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An Assessment of the Value of Blue, Red, and Black Cotton Fibers as Target Fibers in Forensic Science Investigations

REFERENCE: Grieve, M. C., Dunlop, J., and Haddock, P., **"An Assessment of the Value of Blue, Red, and Black Cotton Fibers as Target Fibers in Forensic Science Investigations,"** *Journal of Forensic Sciences*, JFSCA, Vol. 33, No. 6, Nov. 1988, pp. 1332-1344.

ABSTRACT: Color is the primary characteristic used for comparing cotton fibers. Problems arising because of considerable intrasample variation may cause difficulty in assessing the matching of cotton fibers in a casework situation. Because of the number of dye classes used on cotton fibers, dye extraction and examination by thin-layer chromatography are more problematical than with other fiber types. This necessitates greater reliance on microspectrophotometry and fluorescence microscopy for dye comparison. Fibers from blue denim cannot generally be discriminated and are regarded as having little evidential value. Little or no published data exist on the evidential value of cotton fibers of other colors. This study was designed to assess the value of nondenim blue, red, and black cotton fibers as evidence. Of each color 46 samples were chosen at random (giving a total of 1035 comparisons per color). The number of matching pairs was established after using comparison microscopy, microspectrophotometry, and fluorescence microscopy. Some blue denim cotton fibers were also examined. Complementary chromaticity coordinates were computed for all samples. The results show that, provided adequate techniques are used to compare nondenim blue, red, and black cotton fibers, the chance of finding pairs with matching dyes by coincidence is low despite considerable color overlap. Black cotton fibers represent poorer value as evidence than either nondenim blue or red cotton fibers.

KEYWORDS: forensic science, fibers, dyes, microscopy, spectroscopic analyses, color science, comparison and fluorescence microscopy, microspectrophotometry

In forensic science investigations, color is the main feature used to compare cotton, in contrast to synthetic fibers where generic type, cross-sectional shape, diameter, surface morphology, delusterant particle size, and distribution can all be used to differentiate between similar samples. There are several problems associated with comparative microscopy of cotton fibers. There may be color variations within a control sample from a known source, even within individual fibers. This is due to differential dye uptake caused by variance in fiber structure, "dead," or unripe fibers. It can also be the result of dye bath "topping up" or of

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Received for publication 2 Dec. 1987; revised manuscript received 30 Jan. 1988; accepted for publication 22 Feb. 1988.

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overdyeing. The twisted irregular shape of the fibers and differences in lumen thickness can make selection of optimal viewing areas difficult.

In our laboratory, fiber color is examined by comparison microscopy in conjunction with fluorescence examinations, followed by microspectrophotometry, and whenever possible, by thin-layer chromatography. Cotton poses a particular set of problems. Despite the work of Home and Dudley [*1*] in 1981 on extraction of dye from cotton fibers, we find that this is often difficult. Several classes of dye are used on cotton requiring different approaches to dye extraction. We have found no information on the extraction of vat, sulphur, or azoic dyes on a small scale. We have had some success extracting sulphur dyes using dimethylformamide at 130°C for 30 min. This work was not carried out with single fibers. Our efforts to extract vat dyes have remained totally unsuccessful despite using a variety of solvents. Extraction of reactive dyes using 1.5% sodium hydroxide at 100°C was often only partial; bleaching appears to occur if the fibers are left in the solvent in excess of 3 to 4 min.

Because cotton fibers are thinner and often less heavily dyed than their synthetic counterparts, the amount of dye recoverable from a unit length will be less. According to the work of Parybyk and Lokan [*2*], cotton fibers will be subjected to greater fragmentation during transfer than synthetic fibers increasing the tendency for recovered fragments to be short and therefore less suitable for dye extraction and comparison using thin-layer chromatography. These difficulties mean that in casework extra reliance is placed on microspectrophotometry as a means of color comparison. These instruments are not, however, in universal use.

In 1979, Macrae et al. [*3*] studied the characterization of visually similar dyed wool fibers by microspectrophotometry. No comparable work has been published on the ability of this instrument to discriminate between cotton fibers of similar color. The fact that color variations are found within one control sample producing spectral differences such as an alteration of peak ratios (Fig. 1) and shifts in the position of maximum absorption (Fig. 2) can often cause difficulties in deciding whether a questioned spectrum will fall within the range of the control (known) spectra.

