.83	72.67	64.91	7.31	20.56
STDEV	0.55	0.6	0.84	0.34	0.58

61923.1	X	Y	Z	Y-Z	YI-D1925
1	71.19	75.156	68.305	6.851	18.76
2	71.122	75.097	68.459	6.638	18.42
3	71.551	75.566	69.387	6.179	17.64
4	71.692	75.772	69.215	6.557	18.09
5	72.258	76.305	69.826	6.479	18.01
6	71.031	74.98	68.042	6.938	18.94
7	71.213	75.193	68.475	6.718	18.53
8	71.435	75.41	68.975	6.435	18.1
9	70.782	74.74	68.025	6.715	18.59
10	71.501	75.514	68.611	6.903	18.75
Mean	71.38	75.37	68.73	6.68	18.38
STDEV	0.41	0.45	0.6	0.18	0.41

61945.2	X	Y	Z	Y-Z	D1925 YI
1	67.819	71.48	63.718	7.762	20.97
2	68.348	72.051	64.097	7.954	21.15
3	67.377	71.02	63.07	7.95	21.35
4	67.47	71.136	63.423	7.713	20.91
5	66.832	70.427	62.538	7.889	21.39
6	67.618	71.267	63.663	7.604	20.76
7	67.686	71.337	63.28	8.057	21.48
8	66.861	70.495	62.475	8.02	21.52
9	67.069	70.688	62.759	7.929	21.39
10	67.208	70.872	62.722	8.15	21.65
Mean	67.07	70.69	62.76	7.93	21.39
STDEV	0.47	0.49	0.55	0.12	0.29

61920.5	X	Y	Z	Y-Z	YI-D1925
1	69.938	73.823	66.201	7.622	20.17
2	69.301	73.129	65.579	7.55	20.21
3	69.183	72.986	65.407	7.579	20.31
4	68.975	72.81	65.226	7.584	20.27
5	69.87	73.747	66.103	7.644	20.23
6	69.185	73.031	65.452	7.579	20.23
7	69.492	73.306	65.65	7.656	20.39
8	69.805	73.688	65.811	7.877	20.58
9	69.12	72.933	65.47	7.463	20.11
10	69.286	73.164	65.348	7.816	20.54
Mean	69.41	73.26	65.62	7.58	20.3
STDEV	0.34	0.37	0.32	0.07	0.15

61920.5	X	Y	Z	Y-Z	YI-D1925
1	69.938	73.823	66.201	7.622	20.17
2	69.301	73.129	65.579	7.55	20.21
3	69.183	72.986	65.407	7.579	20.31
4	68.975	72.81	65.226	7.584	20.27
5	69.87	73.747	66.103	7.644	20.23
6	69.185	73.031	65.452	7.579	20.23
7	69.492	73.306	65.65	7.656	20.39
8	69.805	73.688	65.811	7.877	20.58
9	69.12	72.933	65.47	7.463	20.11
10	69.286	73.164	65.348	7.816	20.54
Mean	69.41	73.26	65.62	7.58	20.3
STDEV	0.34	0.37	0.32	0.07	0.15

62020.0	X	Y	Z	Y-Z	YI-D1925
1	70.498	74.509	67.085	7.424	19.6
2	70.649	74.666	67.12	7.546	19.77
3	71.685	75.801	68.637	7.164	18.95
4	70.542	74.543	67.143	7.4	19.58
5	69.554	73.485	65.91	7.575	20.04
6	70.391	74.417	67.131	7.286	19.37
7	69.853	73.78	66.23	7.55	19.99
8	69.584	73.521	65.948	7.753	20.02
9	70.071	74.044	66.587	7.457	19.75
10	69.777	73.729	66.407	7.322	19.59
Mean	70.26	74.25	66.82	7.52	19.67
STDEV	0.64	0.7	0.8	0.14	0.33

