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The Dyeing of Tencel. Part 1: Reactive Dyes

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ABSTRACT

Three examples of three types of reactive dye were applied to cotton, regular viscose and Tencel at 2% o.m.f. It was found that the colorimetric parameters of all the dyes on the three types of fibre reflected those of the undyed substrates and, in general, that there was relatively little difference in colour between the dyeings on the three fibre types. The colour strength of the dyeings was lowest on cotton, the dyeings on Tencel being of slightly lower colour strength than those on viscose. From the results, it appears that Tencel exhibits similar dyeability to regular viscose with reactive dyes.

INTRODUCTION

Cellulosic fibres dominate the global consumption of textiles; in 1990, cotton accounted for 48·7% (19 × 10^6 t) and viscose rayon 7·5% (2·6 × 10^6 t) of the total world textile fibre consumption, these two figures being predicted to change to 49% (24 × 10^6 t) and 3·5% (1·6 × 10^6 t) by the end of the millennium.[1] However, although cotton may continue to be the most widely used of all textile fibres, concern has recently attended the environmental aspects of its production;[2] furthermore, increasing environmental concern has centred on the conventional preparation of regenerated cellulosic fibres, such as viscose rayon.[3] The relatively recent introduction by Courtaulds, of Tencel, the first commercially available solvent-spun cellulosic fibre, is claimed to offer environmental advantages over other regenerated fibres insofar as the amine oxide solvent is recyclable[4] and the wood pulp that serves as the source of cellulose is harvested from renewable sources.[5]

Although preliminary findings on the dyeability and printability of Tencel with reactive dyes have been published,[4] a detailed study of the dyeing and printing characteristics of the new fibre has not appeared. The purpose of this work was to examine the dyeability of Tencel with sulphur, direct and reactive dyes as well as the printability of the substrate with reactive dyes and, in addition, to compare the dyeing and printing behaviour of the new fibre with that of both cotton and viscose. This first part of the paper concerns the dyeing of Tencel, cotton and viscose with three types of reactive dye.

EXPERIMENTAL

Materials

Fabric

Scoured and bleached woven Tencel (123·5 g m^{-2}), cotton (186·5 g m^{-2}) and viscose (187·5 g m^{-2}) were generously supplied by Courtaulds Research.

Dyes

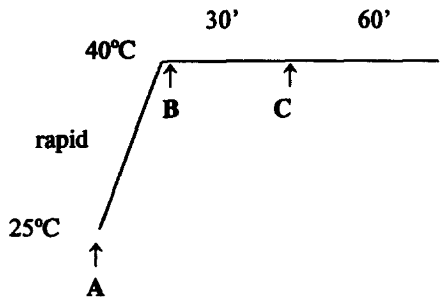
The nine reactive dyes used (Table 1) were commercial samples that were not purified prior to use; the Drimarene dyes were kindly supplied by Sandoz UK and the Sumifix Supra and Kayacelon React dyes by LJ Specialities Ltd. The structures of the dyes are not disclosed in the Colour Index.[6]

Auxiliaries

Commercial samples of Sandopur RSK liquid, which was used for washing-off the Drimarene K dyeings, was supplied by Sandoz and Adekatol TS-800C, which was used for washing-off the Kayacelon React and Sumifix

TABLE 1
Dyes Used

Commercial name	*CI reactive*	*Manufacturer*
Drimarene Golden Yellow K-2R	Yellow 125	
Drimarene Brilliant Red K-4BL	Red 147	Sandoz
Drimarene Blue K-2RL	Blue 209	
Sumifix Supra Yellow 3-RF	Yellow 145	
Sumifix Supra Red 3-BF	Red 195	Sumitomo
Sumifix Supra Blue BRF	Blue 221	
Kayacelon React Golden Yellow CN–GL	Yellow 178	
Kayacelon React Red CN-3B	Red 221	Nippon Kayaku
Kayacelon React Blue CN–BL	Blue 216	



A	Fabric (8 g)
	NaCl
B	Dye
C	Na_2CO_3

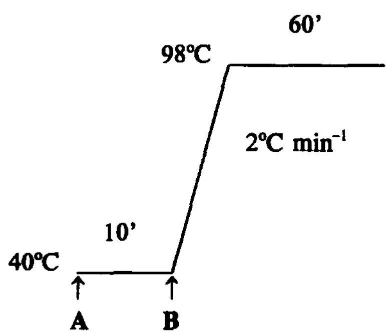
Fig. 1. Dyeing method used for Drimarene K dyes.

