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ELSEVIER

Reduction of Quenching Effects of Fluorescent Whitening Agents by Blending

S. H. Amirshahi & M. T. Pailthorpe*

Department of Textile Technology, School of Fibre Science and Technology, University of New South Wales, Sydney NSW 2052, Australia

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ABSTRACT

A method for the reduction of the quenching effects of fluorescent whitening agents (FWAs) on textiles has been investigated. The total radiance factors of different samples which were produced by normal after-treatment of coloured fibres were compared with a series of blends of coloured and FWA treated fibres. The higher brilliancy of the blended series indicates lower quenching effects of the FWAs in the blended samples. In spite of higher shade changes in the blended series no other side effects, such as colour broken effects, were observed in the blends in comparison with the normally treated samples.

INTRODUCTION

Increasing the brightness of textiles by the subsequent application of fluorescent whitening agents (FWAs) for pale shades has been suggested in some papers;[1,2] however, the treatment has a significant effect on the shade. On the other hand, domestic detergents usually contain FWAs, which can cause the same effect on pale shades after washing. In order to minimise shade alterations, it was suggested to after-treat the pale shade with FWAs.[3]

The relationships between optimum brilliancy, shade alteration and FWA concentration have been investigated by Soljacic *et al.*[1] Although they did not directly investigate any quenching effects of FWAs, according to the data in this paper the lightness decreased for the heavier

* To whom correspondence should be addressed.

depths. The optical quenching of FWAs, which occurs due to the interactions between the FWAs and other substances present, was first reported by Morton.[4] Through this phenomenon, the fluorescence property of the material is diminished by the other non-fluorescent substances present. According to Allen[5] this effect is always possible but rather unpredictable.

In order to minimise the quenching effects of fluorescent whitening agents, we have taken advantage of the blending of pre-FWA treated and pre-coloured fibres. Hence, the purpose of this paper is to present an alternative method for the enhancement of the brilliancy of textiles.

BACKGROUND

Blending models between the fully subtractive and fully partitive colour mixing models have been suggested for the description of the colour of the blends of pre-coloured fibres.[6,7] It has been shown that the colour of blends is lighter than the colour of dyed materials which contain the same amounts of identical dyestuffs.[7,8] Amirshahi and Pailthorpe[7] described the colour of blends by the partitive mixing of a series of coloured dots which were produced by the subtractive mixing of coloured fibres in different configurations. The number of coloured dots which come into view or measurement are related to the transparency of the fibres. It was also shown that the number of dots is related to the fibre translucency which, itself, depends on several factors such as fibre type, colour and the colour depth.

EXPERIMENTAL

Combed cotton was bleached in a laboratory scale stock-dyeing machine using a commercial hydrogen peroxide recipe. Then, in order to provide yellow, red and blue coloured samples, the bleached fibres were dyed in the same dyeing machine with 1% of CI Direct Yellow 27, CI Direct Red 23 and CI Direct Blue 86 respectively. Furthermore, a part of the bleached cotton was treated with a FWA (0·1% of CI Fluorescent Brightener 113) for the production of fluorescent fibres. Table 1 shows the colour specifications of the primary samples. Also, three samples which had been bleached and dyed with a suitable amount of each dyestuff, were after-treated with the FWA, according to the commercial method.

By blending the fluorescent treated fibres with each of the pre-coloured

TABLE 1
Colour Specifications of the Primary Colours and FWA Treated Fibres

Sample	a^*	b^*	L^*
Fluorescent	−1·19	−1·98	102·54
Yellow	−12·76	62·62	97·93
Red	56·87	24·01	49·14
Blue	−32·15	−28·49	77·22

fibres in 13 different blend ratios, 39 samples were prepared. Randomised blends were prepared by passing the fibres through a Shirley Analyser at least 10 times.

A Pacific Scientific Spectrogard Colour computer system was used for the reflectance measurements. The total spectral radiance factors were measured for the fluorescent samples. The specular component of reflectance was excluded. Some (2·5 g) of the fibre blends were placed in a fibre measurement cell with a quartz glass cover. Samples were measured from 400 nm to 700 nm at 20 nm intervals. The measurement was carried out at four rotational positions. The average of the four measurements was taken to be the true reflectance. The CIELAB colour system was chosen to express the colorimetric data using Illuminant D65 and the 1964 (10°) standard observer.