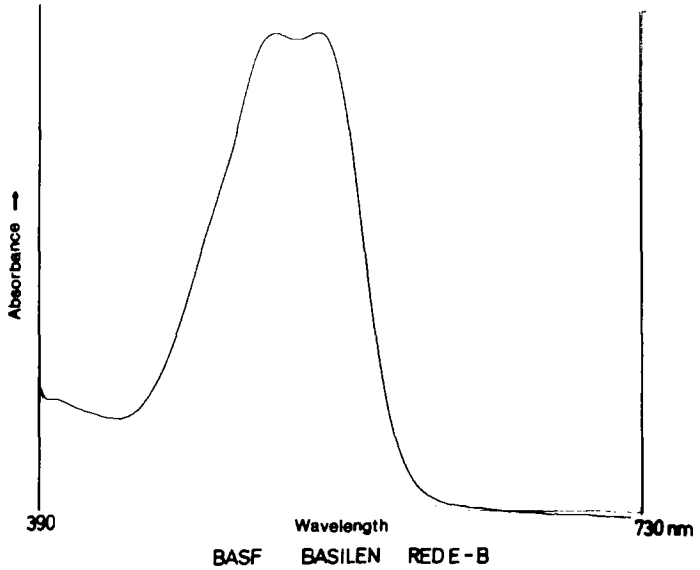

FIG. 1—*Absorption spectra recorded from cotton fibers taken from cloth dyed with BASF Basilen Red E-B, showing alteration of peak ratio.*

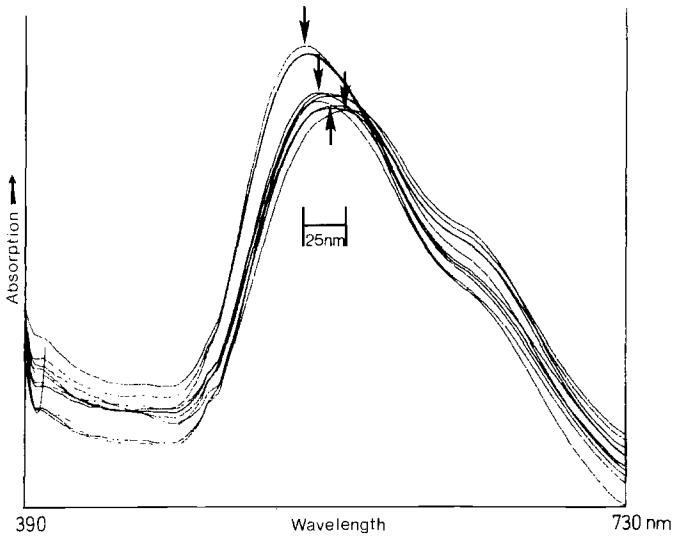

FIG. 2—*Absorption spectra recorded from cotton fibers taken from cloth dyed with Cibanon Dark Blue MBN showing variance in absorption maxima over a range of approximately 25 nm.*

Our aim was to find out to what extent pairs of blue, red, and black cotton fibers were both visually and spectrally indistinguishable. Blue denim fibers are already known to be basically indistinguishable over the visible spectral range [*4*], which makes them evidentially valueless in most instances. If spectral discrimination between nondenim blue cottons and cotton fibers of other colors is similarly poor, do these fibers justify the time spent on recovering and examining them, especially if other more suitable target fibers are present in the same case? Do some colors appear to offer better potential as evidence than others?

Method

We concentrated on cotton fibers taken from blue, red, and black garments, as our experience has shown these to be the colors most frequently encountered in casework. Some garments were case items, others were not laboratory related. Samples yielding fibers too pale to normally be considered as target fibers were rejected. Details of the sources of all fibers are given in Tables 1 through 3. For each color 46 samples were used. Individual microscope slide mounts were made from each sample by teasing the fibers out in XAM Neutral Improved White® (Searle Diagnostic) mountant. Within each color, each sample was compared visually with all other samples using a Leitz Ortholux comparison microscope at a magnification of ×240. If any fibers in a sample could be matched to any in the opposing sample, this was recorded as a positive result. This represents a total of 1035 comparisons for each color.

Ten replicate absorption spectra were recorded from fibers in each sample taking care to include the range of color and concentration variations. The instrument used was a Nanospec® 10S Microspectrophotometer fitted to a Leitz Ortholux® microscope. Spectra were recorded over the range 390 to 730 nm at a 200-nm/min scan rate. The slit aperture used was 5 by 40 μm; positioning over twists and irregularities was avoided if possible. In addition to the above, absorbance values recorded at 10-nm intervals were transferred by an analogue-to-digital converter (Anaspec Data Systems) to a Commodore PET microcomputer for computation of color coordinates and error ellipses.