Supra dyeings, was supplied by LJ Specialities; Kayaku Buffer P-7, which was used to control dyebath pH in the case of the Kayacelon React dyeings, was also supplied by LJ Specialities. All other reagents were of general purpose grade.

Procedures

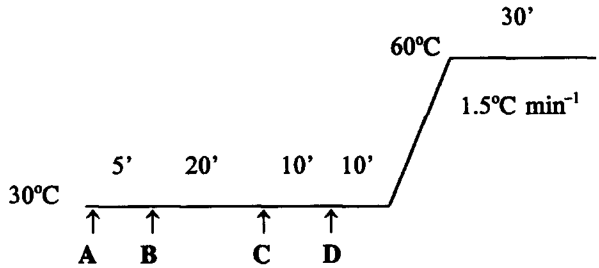
Dyeing

All dyeings were carried out using fabric which had been wetted out in cold tap water, in partially sealed, glass dyepots of 200 cm^3 capacity housed in a Zeltex Vistacolor laboratory-scale dyeing machine, employing a



A	Fabric (8 g)
	Dye
	Kayaku Buffer P–7
B	Na_2SO_4

Fig. 2. Dyeing method used for Kayacelon React dyes.



A Fabric (8 g)
Na_2SO_4
B Dye
C 50% of Na_2CO_3
D 50% of Na_2CO_3

Fig. 3. Dyeing method used for Sumifix Supra dyes.

20 : 1 liquor ratio. The dyeing methods used for the three types of dye are shown in Figs 1–3; the additions made to the various dyebaths are shown in Table 2. For each of the three dye types on each of the three types of fibre, single shade dyeings of 2% o.m.f. of each dye were made; also, trichromat dyeings of 6% o.m.f. depth were carried out for each of the three types of dye on each of the three substrates. At the end of each dyeing, the dyed sample was removed, rinsed and washed-off according to the respective dye maker's recommendation (Table 3) and allowed to dry in the open air.

Dyebath exhaustion

For each of the nine dyes used, the extent of exhaustion achieved for a 2% o.m.f. dyeing on each of the three types of fibre was determined using absorbance spectroscopic analysis of the dyebath before and after dyeing.

TABLE 2
Dyebath Additions

Dye type	*Addition*	*Depth of shade (g litre^{-1})*	
		2% o.m.f.	*6% o.m.f.*
Drimarene K	NaCl	40	50
	Na_2CO_3	15	20
Kayacelon React	Na_2SO_4	60	60
	Kayaku Buffer P-7	1	1
Sumifix Supra	Na_2SO_4	45	50
	Na_2CO_3	20	20

TABLE 3
Wash-off Procedures Used

Dye type	*Procedure (sequential)*	*Wash-off conditions*
Drimarene K	Hot rinse (2 min); wash-off Hot rinse (2 min) Cold rinse (2 min)	Sandopur RSK liq. 2 g litre^{-1} Na_2CO_3 0·5 g litre^{-1}; 98°C 15 min; 20 : 1 liquor ratio
Kayacelon React	Hot rinse (2 min); wash-off Cold rinse (2 min)	Adekatol TS-800°C 0·75 g litre^{-1} 10 min; 98°C 20 : 1 liquor ratio
Sumifix Supra	Cold rinse; hot rinse (2 min) Neutralise; wash-off; hot rinse Cold rinse (2 min)	As for Kayacelon React

A calibration curve for each dye was constructed by carrying out dyeings (2% o.m.f.), using the dyeing method shown in Figs 1–3 that was appropriate to each dye type, in the absence of fabric. The ensuing dye liquor was allowed to cool to room temperature and several portions of different volume were diluted using distilled water; the absorbance of the series of diluted dye liquors was measured at the λ_{max} of the dye using a pair of matched, 1 cm path length glass cells, employing distilled water as reference solvent, housed in a Pye-Unicam SP800 spectrophotometer (Phillips, UK). A plot of absorbance versus concentration was constructed for each dye from which the extinction coefficient was calculated; all dyes were found to obey Beer's Law over the concentration range studied.