RESULTS AND DISCUSSION

Tables 2, 3, and 4 show the colour specifications of the different blends with different ratios of fluorescently brightened and coloured fibres. For comparing the usual treatment of textiles with fluorescent whitening agents with our blending method, three bleached samples were dyed with each colour individually, and then treated with the same fluorescent brightening agent in a manner such that each sample contained the same amount of dye and fluorescent brightening agent as the blend of 10% coloured and 90% fluorescent treated fibres. The colour specifications of the subsequently dyed and whitened samples are also shown in Tables 2–4. As these tables show, the L^* values for the blended samples are significantly higher than for the dyed and after-treated samples which have the same amount of dye and FWA. In fact, the lightnesses of the dyed and after-treated samples are approximately equal to sample No. 6 in the yellow, sample No. 5 in the red and sample No. 6 in the blue blended series.

TABLE 2
Colour Specifications of the Different Blends of Yellow and Fluorescent Fibres and the Dyed and After-treated Sample

Blend No.	*Specification*	*a**	*b**	*L**
1	100% FWA	−1·19	−1·98	102·54
2	95% FWA	−5·16	11·18	101·68
3	90% FWA	−7·43	20·62	101·04
—	Dyed and after-treated	−12·01	41·35	99·83
4	80% FWA	−9·28	28·48	100·57
5	70% FWA	−10·51	35·62	100·09
6	60% FWA	−11·87	43·63	99·66
7	50% FWA	−12·36	48·07	99·32
8	40% FWA	−12·41	51·29	99·01
9	30% FWA	−12·73	55·87	98·69
10	20% FWA	−12·81	59·03	98·40
11	10% FWA	−12·89	61·24	98·20
12	5% FWA	−12·81	62·23	98·03
13	0% FWA	−12·76	62·62	97·93

TABLE 3
Colour Specifications of the Different Blends of Red and Fluorescent Fibres and the Dyed and After-treated Sample

Blend No.	*Specification*	*a**	*b**	*L**
1	100% FWA	−1·19	−1·98	102·54
2	95% FWA	13·41	−0·49	90·68
3	90% FWA	21·53	2·04	83·20
—	Dyed and after-treated	34·02	10·84	69·64
4	80% FWA	27·76	4·54	76·78
5	70% FWA	34·99	7·76	70·17
6	60% FWA	42·10	10·88	64·95
7	50% FWA	43·83	12·57	61·71
8	40% FWA	48·24	15·63	58·39
9	30% FWA	50·22	17·44	55·74
10	20% FWA	54·05	20·79	52·62
11	10% FWA	55·42	22·56	50·70
12	5% FWA	55·51	22·88	49·82
13	0% FWA	56·86	24·01	49·14

TABLE 4
Colour Specifications of the Different Blends of Blue and Fluorescent Fibres and the Dyed and After-treated Sample

Blend No.	*Specification*	a^*	b^*	L^*
1	100% FWA	−1·19	−1·98	102·54
2	95% FWA	−7·66	−6·99	98·73
3	90% FWA	−12·67	−11·44	95·23
—	Dyed and after-treated	−20·87	−15·57	86·61
4	80% FWA	−17·72	−16·16	91·48
5	70% FWA	−21·05	−19·21	88·70
6	60% FWA	−23·24	−21·10	86·77
7	50% FWA	−24·70	−22·37	85·39
8	40% FWA	−26·68	−23·80	83·70
9	30% FWA	−27·71	−25·08	82·26
10	20% FWA	−29·58	−26·46	80·59
11	10% FWA	−31·37	−27·69	79·11
12	5% FWA	−31·75	−28·07	78·08
13	0% FWA	−32·15	−28·49	77·22

Figures 1, 2 and 3 show the total spectral radiance factors for blended and normally treated samples, which have same amount of dye and FWA, for each colour. As these figures show, the total radiance factors for the blended samples are higher than for the after-treated samples.

The higher brilliancy of the blended samples can be explained by the special colour mixing characteristics of the blends. The creation of different dots on the surface which are formed by different combinations of coloured and fluorescent fibres, and the partitive mixing of them, lead to lower quenching effects of the FWA, and hence higher radiance factors for the blended samples. In other words, the colour mixing law for the normal method is completely substrative, while for a blended sample it is a subtractive-partitive one.