TABLE 1—*Origin of blue cotton samples.*

Sample	Garment	Brand Name	Country of Origin
1	pajama	Schliesser	W. Germany
2	trousers	C & A	Italy
3	cord trousers	Star Jeans	U.S.A.
4	underpants	Jockey	U.S.A.
5	underpants	Jockey	U.S.A.
6	sweatpants	Puma	W. Germany
7	sweatshirt	Alpenland	W. Germany
8	underpants	...	U.S.A.
9	cord trousers	...	W. Germany
10	sweatshirt	Fruit of the Loom	W. Germany
11	sweatshirt	Fruit of the Loom	W. Germany
12	cord trousers	C & A	W. Germany
13	underpants	Marks & Spencer	England/Israel
14	shirt	...	U.S.A.
15	pajama	Schliesser	W. Germany
16	shorts	Dodger Sportswear	U.S.A.
17	T-shirt	...	W. Germany
18	T-shirt	...	Greece
19	sweatpants	Rodeo 52 C & A	Unknown
20	jacket	Gino Parozzi	Unknown
21	shirt	Kennington Western	U.S.A.
22	shirt	Lee Western	U.S.A.
23	shirt	Simeon	Hong Kong
24	velour pullover	Trigema	W. Germany
25	unknown case sample	...	...
26	dress	...	...
27	coat	Ninoflex	W. Germany
28	cord trousers	Elastisches Sportwel	W. Germany
29	velour pullover	C & A	W. Germany
30	jogging suit	...	U.S.A.
31	undershirt	...	...
32	cord trousers	Levis	U.S.A.
33	flannel shirt	...	U.S.A.
34	shirt	Hobby Shirt	W. Germany
35	cord trousers	...	U.S.A.
36	T-shirt	...	U.S.A.
37	trousers	Gloria Vanderbilt	Hong Kong
38	shirt	Tom Tailor	W. Germany
39	trousers	C & A	Italy
40	bathrobe	Robes of California	U.S.A.
41	football jersey	...	U.S.A.
42	sweatshirt	...	W. Germany
43	cord trousers	Brittania	Macau
44	sweatshirt	Sportswear U.S.A.	U.S.A.
45	underpants	Jockey	U.S.A.
46	jeans	Easy Care	U.S.A.

Color Measurement

The Commission International de l'Eclairage (CIE) system uses tristimulus values as a method of color notation. For any color, three numbers, specified as X, Y, and Z are assigned and describe a precise color as viewed under standard conditions. Chromaticity coordinates x, y, and z represent an alternative way of describing a precise color. If one tristimulus value, for example, X, is divided by the sum of the three tristimulus values, the chromaticity coordinate x is the result. The sum of x, y, and z is always 1, therefore, one needs only to use the x and y values to describe chromaticity. By measuring absorbance and

TABLE 2—*Origin of red cotton samples.*

Sample	Garment	Brand Name	Country of Origin
1	T-shirt	...	...
2	pullover	...	...
3	T-shirt	Artex	U.S.A.
4	pullover	Hanes	U.S.A.
5	unknown case sample	...	...
6	unknown case sample	...	...
7	shirt	...	...
8	underpants	Jockey	U.S.A.
9	T-shirt	Champion	U.S.A.
10	T-shirt	Punk	England
11	T-shirt	...	W. Germany
12	T-shirt	...	Italy
13	sweat pants	Russell Athletic	U.S.A.
14	shirt	II Classico	...
15	anorak	...	...
16	bathrobe	Van Heusen	...
17	towel	"More" Royal	W. Germany
18	towel	Marks & Spencer	England
19	T-shirt	Men's Fashion	W. Germany
20	sweatshirt	...	W. Germany
21	towel	Armadeo Prat	Spain
22	sweatshirt	Fruit of the Loom	W. Germany
23	pullover	Avon Fashions	...
24	underpants	Marks & Spencer	England
25	pullover	Fashion In	W. Germany
26	velour pullover	Nicki	W. Germany
27	pajama	Schliesser	W. Germany
28	pajama	Hom	France
29	underpants	Jockey	U.S.A.
30	underpants	Marks & Spencer	England/Israel
31	T-shirt	Marks & Spencer	England
32	pillow	...	...
33	unknown case sample	...	...
34	jacket	Jacket for Champions	U.S.A.
35	shirt	...	U.S.A.
36	shirt	Runner-up by Admit One	U.S.A.
37	shirt	...	...
38	sweatshirt	Angelo Litrico	Peru
39	underpants	...	...
40	sweatshirt	Jerzees by Russell	U.S.A.
41	dress	...	...
42	underpants	...	U.S.A.
43	slip	Ripcosa	W. Germany
44	T-shirt	...	W. Germany
45	jeans	Pioneer	W. Germany
46	underpants	Marks & Spencer	England