At the end of dyeing, each dyed sample was removed from the dyebath and the ensuing dyebath allowed to cool to room temperature. A portion of the cool dyebath liquor was diluted using distilled water and the absorbance of the diluted solution measured at the λ_{max} of the dye using a pair of matched, 1 cm path length glass cells, employing distilled water as reference solvent, housed in a Pye-Unicam SP800 spectrophotometer. The concentration of dye in the residual dyebath was determined by reference to the appropriate extinction coefficient of the dye. The percentage dyebath exhaustion (%E) achieved for each dye was calculated using eqn (1):

$$\%E = 100 \times [1 - (C_2/C_1)] \quad (1)$$

where C_1 and C_2 are, respectively, the concentration of dye prior to and after dyeing.

Colour measurement

The reflectance values of the undyed samples of Tencel, cotton and viscose, as well as those of each of the dry, washed-off dyeings on Tencel, cotton and viscose were measured using a Macbeth MS2020 spectrophotometer interfaced to a Digital PC100 personal computer, under illuminant D_{65} using a 10° standard observer with specular component excluded and UV component included from which the corresponding *K/S* values and CIE L^*, a^*, b^*, c^* and h^0 coordinates were calculated at the appropriate λ_{max} for each dye. Each fabric sample was folded twice so as to realise a total of four thicknesses of fabric.

RESULTS AND DISCUSSION

The purpose of this work was to compare the dyeability of Tencel to that of cotton and viscose with three types of reactive dye; it was not the intention to infer superiority of one type of dye or application method.

Table 4 shows the colorimetric data secured for the three undyed fabric samples from which it is evident that although Tencel had the lowest lightness (L^* value), it was the whitest (as shown by the lowest b^* values) but dullest (as evidenced by the lowest c^* values) of the three fabrics; viscose was the most yellow of the fabrics (as given by the highest b^* values) and was of intermediate lightness.

The colorimetric data obtained for the 2% o.m.f. dyeings of the three types of dye used on cotton, viscose and Tencel are shown in Tables 5–7. It is clear from the L^* values, that for each dye used, the lightness of the dyeings decreased in the order cotton > viscose > Tencel; this order is identical to that obtained for the lightness of the undyed fabrics (Table 4) and, thus, the lightness of the dyeings on the three fabrics (Tables 5–7) can be considered to reflect the inherent lightness of the undyed fabrics. In a similar manner, the c^* values of the dyeings (Tables 5–7) also mirrored the inherent chroma of the undyed fabrics, insofar as, for each dye used, the c^* values of the dyeings increased in the order Tencel < cotton < viscose, this order being identical to that obtained for the chroma of the undyed

TABLE 4

Colorimetric Data for Undyed Fabrics

Fabric	L^*	a^*	b^*	c^*	h^0	*K/S*
Viscose	92·48	−0·39	4·75	4·77	94·7	0·05
Tencel	91·35	−0·32	1·72	1·75	100·5	0·04
Cotton	93·89	−0·29	3·07	3·08	95·4	0·03

TABLE 5
Colorimetric Data for 2% o.m.f. Drimarene K Dyeings

Drimarene	*Fibre*	*L**	*a**	*b**	*c**	*h*^{0}	*K/S*
	Viscose	42·9	62·8	0·01	62·8	0·01	17·6
Brilliant Red K-4BL	Tencel	42·0	60·8	2·97	60·9	2·79	17·3
	Cotton	44·7	62·2	0·75	62·2	0·69	14·2
	Viscose	31·5	3·2	−34·7	34·9	275·3	16·9
Blue K-2RL	Tencel	30·6	2·3	−31·9	31·9	274·2	16·2
	Cotton	33·9	1·95	−33·5	33·5	273·3	13·0
	Viscose	71·4	33·3	87·8	93·8	69·2	21·2
Golden Yellow K-2R	Tencel	70·2	32·2	84·7	90·6	69·2	20·4
	Cotton	73·1	30·1	86·4	91·5	70·8	18·1

fabrics (Table 4). Furthermore, it is evident from the *a**, *b** and *h*° values shown in Tables 5–7 that, although in general, the chromaticities of the dyeings reflected those of the undyed fabrics (Table 4), in the case of the three red dyes used, the dyeings on Tencel were more orange than the dyeings on cotton and viscose.

