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The Dyeing of Nylon 6,6 Microfibre

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ABSTRACT

A total of 13 acid dyes were applied to conventional and microfibre knitted nylon 6,6 fabrics using four different dyeing methods. The dyes exhibited a faster rate of uptake, a higher extent and rate of dye desorption, lower wash fastness and lower colour strength on microfabric than on conventional decitex fabric. These findings are attributable to the greater surface area of the microfabric.

INTRODUCTION

The linear density of a filament or fibre is defined as[1] *the mass per unit length of linear textile material* and is normally expressed in decitex per filament (dtexpf) where 1 dtex is[1] *the mass in grams of 10 km of fibre*. A microfibre is defined as[1] *a fibre or filament of linear density approximately 1 dtex or less, although some commercial products may in practice be as coarse as 1·3 dtex*; however, even finer fibres of < 0·3 dtex are produced, these commonly being referred to as 'supermicrofibres'.[2]

Microfibres, whose origins lay[2] in the production of artificial suede[3–6] that first appeared in 1970 are now well established in many apparel and other outlets,[5,7–13] enjoying use either in single fibre fabrics or in conjunction with coarser synthetic or natural fibres. Such fabrics possess enhanced drapeability, lustre, softness and smoothness and, in many cases, novel tactile and visual aesthetics. Whilst the majority of microfibres are microfilaments, microstaple fibres are also produced although the outlets for the latter types of fibre are determined by different criteria than those of filament yarns,[8] even though the drape, handle and appearance of microstaple fibres are similar to those achieved using microfilaments.[2]

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Of the three major man-made fibres, polyester has received the greatest attention in the context of microfibres[2,4,9] Polyamide microfibres have been available for several years[10,14–18] and find usage in outlets such as underwear, sports/leisure wear and as 'cotton-look' outerwear.[10] Very few publications have attended acrylic microfibres even though they have been available for some time.[2]

Despite their established use and growing popularity, relatively few publications have concerned the dyeing of microfibres. This paper concerns the dyeing of a microfibre, knitted nylon 6,6 fabric and a comparison of the dyeability of this fibre type with that of a conventional decitex, knitted nylon 6,6 fabric.

EXPERIMENTAL

Materials

Fabrics

The two types of knitted nylon 6,6 fabrics, namely conventional (78F46; 1·7 dtexpf) and microfibre (85F92; 0·9 dtexpf), each kindly supplied by Du Pont Fibres (UK), were scoured prior to use by the method previously described.[19]

Dyes

The dyes used are divided into four groups according to the methods used for their application.

Group I. Commercial samples of Nylomine Blue A-G (CI Acid Blue 25), Nylomine Navy C-2R (CI Acid Blue 113), each kindly supplied by Zeneca Specialties, as well as Nylosan Bordeaux N-BL (CI Acid Red 119) and Nylosan Orange N-RL (CI Acid Orange 127), each generously supplied by Sandoz (UK) were employed.

Group II. Commercial samples of Tertroxyl Light Blue R (CI Acid Blue 41), Tertroxyl Fast Yellow 2R (CI Acid Yellow 42) and Tertroxyl Fast Red GN (CI Acid Red 337), each kindly supplied by Crompton and Knowles Ltd were used.

Group III. Commercial samples of Nylanthrene Blue RNL (CI Acid Blue 129), Nylanthrene Yellow FLW (CI Acid Yellow 159) and Nylanthrene Rubine 5BLW (CI Acid Red 229), each kindly supplied by Crompton and Knowles Ltd were employed.

Group IV. Commercial samples of Neutrilan Navy S-NL (CI Acid Blue 348), Neutrilan Yellow S-2G (no CI Generic Name) and Neutrilan Red S-GN (CI Acid Red 359), each kindly supplied by Crompton and Knowles Ltd were used.

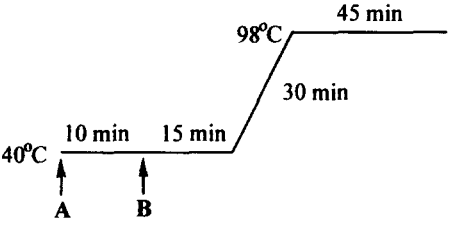
Dyeing auxiliaries
Commercial samples of Matexil LA-NS, Matexil LC-CWL and Lenetol B conc. were kindly supplied by ICI Surfactants and commercial samples of Asta Agent B and Intrasol CLW were generously supplied by Crompton and Knowles Ltd.

All other reagents were of general purpose grade.

Dyeing

Four dyeing methods were used, one for each of the four groups of dyes listed above.

Dyeing method for Group I dyes
Samples (2·000 g) of nylon 6,6 fabric were dyed in sealed, stainless steel dyepots of 300 cm^3 capacity housed in a Zeltex Polycolor laboratory-scale dyeing machine using a liquor ratio of 50:1; the dyeing method used is shown in Fig. 1. At the end of dyeing, the dyed sample was removed, rinsed thoroughly in tap water and allowed to dry in the open air.



A	fabric	
	HCOOH	1% omf
	CH_3COONH_4	3.5% omf
B	dye	
	Matexil LC-CWL	1% omf
	Matexil LA-NS	1% omf

Fig. 1. Dyeing method for Group I dyes.

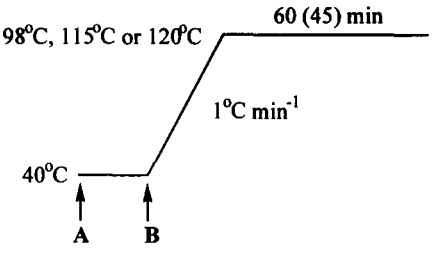


Figure in brackets refer to Group IV dyes

Group II dyes		
A	$(NH_4)_2SO_4$	2% omf for 0.5%, 1% and 2% omf dyeings
	CH_3COOH	to pH 5.5 for 4% omf dyeings
	Asta agent B	1% omf
B	Dye	
Group III dyes		
A	$(NH_4)_2SO_4$	2 g dm^{-3} for 0.5%, 1% and 2% omf dyeings
	monosodium phosphate	to pH 5.5 for 4% omf dyeings
	Asta agent B	1% omf
B	Dye	
Group IV dyes		
A	CH_3COONH_4	4% omf
	CH_3COOH	to pH 6.5 for 0.5% and 1% omf dyeings, pH 6 for 2% omf dyeing and pH 5 for 4% omf dyeing
	Intrasol CLW	1% omf
B	Dye	

Fig. 2. Dyeing method for Group II–IV dyes.