not transmittance, linearity between the tristimulus values and dye concentration is guaranteed. Having achieved linearity, the chromaticity coordinates are now referred to as complementary chromaticity coordinates (CCC) and are specified as x' and y'. This system of color measurement has been described in detail in Venkataraman [5] and by both Paterson and Cook [6] and Laing et al. [7] in a forensic science context. A plot of x' versus y' forms a horseshoe shaped spectrum locus known as the complementary chromaticity diagram. The plotting of ten replicate complementary coordinates on this diagram shows that values fall into an elliptical area, the size and inclination of which can be calculated [7].

The spectra of all microscopically matching pairs were compared visually by overlaying

TABLE 3—*Origin of black cotton samples.*

Sample	Garment	Brand Name	Country of Origin
1	towel	Armadeo Prat	Spain
2	T-shirt	Artex	U.S.A.
3	trousers	Dickies	U.S.A.
4	trousers	Laufenmuhle	W. Germany
5	jeans	...	...
6	T-shirt	Screen Stars	U.S.A.
7	shorts	Jockey	U.S.A.
8	underpants	Marks & Spencer	England/Israel
9	trousers	...	...
10	unknown case sample	...	...
11	shirt	...	...
12	panties	Steppi	W. Germany
13	T-shirt	...	W. Germany
14	blouse	Sassoon	France
15	T-shirt	...	W. Germany
16	underpants	Marks & Spencer	England
17	jacket	...	...
18	underpants	Marks & Spencer	England
19	underpants	Marks & Spencer	England
20	T-shirt	...	Austria
21	cushion	...	...
22	trousers	Le Tigre	...
23	T-shirt	...	W. Germany
24	T-shirt	C & A	W. Germany
25	T-shirt	...	Pakistan
26	T-shirt	Fontana	Italy
27	pullover	Logistix	U.S.A.
28	jacket	Brass Bullet	Korea
29	T-shirt	...	England
30	jacket	Brass Bullet	Korea
31	sweatshirt	...	...
32	jacket	Young Style	...
33	shirt	...	Hong Kong
34	shirt	...	...
35	T-shirt	...	...
36	panties	...	W. Germany
37	shirt	...	...
38	jeans	Levis 501	England
39	T-shirt	...	...
40	sweatpants	...	...
41	jeans	Shades	France
42	T-shirt	...	...
43	pullover	...	...
44	sweatshirt	Merryweather Athletic	U.S.A.
45	shorts	...	U.S.A.
46	sweatpants	Adidas	W. Germany

the ten replicate spectral traces from one sample on top of those from microscopically matching samples, using a light box. When one or more of the replicate curves could not be distinguished from one or more curves in the opposing sample this was recorded as a match. Any pairs with matching spectra were compared further by fluorescence microscopy. This was carried out on a Leitz Ortholux comparison microscope fitted with twin Leitz Ploemopaks® using the filters A (ultraviolet), H2 (violet plus blue), and N (green). Note that the selection of matching pairs was based on a spectral comparison followed by fluorescence examination. The computation of complementary chromaticity coordinates played no part in the selection process. These values were produced to compare the degree of ellipse overlap

with that reported by other workers, and to allow storage of color data which will be used in further research related to this topic.

Samples were also taken from the 30 denim items listed in Table 4 and mounted as previously described. These fibers were also compared to each other visually. Replicate absorption spectra were recorded, and color data recorded from randomly selected samples.

Results

Blue Denim Samples

All the blue denim samples except one ("Easy Care," USA) matched visually. The exception was taken from a pair of blue jeans of true denim construction in which the blue threads were a mixture of cotton and polyester fibers, and a dye suitable for simultaneous dyeing may have been used. Jeans of this type, which may contain a small percentage of spandex fibers, are probably more common in the United States than in Europe. The blue cotton in this sample was a visual but not a spectral match with eight other nondenim samples.