It is well known that the exhaustion of reactive dyes is usually higher on regular viscose than on cotton. The results in Table 8 support this statement, in that, with the exception of only one dye (Kayacelon React Red CN-3B), the extent of dyebath exhaustion achieved was greater on regular viscose than on cotton. Table 8 also shows that the dyebath exhaustion secured for the nine dyes on Tencel was lower than that obtained on viscose and, in addition, that for four of the dyes used, the extent of dyebath exhaustion achieved on Tencel was lower than that on

TABLE 6
Colorimetric Data for 2% o.m.f. Kayacelon React Dyeings

Kayacelon React	*Fibre*	*L**	*a**	*b**	*c**	*h*^{0}	*K/S*
	Viscose	43·8	63·2	4·9	63·4	4·5	18·9
Red CN-3B	Tencel	43·2	61·2	7·6	61·6	7·1	17·5
	Cotton	46·4	62·2	5·3	62·4	4·9	13·9
	Viscose	35·3	1·2	−33·7	33·7	272·0	12·9
Blue CN-BL	Tencel	33·4	1·0	−30·8	30·9	271·9	13·3
	Cotton	40·6	−1·3	−31·9	31·9	267·8	8·3
	Viscose	67·6	36·9	69·9	26·4	62·2	12·5
Golden Yellow CN-GL	Tencel	65·8	37·7	66·4	25·4	60·4	11·9
	Cotton	69·9	34·9	69·7	26·0	63·4	10·3

TABLE 7
Colorimetric Data for 2% o.m.f. Sumifix Supra Dyeings

Sumifix Supra	*Fibre*	L^*	a^*	b^*	c^*	h^0	*K/S*
Red 3-BF	Viscose	40·6	62·1	−1·5	62·2	358·7	20·1
	Tencel	40·7	60·7	1·2	60·7	1·15	17·9
	Cotton	43·3	61·9	−0·9	61·9	359·1	14·9
Blue BRF	Viscose	36·1	1·3	−34·6	34·6	272·2	12·4
	Tencel	35·8	0·1	−31·3	31·3	270·2	11·3
	Cotton	38·4	−0·0	−33·1	33·1	269·9	9·8
Yellow 3-RF	Viscose	70·7	32·6	77·2	83·9	67·1	15·3
	Tencel	68·9	32·3	73·5	80·3	66·3	14·3
	Cotton	71·3	31·4	76·9	83·1	67·8	14·0

cotton and for the remaining five dyes, dye exhaustion on Tencel was higher than that obtained on cotton.

The *K/S* values in Tables 5–7 support the well known fact that the fixation of reactive dyes is higher on viscose than on cotton, insofar as, for each of the three types of dye, the colour strength obtained on viscose was much higher than on cotton; the magnitudes of the differences in colour strength ($\Delta K/S$) obtained for the dyeings on viscose and cotton are shown in Table 9. The results displayed in Tables 5–7 also show that, for each dye under consideration, the dyeings on viscose were of slightly greater colour yield than those on Tencel. Table 9 shows that the difference in colour strength between dyeings on Tencel and cotton was slightly lower than that between regular viscose and cotton; furthermore, the relatively low difference in colour strength observed (Table 9) between

TABLE 8
Dyebath Exhaustion (%) Achieved for the three Types of Dye on Each Fibre Type