61914.6	X	Y	Z	Y-Z	YI-D1925
1	73.118	77.268	71.111	6.157	17.32
2	73.284	77.449	71.139	6.31	17.52
3	72.423	76.522	69.913	6.609	18.11
4	73.126	77.294	70.84	6.454	17.73
5	72.837	76.968	70.292	6.676	18.14
6	72.581	76.688	70.143	6.545	17.99
7	72.381	76.481	69.88	6.601	18.1
8	72.068	76.175	69.789	6.386	17.77
9	72.78	76.903	70.435	6.468	17.84
10	72.667	76.777	70.158	6.619	18.1
Mean	72.73	76.85	70.37	6.53	17.86
STDEV	0.38	0.41	0.5	0.11	0.28

62023.3	X	Y	Z	Y-Z	YI-D1925
1	72.073	76.202	69.267	6.935	18.56
2	71.34	75.412	68.356	7.056	18.88
3	71.854	75.947	69.093	6.854	18.51
4	71.273	75.302	68.652	6.65	18.34
5	71.463	75.601	68.619	6.982	18.65
6	70.086	74.075	67.014	7.061	19.1
7	71.41	75.507	68.711	6.796	18.44
8	70.824	74.881	67.696	7.185	19.13
9	72.039	76.16	69.371	6.789	18.36
10	71.141	75.232	68.245	6.987	18.75
Mean	71.35	75.43	68.5	6.91	18.67
STDEV	0.6	0.63	0.72	0.18	0.29

62010.4	X	Y	Z	Y-Z	YI-D1925
1	68.967	72.831	64.772	8.059	20.97
2	70.034	73.967	66.378	7.589	20.03
3	68.654	72.49	64.793	7.697	20.47
4	69.681	73.613	66.057	7.556	20
5	69.505	73.42	65.534	7.886	20.56
6	70.885	74.901	67.094	7.807	20.16
7	68.472	72.301	64.757	7.544	20.25
8	69.271	73.147	65.474	7.673	20.32
9	68.893	72.769	64.734	8.035	20.91
10	69.346	73.24	65.652	7.588	20.14
Mean	69.37	73.27	65.52	7.77	20.38
STDEV	0.71	0.77	0.8	0.23	0.34

62005.6	X	Y	Z	Y-Z	YI-D1925
1	69.889	73.74	66.24	7.5	20.05
2	69.773	73.591	66.168	7.423	20
3	69.972	73.802	66.721	7.081	19.43
4	69.274	73.039	65.903	7.136	19.68
5	69.699	73.531	66.093	7.438	20
6	70.34	74.237	66.545	7.692	20.23
7	70.367	74.267	66.895	7.372	19.73
8	68.628	72.462	65.073	7.389	19.99
9	69.62	73.455	66.133	7.322	19.82
10	67.781	71.387	63.764	7.623	20.85
Mean	69.53	73.35	65.95	7.5	19.98
STDEV	0.8	0.87	0.92	0.17	0.38

61950.0	X	Y	Z	Y-Z	YI-D1925
1	67.609	71.283	62.955	8.328	21.88
2	66.792	70.389	61.948	8.441	22.29
3	68.314	72.049	63.953	8.096	21.33
4	67.745	71.436	62.849	8.588	22.25
5	67.026	70.658	62.432	8.226	21.85
6	66.667	70.266	61.622	8.644	22.63
7	68.57	72.361	64.253	8.108	21.22
8	66.878	70.514	62.17	8.344	22.05
9	68.299	72.025	63.925	8.1	21.35
10	67.624	71.323	62.611	8.712	22.44
Mean	67.55	71.23	62.87	8.42	21.93
STDEV	0.69	0.75	0.9	0.25	0.5