Only one example from the other nondenim samples (No. 1) contained fibers matching those in any of the remaining denim samples, confirming that blue denim fibers do have a characteristic color with color values located in a small area of the chromaticity diagram [7]. A selection of chromaticity values for blue jeans fibers is given in Table 5. Results are not shown for all samples as they merely confirm the work of Laing and others [7] despite other makes of jeans being represented.

TABLE 4—*Origin of blue denim cotton samples.*

Sample	Garment	Brand Name	Country of Origin
1	jeans	Bonjour	...
2	jeans	Levi Strauss	U.S.A.
3	jeans	Easy Care	U.S.A.
4	jeans	...	...
5	jeans	Males Only	Indonesia
6	jeans	Gitano	U.S.A.
7	jeans	h.i.s. Chic	...
8	jeans	Lee	U.S.A.
9	jeans	Zena	U.S.A.
10	jacket	...	...
11	jeans	Brittania	Macau
12	jeans	Levi Strauss	...
13	jeans	Scotts N.Y.	U.S.A.
14	jeans	Calvin Klein	U.S.A.
15	jeans	Marshall ***	W. Germany
16	jeans	Levi Strauss	...
17	jeans	Brittania	...
18	jeans	Lee Riders	...
19	jacket	Levi Strauss	...
20	jeans	Levi Strauss	...
21	jeans	Levi Strauss	...
22	jeans	Cotler	...
23	jeans	(pinstripe)	...
24	jeans	Brittania	...
25	jeans	Lee	...
26	jeans	Levi Strauss	...
27	jeans	Levi Strauss	...
28	jeans	Sears	U.S.A.
29	jeans	Levi Strauss	U.S.A.
30	jeans	Mustang	W. Germany

TABLE 5—*Complementary chromaticity coordinates for blue denim fibers.*

Sample	Brand Name	x'	y'
2	Levis	0.414	0.383
6	Gitano	0.428	0.392
7	h.i.s. Chic	0.426	0.390
8	Lee®	0.420	0.387
11	Britannia-Macau	0.420	0.386
14	Calvin Klein	0.429	0.393
18	Lee Riders	0.416	0.382
22	Cotler	0.426	0.389
26	Levis	0.421	0.389

Denim is normally dyed with indigo (Color Index No. 73000), which for economic reasons may be mixed with small amounts of other dyes such as sulphur blue, sulphur black, or hydron blue which may cause spectral differences in the ultraviolet or visible regions, as may substitution of chlorine, bromine, or methyl groups in the basic indigo structure [*4*]. Some compounds are only differentiable by using thin-layer chromatography. Spectra from blue denim samples are not all identical. This is illustrated in Fig. 3.

Virtually all samples of blue denim cotton, however, have spectra matching one of these examples or some which will fall within the range of Spectra b and c. As a result, the evidential value of blue denim fibers is necessarily very low.

Nondenim Blue, Red, and Black Cotton Fibers

The results after microscopical, spectral, and fluorescence comparisons are shown in Table 6. This table is self-explanatory. Details of the pairs which matched spectrally are shown in Table 7 in order that this information may be related to that presented in Tables 1 through

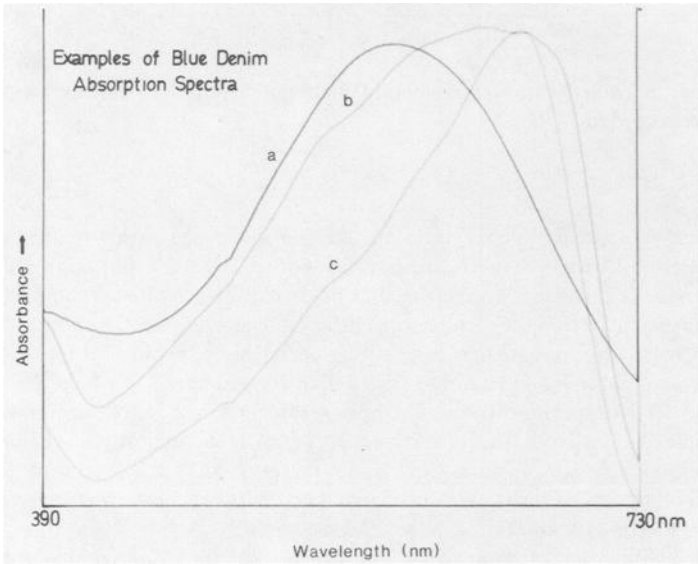

FIG. 3—*Absorption spectra recorded from blue denim cotton fibers taken from* (a) *"Easy Care" jeans* (b) *"Males Only" jeans, and* (c) *"Gitano" jeans.*