Dyeing methods for Group II–IV dyes

Samples (3·000 g) of nylon 6,6 fabric were dyed in partially sealed, glass dyepots of 200 cm^3 capacity housed in a Zeltex Vistacolor laboratory-scale dyeing machine. Each of the nine dyes used was applied at 0·5, 1, 2 and 4% omf at 98, 115 and 120°C using a 50:1 liquor ratio. The dyeing methods employed for the three types of acid dye are shown in Fig. 2. At the end of dyeing, the dyed sample was removed and scoured using 2 g dm^{-3} Lenetol B conc. for 15 min at 80°C using a 50:1 liquor ratio; the scoured sample was then rinsed thoroughly in tap water and allowed to dry in the open air.

Measurement of uptake of CI Acid Blue 25 on to nylon 6,6 fabrics

Samples (2·000 g) of conventional and microfibre nylon 6,6 fabrics were dyed using 1% omf CI Acid Blue 25 employing dyeing method I (Fig. 1).

The extent of dyebath exhaustion at four stages of dyeing, namely after 25 min (at 40°C) and after 55, 75 and 100 min (each at 98°C) was determined by taking aliquots of the dyebath at the end of each of the various stages and measuring the absorbance of the cooled and diluted aliquots at 640 nm (the λ_{max} of the dye) employing a Pye-Unicam PU 8600 spectrophotometer using water as reference solvent. The absorbance data obtained were converted to percentage exhaustion values using eqn (1) where A_0 and A_t are the absorbances at time 0 and t, respectively.

$$\frac{A_0 - A_t}{A_0} \times 100. \tag{1}$$

The degree of dye distribution within the dyed fibre at each of the four stages of dyeing mentioned above was determined using optical microscopical analysis. Cross-sections were obtained of dried samples, from each of the four stages, that had been thoroughly rinsed in tap water as well as samples from each stage that were unrinsed. A fibre bundle was embedded in acrylic resin and sliced using a Feather 535 microtome blade and the ensuing section placed on a glass slide, cleaned using xylene and mounted in Gurr mounting medium under a standard glass cover slip.

Measurement of final dyebath exhaustion

Using the dyeing method described for the Group I dyes, nylon 6,6 fabric was dyed using either 1, 2, or 4% omf of each of the four Group I dyes. At the end of dyeing, the dyed sample was removed and the residual dyebath allowed to cool to room temperature. The concentration of dye remaining in the residual dyebath was determined, after appropriate dilution, by measuring the absorbance of the diluted solution at the λ_{max} of each dye employing a Pye-Unicam PU 8600 spectrophotometer using water as reference solvent, and by reference to the appropriate calibration curve. The extent of dyebath exhaustion (%E) was calculated using eqn (2) where C_0 and C_1 are the concentrations of the dyebath at the start and finish of dyeing, respectively:

$$\%E = \frac{C_0 - C_1}{C_0} \times 100. \tag{2}$$

Measurement of the rate of desorption of CI Acid Blue 25 into 0·05 M aqueous sodium borate solution

Using the dyeing method described for the Group I dyes, nylon 6,6 fabric was dyed using 1% and also 2% omf CI Acid Blue 25. The dyed samples were then treated in a 0.05 M aqueous solution of sodium borate at 60°C

for 30 min using a liquor ratio of 50:1. The borax solution was contained within a partially sealed 200 cm^3 capacity glass dyepot housed in a Zeltex Vistacolor laboratory scale dyeing machine using a liquor ratio of 50:1. Desorption rates were determined by continuously monitoring the absorbance of the washing liquor at 640 nm (the λ_{max} of the dye), using 0.05 M aqueous sodium borate as reference solvent, employing the equipment and arrangement described previously.[19] The absorbance values were converted to concentration by reference to a calibration curve of the dye in 0.05 M aqueous sodium borate solution.

Colour measurement

The reflectance values of the dry dyeings were measured using a Macbeth 2020 spectrophotometer interfaced to a Digital PC under illuminant D_{65}, using a 10° Standard Observer with specular component excluded and UV component included. The *K/S* values were derived from the reflectance values at the λ_{max} of the respective dye. Each sample was folded twice so as to provide a total of four thicknesses of material.

Wash fastness determination

The fastness of dyed samples to the ISO C06/C2 wash test was determined using the standard method.[20]

RESULTS AND DISCUSSION

In this work, two types of nylon 6,6 knitted fabric were used, namely one composed of conventional fibre (1·7 dtexpf) and one composed of microfibre (0·9 dtexpf); each fibre type was of the same amino end group content (66·4 g equiv. 10^{-6} g).[22]

Although it has been suggested[21] that both the rate and extent of dye uptake of both non-metallised acid and pre-metallised acid on microfibre differ only slightly from those obtained on conventional decitex fibres, it was shown[14] that, when applied under identical conditions at 1% omf, the rate of uptake of CI Acid Red 261 on to 1 dtex nylon 6,6 microfibre was lower than that achieved on to 4 dtex conventional nylon 6,6 fibre. The findings displayed in Fig. 3, which show the extent of dyebath exhaustion achieved when 1% omf CI Acid Blue 25 was applied, under identical conditions, to the 0·9 dtexpf microfabric and the 1·7 dtexpf conventional fabric, are contrary to these particular observations.[14,21] In Fig. 3, it is evident that in the initial stages of dyeing (after 25 min at 40°C), dye uptake was greater on micro-

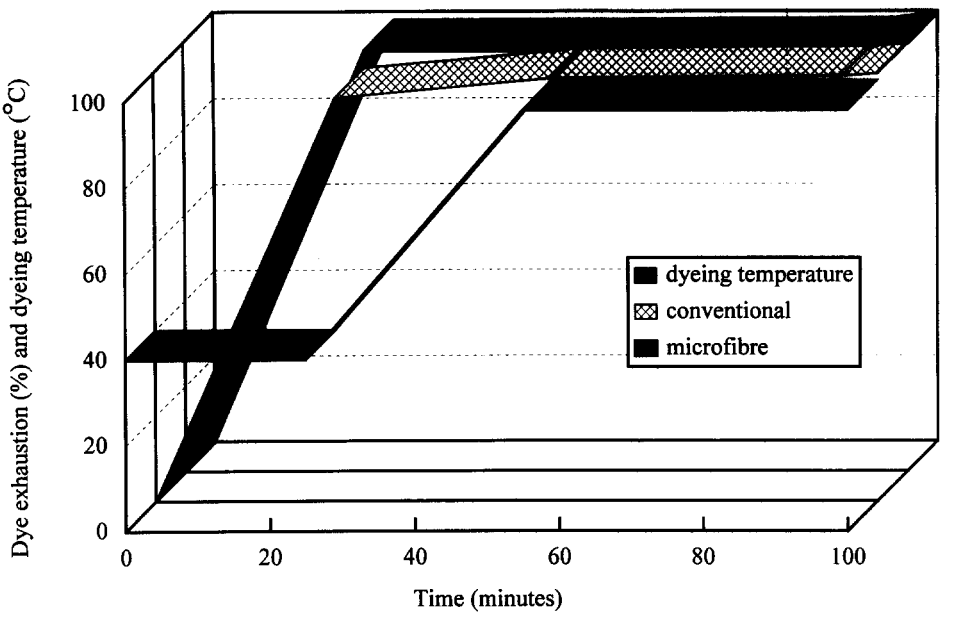


Fig. 3. Rate of uptake of 1% omf CI Acid Blue 25 on to conventional and microfibre nylon 6,6.