61909.1	X	Y	Z	Y-Z	D1925 YI
1	72.601	76.628	70.018	6.61	18.23
2	72.732	76.752	70.059	6.693	18.36
3	72.526	76.554	69.881	6.673	18.33
4	72.48	76.492	69.711	6.781	18.52
5	73.044	77.108	70.503	6.605	18.14
6	71.631	75.616	69.062	6.554	18.26
7	72.672	76.706	70.221	6.485	18.03
8	72.224	76.204	69.856	6.348	17.93
9	72.71	76.776	70.049	6.727	18.33
10	72.547	76.566	69.509	7.057	18.92
Mean	72.52	76.54	69.89	6.75	18.3
STDEV	0.36	0.38	0.38	0.03	0.26

Appendix II: Photostability test on fleece wool discs after UVB irradiation for 4 hours (a)

Fleece wool discs		Before irradiation					After UVB irradiation					Colour changes				
		X	Y	Z	Y-Z	D1925 YI	X	Y	Z	Y-Z	D1925 YI	Δ X	Δ Y	Δ Z	Δ Y-Z	Δ D1925 YI
61928.6	A	68.414	72.177	64.397	7.78	20.76	66.156	69.991	57.7	12.291	28.21	2.258	2.186	6.697	-4.511	-7.45
	B	68.724	72.517	64.926	7.6	20.38	65.508	69.315	56.75	12.565	28.85	3.216	3.202	8.176	-4.965	-8.47
61930.1	A	71.864	75.889	69.092	6.797	18.55	68.999	73.085	61.882	11.203	25.5	2.865	2.804	7.21	-4.406	-6.95
	B	71.915	75.89	68.986	6.904	18.79	69.032	73.102	61.019	12.083	26.91	2.883	2.788	7.967	-5.179	-8.12
61917.2	A	70.082	73.845	67.417	6.428	18.53	68.007	71.851	61.678	10.173	24.47	2.075	1.994	5.739	-3.745	-5.94
	B	69.429	73.058	66.81	6.248	18.52	66.67	70.412	59.476	10.936	26.09	2.759	2.646	7.334	-4.688	-7.57
61910.2	A	70.089	74	66.873	7.127	19.35	67.959	71.97	60.525	11.445	26.18	2.13	2.03	6.348	-4.318	-6.83
	B	69.441	73.285	66.214	7.071	19.42	66.982	70.895	59.541	11.354	26.38	2.459	2.39	6.673	-4.283	-6.96
61915.0	A	69.864	73.76	66.367	7.393	19.8	67.791	71.765	60.273	11.492	26.36	2.073	1.995	6.094	-4.099	-6.56
	B	69.928	73.914	66.729	7.185	19.31	67.183	71.144	59.405	11.739	26.88	2.745	2.77	7.324	-4.554	-7.57
61942.6	A	69.904	73.864	66.644	7.22	19.41	67.414	71.448	59.611	11.837	26.85	2.49	2.416	7.033	-4.617	-7.44
	B	70.477	74.503	67.087	7.416	19.56	68.478	72.625	60.526	12.099	26.87	1.2	1.878	6.561	-4.683	-7.31
62022.2	A	72.718	76.825	70.314	6.511	17.94	69.557	73.72	62.235	11.485	25.71	3.161	3.105	8.079	-4.974	-7.77
	B	72.343	76.399	69.684	6.715	18.35	69.525	73.702	61.466	12.236	26.86	2.818	2.697	8.218	-5.521	-8.51
62000.1	A	69.939	73.681	66.388	7.3	19.92	67.19	71.029	58.754	12.275	27.99	2.749	2.652	7.634	-4.975	-8.07
	B	70.118	73.872	66.772	7.1	19.59	67.662	71.549	59.126	12.423	28.04	2.456	2.323	7.646	-5.323	-8.45
61979.1	A	68.33	72.126	65.006	7.12	19.65	66.085	69.971	58.461	11.51	26.84	2.245	2.155	6.545	-4.39	-7.19
	B	68.66	72.491	65.074	7.417	20.04	65.835	69.733	57.419	12.314	28.18	2.825	2.758	7.655	-4.897	-8.14
61933.4	A	68.804	72.668	65.119	7.549	20.17	66.188	70.07	58.07	12	27.63	2.616	2.598	7.049	-4.451	-7.46
	B	67.696	71.401	63.656	7.745	20.87	64.985	68.75	56.049	12.701	29.26	2.711	2.651	7.607	-4.956	-8.39