TABLE 6—*Summary of comparisons. Each color: 46 samples and 1035 comparisons.*

Color	Visual Match	Spectral Match	
		Before Fluorescence	After Fluorescence
Blue (nondenim)	157 (1 in 7)	6 (1 in 173)	4 (1 in 259)
Red	320 (1 in 3)	10 (1 in 103)	7 (1 in 148)
Black	265 (1 in 4)	40 (1 in 26)	18 (1 in 58)

TABLE 7—*Spectrally matching pairs of cotton fibers.*

BLUE

1 & 15, 2 & 39, 4 & 5, 9 & 38, 16 & 25, and 33 & 42.

RED

1 & 10, 1 & 11, 3 & 29, 5 & 32, 7 & 16, 7 & 23, 8 & 29, 10 & 11, 15 & 40, and 27 & 29.

BLACK

2 & 42
3 & 20, 3 & 36, 3 & 44
5 & 12, 5 & 31, 5 & 36
6 & 34
7 & 20, 7 & 28
12 & 15, 12 & 25, 12 & 27
13 & 25, 13 & 33, 13 & 35, 13 & 41
18 & 19
21 & 23, 21 & 24, 21 & 35, 21 & 36
23 & 24, 23 & 30, 23 & 31, 23 & 41
25 & 26, 25 & 28, 25 & 30, 25 & 33
27 & 30, 27 & 31, 27 & 33, 27 & 35
28 & 30, 28 & 33, 28 & 46
30 & 36
36 & 41, 36 & 44.

3 and to that in Table 8 in which the complementary chromaticity coordinates for all of the samples are recorded.

Discussion

The use of comparison microscopy alone as a means of comparing nondenim blue, red, and black cotton fibers is virtually useless since our results show that approximately one in seven blue, one in three red, and one in four black cottons may be expected to match. Discrimination is so poor that the results are of little value as evidence. The ability of microspectrophotometry to discriminate between cotton fibers of similar color was found to be high. It appears to be greater for blue cotton fibers than for red, both of which are considerably higher than for black cotton fibers. The poor result for black is not surprising since many black samples have almost featureless spectra (Fig. 4). The majority of our black samples were microscopically grey or dark grey. Some, however, although dyed with "black" dyes, exhibited a bluish or greenish color when viewed in a slide preparation. These differences are reflected in the spectra and in the color values.

Using a combination of comparison microscopy and microspectrophotometry together with fluorescence examinations, our results indicate that the chances of finding a match from randomly chosen nondenim blue cottons are of the order of 1 in 260, 1 in 150 for red,