fibre, but, as dyeing proceeded and dyeing temperature increased, the rate of dye uptake on to microfibre decreased, until, at the end of dyeing at 98°C, complete (i.e. 100%) dyebath exhaustion was secured for both types of fibre. The more rapid rate of dyeing observed for microfibre fabric in the early stages of dyeing (Fig. 3) can be attributed to the substrate's greater surface area, as it is well known that a reduction in filament linear density is accompanied by an increase in the surface area per unit volume of the filament, the specific surface increasing markedly with decreasing filament linear density.[2]

Examination of the dye distribution across the dyed filaments revealed that in the early stages of dyeing (at low temperature), the majority of the adsorbed dye was, for both fibre types, situated at the fibre periphery; however, the extent of this ring dyeing was greater for microfibre, a finding that can be again attributed to the greater surface area of the micro yarn. Also, the extent of this ring dyeing was observed to decrease to a greater degree in the case of conventional fibre with increasing time and temperature of dyeing and, at the end of dyeing, whilst ring dyeing was absent in the case of conventional fibre, this was not the case with the microfibre. The greater tendency of the microfibre to ring dye can be attributed to the rate and extent of dye diffusion within the microfibre being lower than that within its conventional decitex counterpart owing to the lower internal volume of the former type of fibre.

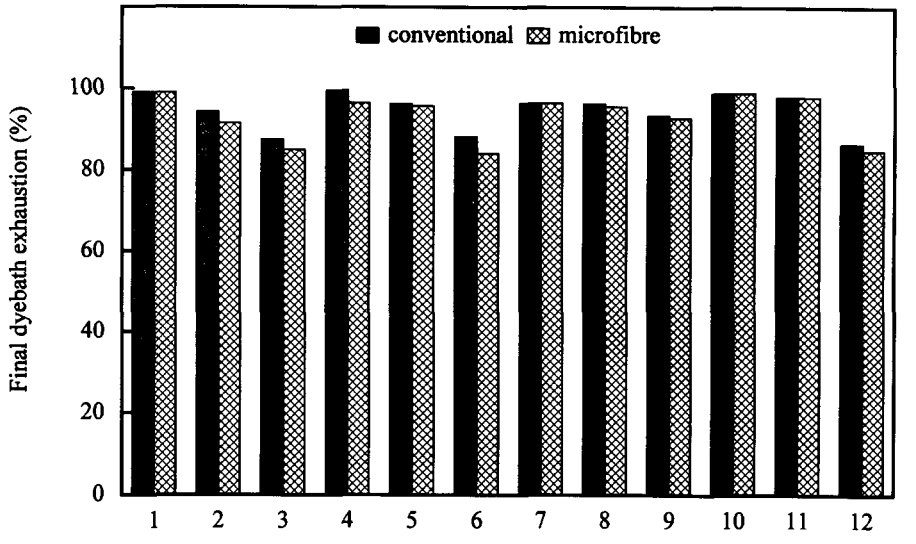


Fig. 4. Final dyebath exhaustion achieved for dyeings on conventional and microfibre nylon 6,6 fabrics at 98°C (1:1% omf, 2: 2% omf, 3: 4% omf CI Acid Blue 25; 4: 1% omf, 5: 2% omf, 6: 4% omf CI Acid Blue 113; 7: 1% omf, 8: 2% omf, 9: 4% omf CI Acid Red 119; 10: 1% omf, 11: 2% omf, 12: 4% omf CI Acid Orange 127).

Figure 4 shows the extent of dyebath exhaustion achieved at the end of dyeing when each of the four Group I dyes had been applied, at 1, 2 and 4% omf, to both types of fibre using dyeing method I. It is apparent that for each dye used, final dyebath exhaustion was slightly greater in the case of the conventional decitex fabric, this difference being more pronounced in the case of the deeper shades applied. The following argument is advanced to explain the observed lower extent of dyebath exhaustion in the case of microfabric. During the dyeing of both micro and conventional substrates, the dye molecules will be adsorbed on to the fibre surface and then diffuse within the interior of the fibre. As the rate of dye diffusion within the fibre can be considered to be governed by the concentration of dye at the fibre surface and the available volume within the interior of the substrate in which the dye molecules diffuse, when both the surface dye concentration and the internal volume are high, the rate of dye diffusion within the fibre (and thus the rate of dyeing) will also be high. However, if the surface dye concentration and the internal volume are both low, the rate of dye diffusion will be low. In the case of microfibres, whilst dye uptake at the fibre surface was found to be high owing to the fibre's large surface area, in comparison, the available internal volume will be low. Hence, it can be proposed that as dyeing of the microfibre proceeds, there is a limit to the amount of dye that can be accommodated within the comparatively low internal volume of the substrate which, in turn, limits the rate of dye

uptake and, therefore, the extent of dyebath exhaustion. Support for this argument accrues from the observation (Fig. 4) that the difference in dyebath exhaustion secured for dyeings of micro and conventional fibres increased with increasing concentration of dye applied. This implies that, in the case of microfibre, even though at higher concentrations of applied dye more dye might be present at the fibre surface this dye cannot diffuse into the small available internal volume of the substrate.

The polymer used in the two types of nylon 6,6 fabric was identical[22] and, therefore, it was expected that each fibre type should display similar dyeability. Evidence for this was secured, by the findings displayed in Tables 1–9, which show that when the six non-metallised acid dyes of Groups II and III and the three monosulphonated 1:2 metal–complex dyes of Group IV, were applied, at five depths of shade (0.5, 1, 2, 3 and 4% omf) and three dyeing temperatures (98, 115 and 120°C), to the two types of nylon 6,6 fabric, there was very little difference in the hue ($H°$) and chroma (a^*, b^*, c^*) of the dyeings on each type of fibre.