Figure 4 shows the specifications for the different blends, and also the normal dyed and treated samples on the CIELAB chromaticity diagram. Since the effects of the existence of the fluorescent brightening agent in the blended series were greater than the usual method, the violet-blue peak of the optical brightener leads to higher shade changing in the blended series in comparison with the normally treated samples.

The other problem which should be considered in the blended series is colour broken effects. In these samples, due to the existence of different fibres with different colour, the formation of a colour broken effect

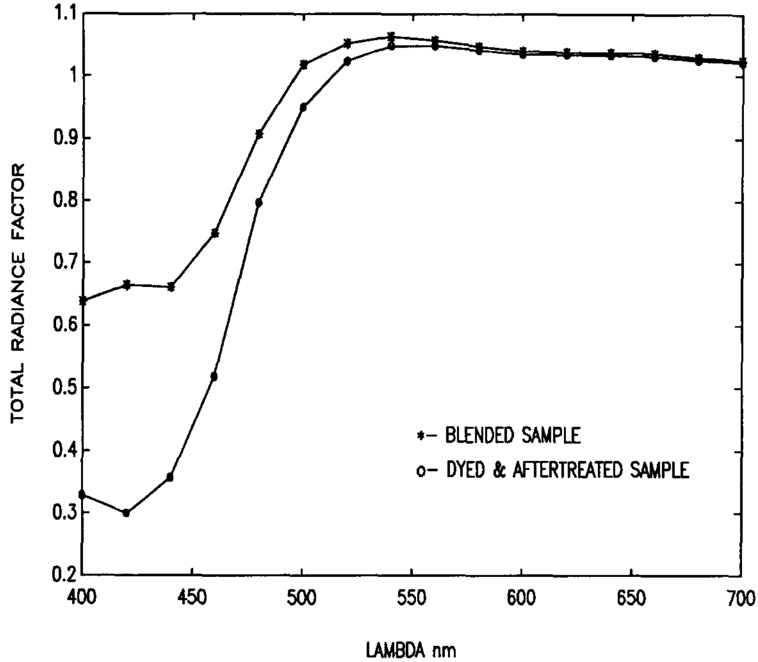

Fig. 1. Total radiance factor of a blend of 10% yellow and 90% FWA treated fibres in comparison with the dyed and subsequently whitened sample.

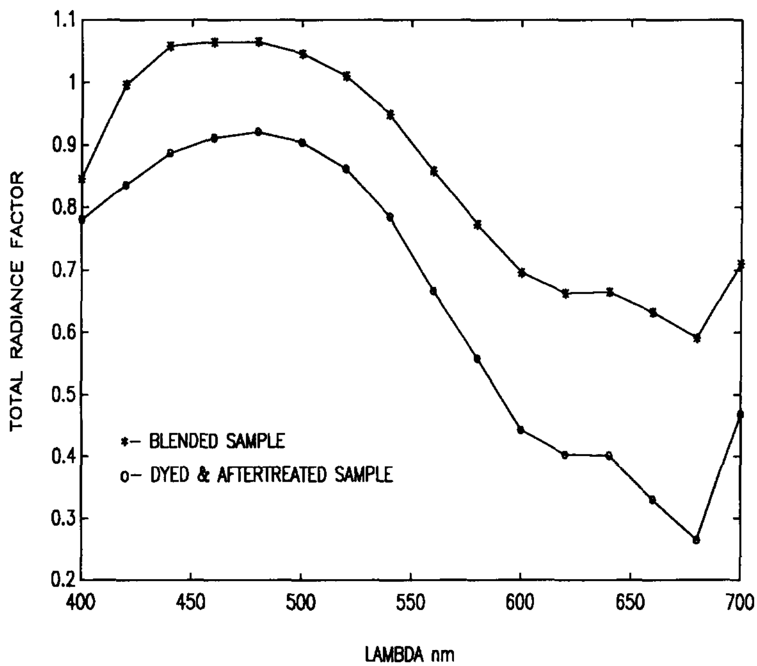

Fig. 2. Total radiance factor of a blend of 10% blue and 90% FWA treated fibres in comparison with the dyed and subsequently whitened sample.