Appendix II: Photostability test on fleece wool discs after UVB irradiation for 4 hours (b)

Fleece wool discs		Before irradiation					After UVB irradiation					Colour changes				
		X	Y	Z	Y-Z	D1925 YI	X	Y	Z	Y-Z	D1925 YI	ΔX	ΔY	ΔZ	$\Delta Y-Z$	$\Delta D1925 YI$
61923.1	A	71.285	75.269	68.284	6.985	18.93	68.519	72.563	61.029	11.534	26.17	2.766	2.706	7.255	-4.549	-7.24
	B	71.272	75.27	68.298	6.972	18.89	68.697	72.8	60.789	12.011	26.79	2.575	2.47	7.509	-5.039	-7.9
61945.2	A	67.139	70.759	62.757	8.002	21.49	64.355	68.024	55.672	12.352	29.01	2.784	2.735	7.085	-4.35	-7.52
	B	68.171	71.862	63.898	7.964	21.21	66.288	70.083	58.34	11.743	27.37	1.883	1.779	5.558	-3.779	-6.16
61920.5	A	69.49	73.354	65.62	7.734	20.42	67.125	71.053	59.049	12.004	27.38	2.365	2.301	6.571	-4.27	-6.96
	B	70.559	74.509	66.918	7.591	19.97	67.96	71.967	59.999	11.968	27.02	2.599	2.542	6.919	-4.377	-7.05
62020	A	70.638	74.67	66.91	7.76	20.07	68.503	72.647	60.005	12.642	27.74	2.135	2.023	6.905	-4.882	-7.67
	B	70.18	74.178	66.637	7.541	19.82	67.176	71.179	59.36	11.819	26.92	3.004	2.999	7.277	-4.278	-7.1
61914.6	A	73.075	77.256	70.612	6.644	17.99	71.05	75.37	64.239	11.131	24.67	2.025	1.886	6.373	-4.487	-6.68
	B	72.225	76.287	69.376	6.911	18.64	70.724	74.962	63.394	11.568	25.54	1.501	1.325	5.982	-4.657	-6.9
62023.3	A	70.686	74.651	67.724	6.927	18.91	69.036	73.175	61.605	11.57	25.97	1.65	1.476	6.119	-4.643	-7.06
	B	72.018	76.147	69.375	6.772	18.32	69.519	73.671	62.875	10.796	24.66	2.499	2.476	6.5	-4.024	-6.34
62010.4	A	69.431	73.312	65.599	7.713	20.36	67.79	71.752	60.448	11.304	26.08	1.641	1.56	5.151	-3.591	-5.72
	B	69.56	73.465	65.613	7.852	20.52	67.667	71.685	59.926	11.759	26.72	1.893	1.78	5.687	-3.907	-6.2
62005.6	A	69.639	73.42	66.166	7.254	19.81	67.797	71.696	60.088	11.608	26.69	1.842	1.724	6.078	-4.354	-6.88
	B	70.326	74.223	66.519	7.704	20.25	67.67	71.59	60.074	11.516	26.52	2.656	2.633	6.445	-3.812	-6.27
61950.0	A	67.641	71.333	62.752	8.581	22.25	66.312	70.111	58.314	11.797	27.45	1.329	1.222	4.438	-3.216	-5.2
	B	67.272	70.909	62.399	8.51	22.27	65.166	68.826	57.01	11.816	27.97	2.106	2.083	5.389	-3.306	-5.7
61909.1	A	72.073	76.053	69.433	6.62	18.35	69.99	74.069	63.073	10.996	25.05	2.083	1.984	6.36	-4.376	-6.7
	B	71.656	75.6	68.796	6.804	18.71	70.642	74.795	63.648	11.147	25.06	1.014	0.805	5.148	-4.343	-6.35