However, Tables 1–9 also reveal that the colour strength (K/S) of identical depth dyeings secured using the total of nine Group II–IV dyes on microfabric was lower than that on its conventional decitex counterpart; Fig. 5 shows that an identical situation was obtained in the case of the four Group I dyes. The observed lower colour strength of dyeings on micro fabric (Tables 1–9 and Fig. 5) is attributable to the greater extent of surface reflection that

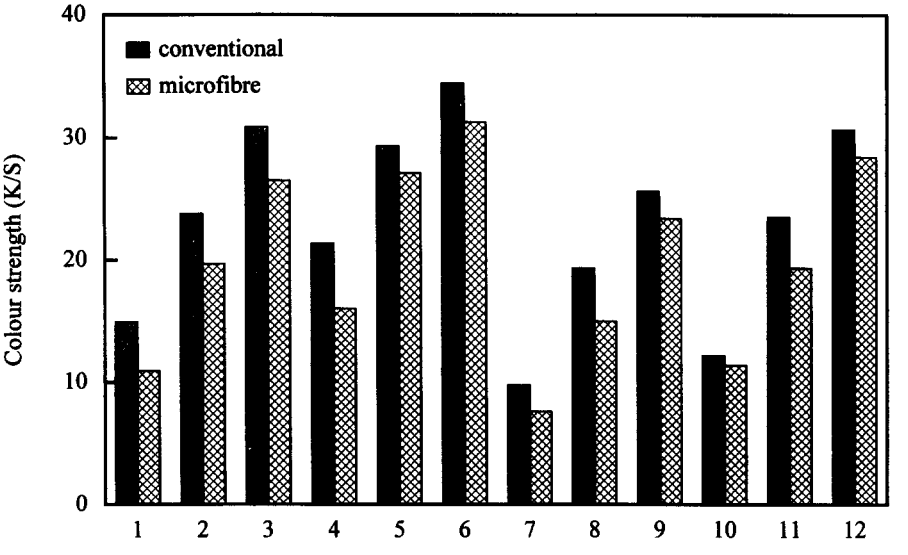


Fig. 5. Color strength (K/S) achieved for dyeings on conventional and microfibre nylon 6,6 fabrics at 98°C (1:1% omf, 2: 2% omf, 3: 4% omf CI Acid Blue 25; 4: 1% omf, 5: 2% omf, 6: 4% omf CI Acid Blue 113; 7: 1% omf, 8: 2% omf. 9: 4% omf CI Acid Red 119; 10: 1% omf, 11: 2% omf, 12: 4% omf CI Acid Orange 127).

results from the greater surface area of polyamide microfibres.[2] This has also been observed by several workers using various types of dye on polyamide fibres;[14,18,21] indeed, it has been proposed[21] that, depending on fibre dtex and lustre, polyamide microfibre may require up to 100% more dye than conventional fibre.

TABLE 1
Colorimetric Data for CI Acid Blue 41

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	63·7	−7·9	−29·3	30·4	254·9	1·61
0·5% M	67·2	−7·8	−26·1	27·5	253·3	1·16
1% C	57·4	−7·0	−33·4	34·2	258·2	2·64
1% M	59·4	−6·8	−30·8	31·0	257·6	2·10
2% C	49·3	−5·3	−35·9	36·4	261·6	4·79
2% M	52·5	−5·6	−34·7	35·1	260·8	3·63
4% C	52·5	−5·4	−35·1	35·6	261·2	3·69
4% M	54·9	−5·4	−33·1	33·6	260·7	2·94
			115°C			
0·5% C	61·9	−7·7	−30·7	31·7	255·9	1·85
0·5% M	63·3	−7·7	−29·5	30·5	255·3	1·63
1% C	53·4	−6·4	−35·9	36·5	259·9	3·66
1% M	55·3	−6·5	−34·4	35·0	259·3	3·06
2% C	45·3	−3·9	−38·9	39·2	264·2	6·82
2% M	48·6	−4·8	−37·2	37·5	262·7	5·11
4% C	48·9	−4·5	−36·5	36·8	262·9	4·85
4% M	51·9	−5·0	−34·3	34·7	261·7	3·71
			120°C			
0·5% C	61·6	−8·4	−30·3	31·5	254·6	1·92
0·5% M	64·9	−8·3	−27·3	28·6	253·1	1·42
1% C	55·9	−7·5	−35·3	35·9	259·6	3·01
1% M	56·8	−6·2	−34·1	34·6	259·8	2·69
2% C	49·2	−4·9	−37·6	37·9	262·4	4·98
2% M	51·5	−5·4	−36·1	36·4	261·6	4·03
4% C	50·7	−5·3	−34·4	34·8	261·6	4·07
4% M	54·9	−5·1	−32·8	33·2	260·8	2·87

C: conventional; M: microfibre.

TABLE 2
Colorimetric Data for CI Acid Yellow 42

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	86·9	2·6	55·3	55·3	87·4	1·82
0·5% M	87·9	2·2	48·3	48·3	87·4	1·27
1% C	85·3	6·9	69·6	69·9	84·3	3·76
1% M	85·3	5·8	63·6	63·9	84·8	2·96
2% C	82·4	10·8	79·0	79·6	82·2	7·08
2% M	83·3	10·0	75·5	76·2	82·5	5·71
4% C	79·5	12·4	77·9	78·9	80·9	8·87
4% M	81·8	11·6	74·2	75·1	81·2	5·92
			115°C			
0·5% C	77·7	4·4	39·7	36·9	83·8	1·76
0·5% M	86·1	4·8	40·7	41·0	83·2	1·06
1% C	82·9	7·1	65·4	65·8	83·3	3·70
1% M	83·4	6·4	56·1	56·5	81·2	2·46
2% C	81·4	13·3	78·8	79·9	80·4	7·96
2% M	81·9	11·5	74·3	75·2	81·2	5·97
4% C	82·4	11·8	78·3	79·2	81·4	6·78
4% M	82·5	9·7	72·0	72·7	82·3	5·15
			120°C			
0·5% C	85·7	5·4	42·9	43·3	82·7	1·17
0·5% M	86·9	4·9	34·6	34·9	82·0	0·76
1% C	82·9	9·9	62·4	63·2	80·9	3·23
1% M	83·6	8·4	53·2	53·9	81·1	2·13
2% C	81·7	12·3	76·4	77·4	80·9	6·59
2% M	82·1	10·8	71·1	71·91	81·4	5·15
4% C	82·5	10·7	73·1	73·9	81·7	5·29
4% M	81·8	12·6	76·5	77·5	80·6	5·18

C: conventional; M: microfibre.

TABLE 3
Colorimetric Data for CI Acid Red 337

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	60·8	50·5	3·5	50·6	3·9	3·05
0·5% M	63·3	46·3	2·6	46·4	3·6	2·26
1% C	53·9	56·4	8·5	57·0	8·6	6·30
1% M	56·1	53·7	7·3	54·2	7·8	4·83
2% C	47·8	59·9	14·0	61·3	13·2	12·36
2% M	49·8	57·0	11·7	58·2	11·5	9·36
4% C	46·0	59·3	15·3	61·3	14·5	14·49
4% M	49·9	56·9	11·9	58·1	11·9	9·25
			115°C			
0·5% C	59·5	51·2	3·8	51·3	4·3	3·44
0·5% M	62·8	47·3	2·8	47·4	3·4	2·42
1% C	53·6	56·4	8·5	57·1	8·6	6·48
1% M	55·9	53·9	7·4	54·4	7·8	4·94
2% C	47·6	59·3	13·8	60·8	13·1	12·35
2% M	50·2	57·7	12·0	58·9	11·8	9·23
4% C	46·5	59·1	14·8	60·9	14·1	13·72
4% M	49·8	57·2	12·4	58·6	12·2	9·48
			120°C			
0·5% C	59·6	50·1	3·6	50·2	4·1	3·28
0·5% M	62·3	45·2	2·8	45·3	3·5	2·33
1% C	52·7	53·2	6·5	53·6	6·9	6·22
1% M	55·7	52·8	7·3	52·8	7·9	4·82
2% C	47·6	58·9	13·6	60·5	13·0	12·28
2% M	49·9	57·1	11·9	58·3	11·8	9·19
4% C	48·1	57·9	13·1	59·1	12·7	11·13
4% M	49·9	56·4	11·7	57·6	11·7	9·05

C: conventional; M: microfibre.