Dye	*Viscose*	*Tencel*	*Cotton*
Drimarene Brilliant Red K-4BL	96·3	92·3	91·7
Drimarene Blue K-2RL	96·0	94·3	95·4
Drimarene Golden Yellow K-2R	97·0	95·3	95·7
Kayacelon React Red CN-3B	91·0	87·0	93·3
Kayacelon React Blue CN–BL	94·2	93·0	94·0
Kayacelon React Golden Yellow CN–GL	95·3	93·7	89·7
Sumifix Supra Red 3-BF	94·5	93·8	89·8
Sumifix Supra Blue BRF	99·0	98·4	98·1
Sumifix Supra Yellow 3-RF	97·8	94·4	96·5

TABLE 9
Difference in Colour Strength ($\Delta K/S$) for 2% o.m.f. Dyeings

Dye	*V-C*	*T-C*	*V-T*
Drimarene Brilliant Red K-4BL	3·4	3·1	0·3
Drimarene Blue K-2RL	3·9	3·2	0·7
Drimarene Golden Yellow K-2R	0·3	2·3	0·8
Kayacelon React Red CN-3B	5·0	3·6	1·4
Kayacelon React Blue CN–BL	4·6	5·0	−0·4
Kayacelon React Golden Yellow CN–GL	2·2	1·6	0·6
Sumifix Supra Red 3-BF	5·2	3·0	2·2
Sumifix Supra Blue BRF	2·6	1·1	1·1
Sumifix Supra Yellow 3-RF	1·3	1·0	1·0

dyeings on viscose and Tencel implies that, in terms of colour strength, dyeings on Tencel were similar to those on regular viscose and, therefore, that the dyeability of Tencel was more similar to that of regular viscose than cotton. The similar dyeability of Tencel and viscose observed is not entirely surprising, since although the two types of fibre are produced using different processes, each is a regenerated cellulosic fibre.

Further evidence that the dyeability of Tencel more closely resembled that of viscose rather than cotton was provided by the results obtained for the 6% o.m.f. trichromat dyeings on the three types of fibre; as Table 10 shows, the trichromat dyeings on Tencel were more similar, in terms of chromaticity, lightness and colour yield, to those on viscose rather than those on cotton.

The three types of reactive dye used in this study were chosen so as to

TABLE 10
Colorimetric Data for 6% o.m.f. Trichromat Dyeings

Trichromat	*Fibre*	L^*	a^*	b^*	c^*	h^0	K/S
	Viscose	19·2	5·9	1·4	6·1	13·7	19·9
Drimarene	Tencel	21·4	5·8	2·5	6·3	23·2	17·8
	Cotton	22·0	5·7	3·1	6·5	28·7	17·5
	Viscose	26·5	15·6	−4·5	5·4	344·1	13·4
Kayacelon React	Tencel	26·1	13·5	−4·1	4·7	343·1	12·9
	Cotton	31·5	17·6	−1·9	5·9	353·6	9·6
	Viscose	19·5	12·5	−5·6	13·7	335·5	22·6
Sumifix Supra	Tencel	21·5	12·8	−4·6	13·7	340·2	18·5
	Cotton	23·6	12·6	−2·6	12·9	348·6	15·5

determine whether the type of reactive group, namely difluoro-monochloropyrimidine (*Drimarene K*), monochlorotriazine-monosulphatoethylsulphone (*Sumifix Supra*) and mono-(*m*-carboxypyridinium)-triazine (*Kayacelon React*) or application temperature, namely 40°C (*Drimarene K*), 60°C (*Sumifix Supra*) and 98°C (*Kayacelon React*) were of significance in the dyeability of Tencel. The results presented in Tables 5–7 and Table 9 show that, in terms of colour strength, neither the type of reactive group nor the application temperature was of significance with regards the dyeability of all three fibre types employed.

CONCLUSIONS

The colorimetric parameters of the dyeings obtained using the nine dyes on the three types of fibre reflected those of the undyed substrates and, in general, there was relatively little difference in colour between the dyeings on the three fibre types. Although dyebath exhaustion was higher on regular viscose than on Tencel and cotton, there was relatively little difference in dyebath exhaustion secured for the dyes on the latter two fibre types. The colour strength of the dyeings was lowest on cotton, the dyeings on Tencel being of slightly lower colour strength than those on viscose. The results obtained suggest that the dyeability of Tencel with the three types of reactive dye more closely resembles that of regular viscose than cotton.

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