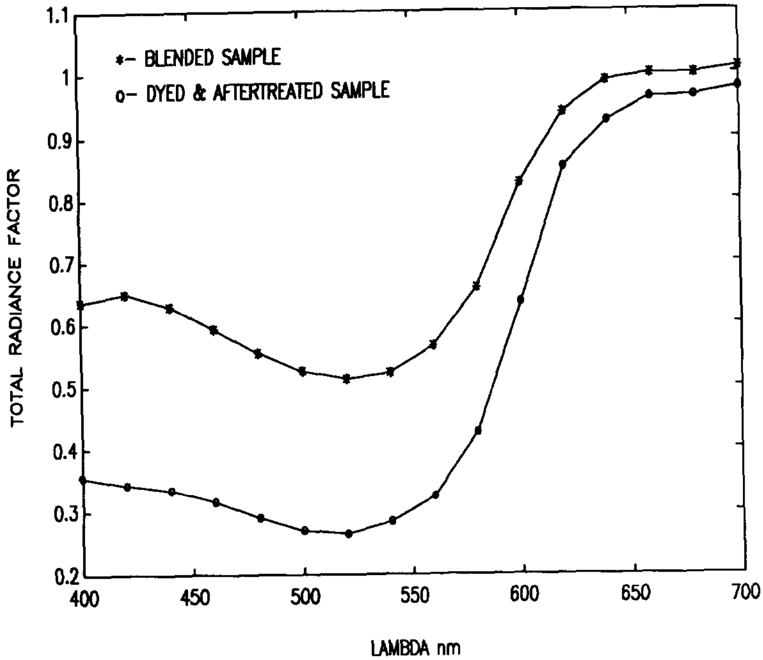

Fig. 3. Total radiance factor of blend of 10% red and 90% FWA treated fibres in comparison with the dyed and subsequently whitened sample.

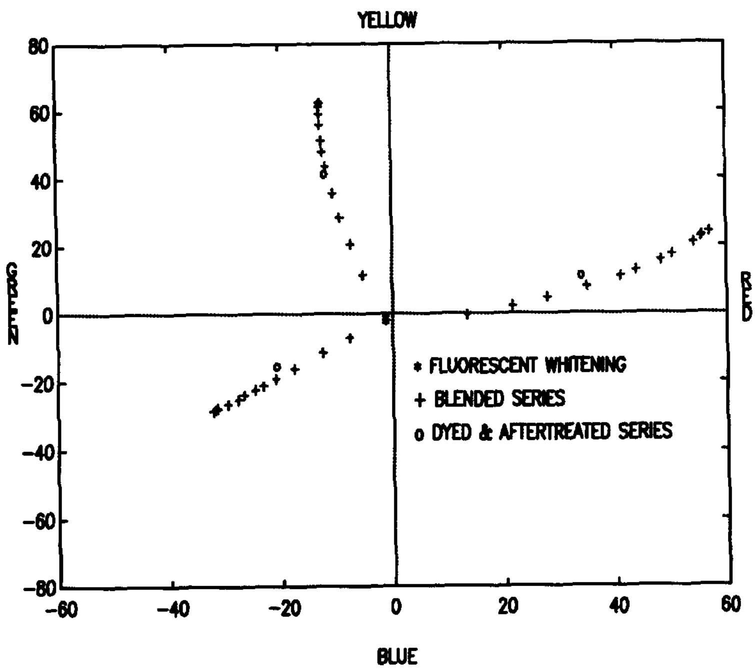

Fig. 4. The specification of different blends, dyed and subsequently whitened samples and fluorescence brightener agent on the CIELAB chromaticity diagram.

should be considered. The effect depends on the subjective viewing distance, the colour of the components, the differences between the luminance of the components, the fibre diameter and also on the fraction of each fibre in blend.[9] The effect of luminance was discussed by Guthrie *et al.*[9] They concluded that solid effects would be achieved for blends which contain components with high values of lightness. Here, since we were faced with pale shades, the lightnesses of the coloured fibres were high enough to produce solid effects when blended with fluorescent fibres.[9,10]

CONCLUSIONS

By the application of the suggested technique, lower quenching effects and higher brilliancy are achievable using the same amount of FWA and dye. This finding results from the special optical behaviour of the blends of the pre-coloured and pre-whitened fibres which obey the subtractive-additive rule in colour mixing.

As usual in blends, the formation of colour broken effects should be considered; however, since both components in the blends normally have high lightness values, colour broken effects do not occur in most cases.

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