TABLE 4
Colorimetric Data for CI Acid Blue 129

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	51·7	3·3	–45·4	45·5	274·2	4·17
0·5% M	54·9	2·1	–43·3	43·3	272·8	3·17
1% C	43·7	8·4	–50·7	51·3	279·4	8·07
1% M	46·7	6·1	–47·9	48·4	277·2	6·12
2% C	37·5	12·1	–51·8	53·3	273·1	13·06
2% M	40·5	9·5	–50·2	51·1	280·6	10·06
4% C	32·8	15·6	–52·3	54·6	286·6	18·32
4% M	36·4	11·9	–50·6	51·9	283·2	13·64
			115°C			
0·5% C	50·9	2·8	–45·7	45·8	273·5	4·52
0·5% M	54·3	0·7	–41·6	41·6	271·0	3·29
1% C	43·9	7·0	–49·5	50·0	278·1	7·86
1% M	47·4	4·6	–46·5	46·7	275·6	5·74
2% C	37·8	10·9	–51·5	52·6	282·1	12·95
2% M	41.8	7·6	–49·2	–81·1	270·1	5·11
4% C	33·5	13·7	–51·2	53·0	285·0	17·46
4% M	36·7	1·7	–49·9	50·0	282·1	13·51
			120°C			
0·5% C	50·1	3·2	–45·3	45·4	274·0	4·70
0·5% M	54·5	1·0	–41·9	41·9	271·4	3·23
1% C	42·3	7·8	–49·5	50·1	278·9	8·61
1% M	45·4	5·9	–47·5	47·8	277·7	6·71
2% C	34·5	13·4	–51·7	53·4	284·5	16·38
2% M	37·6	10·5	–50·1	51·2	281·9	12·57
4% C	29·8	16·6	–50·9	53·5	288·1	21·64
4% M	31·4	14·5	–50·2	52·3	286·6	19·51

C: conventional; M: microfibre.

TABLE 5
Colorimetric Data for CI Acid Yellow 159

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	81·4	4·7	48·1	–48·3	84·5	3·43
0·5% M	84·2	6·8	46·7	47·2	81·7	2·57
1% C	78·4	14·5	59·4	61·2	76·3	7·02
1% M	79·9	13·5	55·9	57·6	76·4	5·33
2% C	74·6	28·8	66·9	72·8	66·7	12·57
2% M	75·3	21·5	63·8	67·3	71·3	10·57
4% C	69·7	30·5	69·4	75·8	66·3	18·24
4% M	70·4	27·2	66·2	71·6	67·3	16·02
			115°C			
0·5% C	83·3	8·6	50·4	51·1	80·4	3·28
0·5% M	84·3	7·0	46·5	46·9	81·4	2·50
1% C	79·1	15·2	59·7	61·6	75·8	6·78
1% M	80·1	14·2	56·2	57·9	75·9	5·31
2% C	74·5	22·8	66·1	69·9	79·4	12·49
2% M	76·6	20·1	62·7	65·8	72·2	9·18
4% C	68·9	29·0	68·6	72·3	67·1	19·01
4% M	71·4	25·2	65·9	70·6	69·1	14·99
			120°C			
0·05% C	81·8	5·5	48·1	43·4	83·4	3·33
0·05% M	82·3	5·7	45·6	45·9	82·8	2·83
1% C	76·1	13·0	55·5	56·9	76·8	6·99
1% M	78·1	10·9	54·2	55·3	78·5	5·69
2% C	74·1	23·6	66·6	70·7	70·5	12·95
2% M	73·6	21·3	62·9	66·4	71·3	10·04
4% C	68·3	32·2	69·6	76·3	68·8	19·93
4% M	69·8	29·2	67·4	73·5	66·6	17·13

C: conventional; M: microfibre.

TABLE 6
Colorimetric Data for CI Acid Red 229

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	39·2	29·5	−19·2	35·2	324·1	5·88
0·5% M	42·6	27·9	−18·1	33·3	327·0	4·51
1% C	29·5	30·4	−18·4	35·4	328·9	12·43
1% M	32·8	29·9	−18·1	35·0	328·8	9·53
2% C	22·6	27·8	−15·8	31·9	330·5	20·56
2% M	25·3	28·9	−16·5	33·3	330·5	17·00
4% C	17·8	20·9	−11·5	23·9	331·2	26·66
4% M	20·1	24·6	−13·3	27·8	331·5	23·52
			115°C			
0·5% C	39·8	29·4	−18·8	34·9	327·5	5·62
0·5% M	42·5	27·9	−17·7	32·9	328·1	4·57
1% C	29·3	30·6	−17·9	31·6	328·1	12·68
1% M	32·7	29·8	−17·6	34·6	329·6	9·57
2% C	22·2	27·4	−15·1	31·3	331·1	16·75
2% M	25·3	28·4	−15·6	35·5	331·8	25·50
4% C	18·5	21·8	−11·7	24·7	331·7	25·46
4% M	20·5	24·9	−13·2	28·2	332·1	23·16
			120°C			
0 5% C	37·6	30·2	−18·5	35·5	328·5	6·69
0·5% M	42·8	27·7	−16·9	32·4	328·7	4·45
1% C	28·4	30·4	−17·4	35·0	330·3	13·59
1% M	32·2	29·7	−16·9	34·2	330·3	9·99
2% C	22·2	27·1	−14·9	30·9	331·1	20·94
2% M	25·1	28·3	−15·4	32·2	331·3	16·94
4% C	18·1	21·4	−11·3	24·2	332·2	11·13
4%M	20·2	24·2	−12·7	27·3	332·3	23·17

C: conventional; M: microfibre.

TABLE 7
Colorimetric Data for CI Acid Blue 348

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	43·2	−3·5	−14·3	14·7	256·8	4·27
0·5% M	47·1	−3·5	−13·6	14·1	255·7	3·26
1% C	33·1	−2·5	−14·7	14·9	260·3	8·81
1% M	39·0	−3·2	−13·7	14·0	256·9	5·66
2% C	29·1	−0·9	−13·9	13·9	266·1	17·00
2% M	26·8	−1·6	−13·9	14·1	263·3	14·00
4% C	17·0	1·6	−10·9	10·4	277·7	26·78
4% M	19·4	0·6	−12·2	12·2	272·6	23·28
			115°C			
0·5% C	42·9	−2·8	−15·1	15·3	259·6	4·39
0·5% M	45·6	−2·8	−13·9	14·1	258·7	3·55
1% C	30·5	−1·3	−15·4	15·4	265·2	10·66
1% M	36·2	−1·9	−15·1	15·2	262·3	6·97
2% C	22·7	0·9	−14·9	14·9	276·5	18·69
2% M	24·5	0·6	−14·7	14·7	272·7	16·14
4% C	17·5	3·2	−12·8	13·2	284·1	25·61
4% M	19·6	2·2	−13·7	13·9	278·9	22·71
			120°C			
0·5% C	44·1	−2·8	−14·6	14·9	259·2	4·01
0·5% M	46·9	−2·8	−13·8	14·1	258·5	3·23
1% C	34·6	−1·9	−15·1	15·3	262·9	7·85
1% M	37·3	−2·2	−14·7	14·8	261·5	6·41
2% C	23·5	0·5	−14·8	14·8	272·1	17·67
2% M	25·8	−0·2	−14·8	14·8	269·2	14·89
4% C	17·8	2·9	−12·9	13·3	282·8	25·20
4% M	20·0	2·1	−13·8	13·9	278·5	21·84

C: conventional, M: microfibre.

TABLE 8
Colorimetric Data for CI Neutrilan Yellow S-2G

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	74·9	13·1	54·2	55·8	76·4	3·63
0·5% M	75·1	12·8	51·5	53·1	76·1	3·18
1% C	67·9	17·4	58·9	61·5	73·6	7·52
1% M	68·7	16·5	55·4	57·8	73·5	6·00
2% C	59·5	21·9	60·3	64·1	69·9	16·68
2% M	61·3	20·4	59·6	63·0	71·1	13·65
4% C	53·4	24·9	56·7	61·9	66·3	24·26
4% M	54·8	23·1	56·9	61·4	67·9	21·43
			115°C			
0·5% C	73·7	12·3	53·1	54·4	76·9	3·78
0·5% M	75·6	11·9	49·8	51·2	76·6	2·83
1% C	67·2	18·2	60·1	62·8	73·1	8·49
1% M	68·4	15·5	55·9	57·2	74·6	6·31
2% C	60·9	21·6	60·9	64·7	70·5	15·25
2% M	62·0	20·3	59·9	61·3	71·3	13·14
4% C	53·1	24·6	56·1	61·3	66·3	24·16
4% M	55·8	22·5	57·9	62·1	68·8	20·56
			120°C			
0·5% C	74·7	13·1	54·1	56·1	76·5	3·71
0·5% M	75·8	12·3	50·9	52·4	76·4	2·99
1% C	58·6	17·4	59·8	60·3	73·8	8·46
1% M	69·7	15·7	57·4	59·5	74·7	6·04
2% C	59·6	22·1	60·1	63·9	69·8	16·78
2% M	61·8	20·1	59·6	62·9	71·4	13·14
4% C	53·5	24·3	55·8	60·9	66·5	23·28
4% M	56·4	22·5	58·2	62·4	68·9	20·11

C: conventional; M: microfibre.

TABLE 9
Colorimetric Data for CI Acid Red 359

% omf/fibre	*L**	*a**	*b**	*c**	*H°*	*K/S*
			98°C			
0·5% C	53·8	42·1	11·9	43·8	15·8	3·96
0·5% M	56·9	39·4	10·8	40·9	15·3	2·94
1% C	45·5	45·3	15·2	47·9	18·5	8·26
1% M	47·3	43·9	14·3	46·2	18·1	6·81
2% C	38·6	45·7	17·8	49·1	21·4	16·68
2% M	40·8	45·4	16·7	48·3	20·2	12·96
4% C	32·7	43·5	18·5	47·4	23·1	22·82
4% M	35·0	44·5	18·5	48·2	22·6	20·02
			115°C			
0·5% C	53·8	42·3	11·8	43·9	15·6	3·97
0·5% M	56·8	40·3	10·7	41·7	14·9	3·05
1% C	43·3	46·1	13·9	44·5	16·8	9·85
1% M	48·9	43·5	12·0	45·1	15·5	5·85
2% C	35·9	45·2	15·2	48·5	18·6	18·14
2% M	40·7	45·5	14·4	47·7	17·6	12·18
4% C	31·7	43·2	15·3	45·9	19·5	23·52
4% M	34·3	44·6	15·9	47·3	19·8	20·29
			120°C			
0·5% C	54·4	42·3	10·7	43·6	14·2	3·76
0·5% M	56·5	39·9	10·1	41·1	14·1	3·02
1% C	45·7	45·7	13·5	47·6	16·5	8·07
1% M	47·9	43·9	12·6	45·7	16·0	6·42
2% C	36·9	45·6	15·6	48·2	18·9	16·95
2% M	39·4	45·7	14·9	48·0	18·1	13·81
4% C	31·8	43·3	15·1	45·8	19·2	23·28
4% M	34·3	44·5	16·1	47·3	19·9	20·29

C: conventional; M: microfibre.

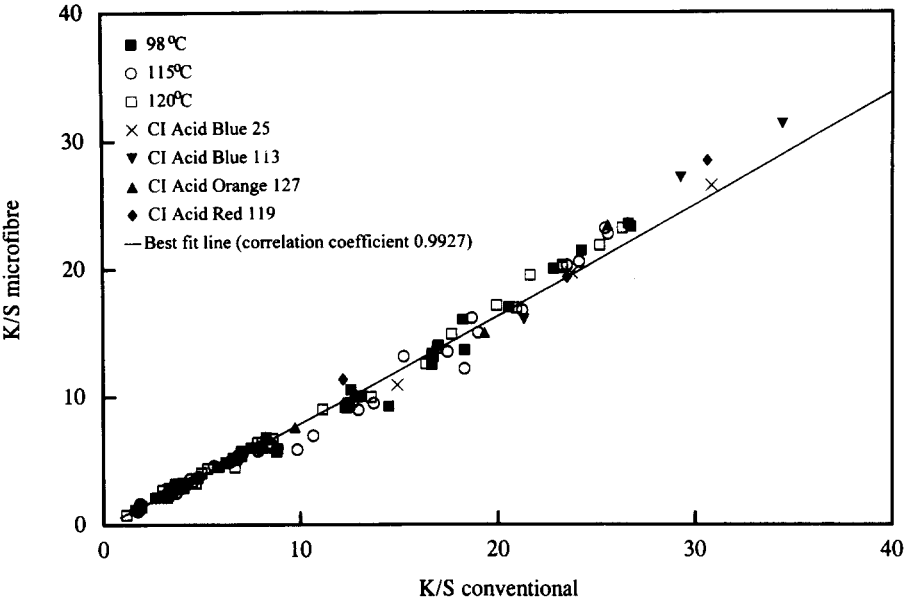


Fig. 6. Relationship between colour strengths of dyed conventional (1·7 dtexpf) and microfabric (0·9 dtexpf) nylon 6,6.

Figure 6 shows the relationship between the colour strength (*K/S* values) of dyeings that were obtained on the micro and conventional nylon 6,6 fabrics. A total of 120 points are displayed, these having been obtained for the four Group I non-metallised acid dyes at three depths of shade (1, 2 and 4% omf) at 98°C as well as the six non-metallised acid dyes of Groups II and III and three 2:1 pre-metallised acid dyes of Group IV each at five depths of shade (0.5, 1, 2, 3 and 4% omf) and three dyeing temperatures (98, 115 and 120°). It is evident that although four different methods had been used to apply the various dyes to the two types of fabric (Figs 1 and 2), a relationship exists between the colour strengths of the dyed micro and conventional decitex fabrics. However, the power regression line fitted to the data clearly shows that this relationship was not linear, insofar as the colour strength of the dyed microfibre approaches that of its conventional decitex counterpart with increasing *K/S*. The effect of reduced filament linear density on depth of shade has been studied by several workers and equations have been derived to relate the concentration of dye required to achieve the same visual depth of shade on two similar fibres of differing dtex[23] and the variation in depth of shade with fibre fineness.[24] However, these equations did not describe the colour strength relationship displayed in Fig. 6 and further work is in hand to derive an equation that will provide a description of the relationship between the colour strengths of the dyed micro and conventional decitex fabrics displayed in Fig. 6.

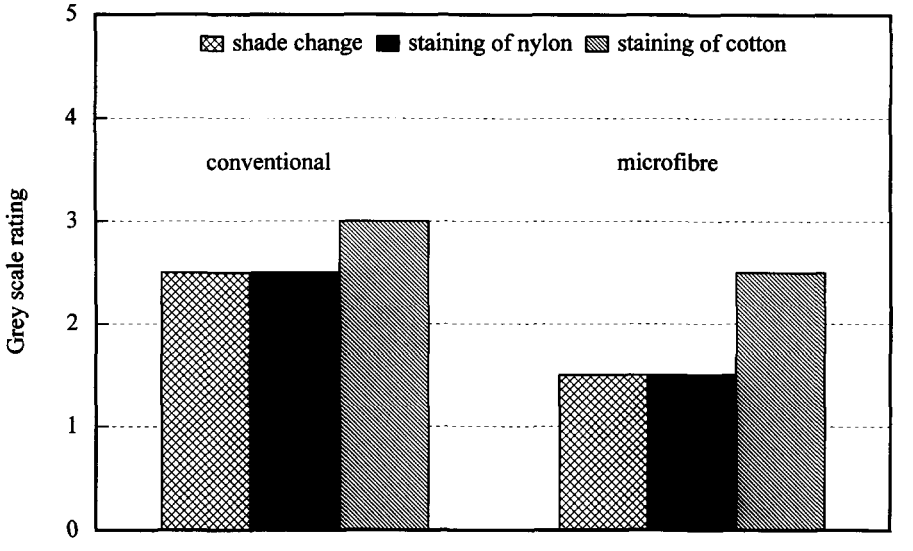
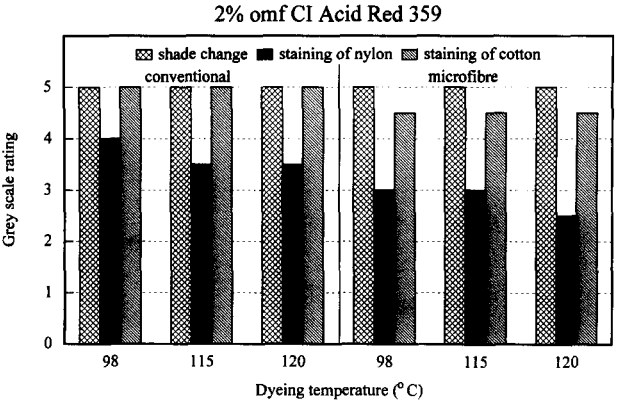
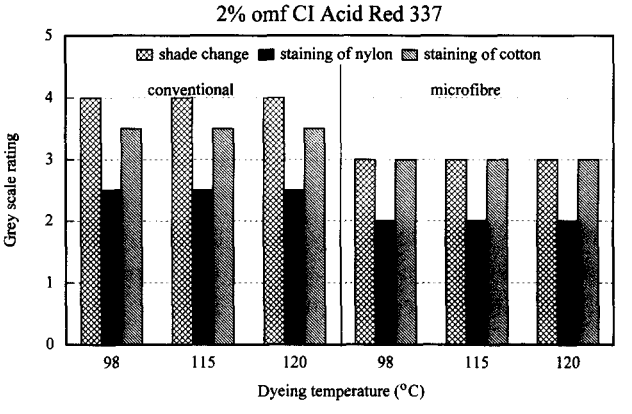


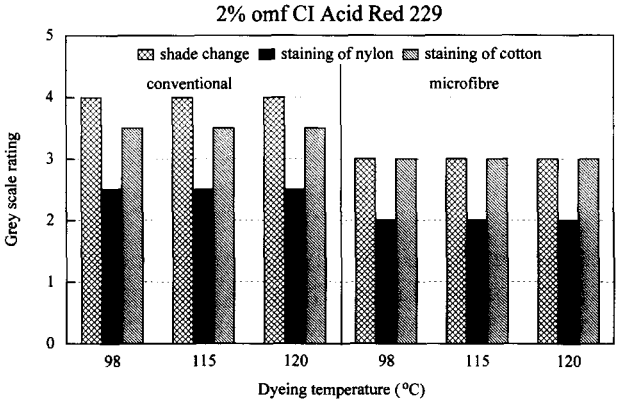
Fig. 7. Wash fastness of 1% omf CI Acid Blue 25 dyeings on conventional and microfibre nylon 6,6 fabrics.

As more dye has to be applied to polyamide microfibre to obtain the same visual depth of shade as its dyed conventional decitex counterpart, owing to its smaller decitex and greater surface area, for dyeings of the same visual depth, the wet fastness of a given dye on polyamide microfibre is lower than that on a conventional decitex fibre.[2,14,21] Figure 7 reveals that when the same concentration (1% omf) of CI Acid Blue 25 was present within micro and conventional nylon 6,6 fabrics, the dyed microfabric exhibited lower fastness to the ISO C06/C2 wash test, this being attributable to the larger surface area of the microfibre from which dye desorption occurred. Further evidence of the lower wash fastness of dyeings on microfibre is displayed in Figs 8–10 which show the fastness of 2% omf dyeings of a Group II, Group III and also a Group IV dye when applied at 98, 115 and 120°C, respectively. In all cases, the wash fastness of the dyeings on microfabric was lower than its comparable-depth counterpart on conventional decitex fabric.

In order to obtain further information concerning the difference in wash fastness of dyed conventional and micro fabrics, an attempt was made to measure the rate of desorption of dye that occurred from dyed micro and conventional fabrics during the ISO C06/C2 wash test. However, problems arose with spectrophotometric analysis of the wash liquor owing to the turbidity of the aqueous, alkaline washing solution and it was therefore decided to employ 0.05 M aqueous sodium borate solution rather than the sodium carbonate/ECE detergent that are used in the ISO C06/C2 wash test;







Figs 8–10. Wash fastness of 2% omf dyeings on conventional and microfibre nylon 6,6 fabrics.

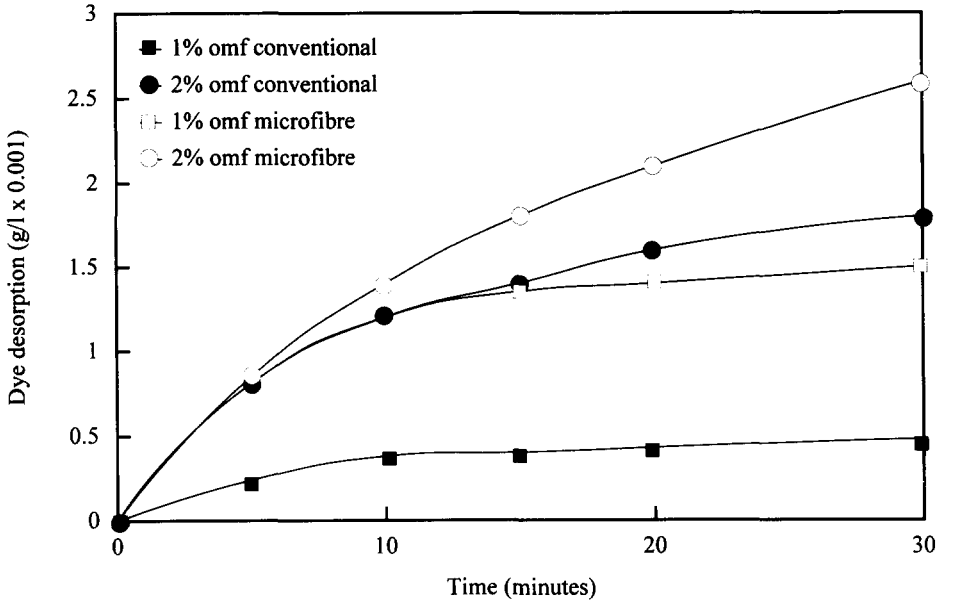


Fig. 11. Desorption of CI Acid Blue 25 from dyed (1 and 2% omf) micro and conventional nylon 6,6 fabrics into 0·05 M aqueous sodium borate at 60°C and 50:1 liquor ratio.

this particular medium has previously been used to simulate the aqueous alkaline conditions prevalent in such a wash test liquor.[25] Figure 11 shows the difference in the rate of desorption of CI Acid Blue 25 that occurred from both 1 and 2% omf dyeings on micro and conventional nylon 6,6 fabrics into 0.05 M aqueous sodium borate at 60°C, from which it is evident that both the rate and extent of dye desorption were greater in the case of the dyed microfibre. As the same concentration of dye was present in both types of dyed fibre at each of the two concentrations of CI Acid Blue 25 used (1 and 2% omf), this finding can be attributed to the greater surface area of the microfibre.

CONCLUSIONS

The results presented for the 13 acid dyes used show that on the microfibre (0·9 dtexpf) knitted nylon 6,6 fabric, the dyes exhibited a faster rate of dye adsorption, a greater rate and higher extent of dye desorption which resulted in reduced wash fastness and lower colour strength than on the conventional (1·7 dtexpf) fabric. These differences arise primarily from the greater surface area of the microfabric.

REFERENCES

1. *Textile Terms and Definitions*, 9th edn, ed. M. C. Tubbs & P. N. Daniels. Textile Institute, Manchester, 1991.
2. Burkinshaw, S. M., *Chemical Principles of the Dyeing of Synthetic Fibres.* Chapman & Hall, Glasgow, 1995.
3. Anon, *Jap. Text. News*, **5** (1992) 83.
4. Hongu, T. & Phillips, G. O., *New Fibres.* Ellis Horwood, New York, 1990.
5. Okamoto, M. In *Tomorrows Ideas and Profits: Polyester 50 Years of Achievement*, ed. D. Brunnschweiler & J. W. S. Hearle. Textile Institute, Manchester, 1993, p. 108.
6. Berkowitch, J. E. In *Tomorrows Ideas and Profits: Polyester 50 Years of Achievement.* ed. D. Brunnschweiler & J. W. S. Hearle. Textile Institute, Manchester, 1993, p. 112.
7. Baumann, J. & Jerg, G., *Text. Chem. Col.*, **22**(12) (1990) 12.
8. Heidenreich, I. & Ninow, H., *Economist Intelligence Unit, Texl. Int. Outlook*, **40** (March) (1992) 37.
9. Brierley, D., *Review of the Development of Polyester Microfibre*, Zeneca Internal Report, 1992.
10. Anon, *Textile Month.*, **1** (1992) 23.
11. Partin, A., *Am. Dyest. Rep.*, **11** (1991) 45.
12. Honorati, G. In *Tomorrows Ideas and Profits: Polyester 50 Years of Achievement*, ed. D Brunnschweiler & J. W. S. Hearle. Textile Institute, Manchester, 1993, p. 220.
13. Leadbetter, P. & Dervan, S., *J. Soc. Dyers Colour.*, **108** (1992) 369.
14. Anon, *Colour Chronicle*, Sandoz, Oct./Dec. (1992) 1.
15. Jacques, M. L., *Textile Asia*, (11) (1992) 50.
16. Anon., *Textile Month*, (1) (1992) 29.
17. Anon., *Textile Month*, (1) (1992) 32.
18. Anon, *Int. Text. Bull.*, (2) (1994) 10.
19. Burkinshaw, S. M., Gordon, R., Marfell, D J. & Maseka, K. D., *Dyes and Pigments*, in press.
20. *Methods of Test for Colour Fastness of Textiles and Leather*, 4th edn. Society of Dyers and Colourists, Bradford, 1978.
21. Weigner, D., *Int. Text. Bull.*, (3) (1992) 23.
22. Marfell, J., Du Pont Fibres (UK), personal communication.
23. Fothergill, F., *J. Soc. Dyers Colour.*, **60** (1944) 93.
24. Dorsch, P., Wilsing, H. & Peters, K.-H., *Mell. Textil.*, **62** (1981) 188.
25. Burkinshaw, S. M., *PhD Thesis*, Bradford University, 1981.