TABLE 8—*Complementary chromaticity coordinates of all cotton fibers used.*

	Blue		Red		Black	
	x'	y'	x'	y'	x'	y'
1	0.428	0.387	0.193	0.327	0.331	0.338
2	0.365	0.357	0.222	0.358	0.330	0.342
3	0.357	0.370	0.215	0.374	0.307	0.322
4	0.410	0.400	0.207	0.360	0.325	0.337
5	0.402	0.390	0.227	0.367	0.319	0.323
6	0.391	0.392	0.206	0.353	0.325	0.329
7	0.375	0.373	0.203	0.358	0.316	0.327
8	0.374	0.376	0.234	0.365	0.328	0.322
9	0.358	0.368	0.215	0.311	0.355	0.351
10	0.409	0.370	0.206	0.340	0.338	0.343
11	0.361	0.364	0.193	0.336	0.309	0.317
12	0.366	0.374	0.235	0.399	0.320	0.326
13	0.463	0.408	0.234	0.376	0.323	0.336
14	0.397	0.463	0.209	0.284	0.313	0.321
15	0.413	0.375	0.211	0.346	0.325	0.332
16	0.368	0.372	0.187	0.347	0.347	0.340
17	0.389	0.389	0.233	0.390	0.333	0.332
18	0.376	0.374	0.213	0.407	0.342	0.342
19	0.341	0.341	0.239	0.392	0.332	0.334
20	0.367	0.386	0.224	0.386	0.316	0.319
21	0.391	0.347	0.220	0.345	0.325	0.333
22	0.384	0.398	0.267	0.402	0.322	0.319
23	0.429	0.387	0.212	0.386	0.322	0.331
24	0.412	0.420	0.223	0.379	0.326	0.334
25	0.362	0.367	0.204	0.367	0.324	0.330
26	0.389	0.386	0.229	0.385	0.327	0.334
27	0.363	0.360	0.229	0.357	0.327	0.334
28	0.368	0.358	0.240	0.355	0.322	0.324
29	0.386	0.388	0.221	0.377	0.310	0.316
30	0.360	0.354	0.246	0.458	0.321	0.325
31	0.381	0.380	0.254	0.407	0.322	0.328
32	0.341	0.350	0.220	0.375	0.312	0.323
33	0.400	0.380	0.195	0.371	0.320	0.328
34	0.385	0.366	0.206	0.349	0.319	0.319
35	0.344	0.340	0.231	0.352	0.323	0.331
36	0.356	0.353	0.195	0.374	0.318	0.329
37	0.356	0.349	0.213	0.374	0.318	0.327
38	0.360	0.370	0.202	0.340	0.334	0.345
39	0.356	0.352	0.189	0.336	0.328	0.335
40	0.407	0.378	0.209	0.367	0.326	0.334
41	0.379	0.376	0.209	0.363	0.327	0.334
42	0.407	0.375	0.225	0.399	0.330	0.344
43	0.387	0.375	0.208	0.342	0.330	0.338
44	0.351	0.358	0.201	0.340	0.314	0.327
45	0.377	0.381	0.213	0.351	0.321	0.330
46	0.371	0.382	0.217	0.356	0.319	0.322

and 1 in 60 for black. Note that of the matching pairs, 3 out of the 4 blues (Nos. 4 and 5, underpants—Jockey®; Nos. 1 and 15, pajamas—Schliesser; and Nos. 2 and 39, trousers—C & A) and 1 pair of black cottons (Nos. 18 and 19, underpants—Marks & Spencer PLC) were made by the same manufacturer. One pair of red cottons with matching spectra but excluded under fluorescence were also both Jockey underpants. This suggests that the fluorescence was caused by a difference in treatment of the fabric, not by the dye. The spectrum obtained from the matching black cottons referred to above was highly characteristic and is

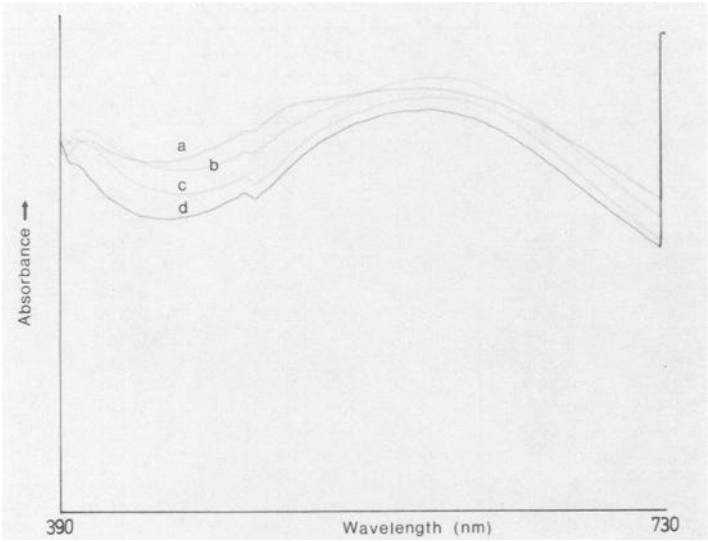

FIG. 4—*Typically featureless absorption spectra taken from black cotton fibers taken from various sources:* (a) *sweatshirt—U.S.A.*, (b) *jacket—Korea,* (c) *T-shirt—Pakistan, and* (d) *T-shirt—Italy.*

shown in Fig. 5. The coincidental discovery of these matches was gratifying in that it confirms consistency of dye usage by large companies (at least over a period of time), and gives hope of eventual identification of some dyes in the future.

The figures shown in Table 6 show that nondenim blue and red cotton fibers definitely do justify their selection as "target" fibers in transfer cases, even without the use of thin-layer chromatography. Black cottons, however, offer less value as evidence, especially if they are of the microscopically grey or dark grey variety.

It has already been shown by Laing and others in 1986 [*7*] that there is a large overlap of color ellipses among blue and red cotton fibers. The error ellipses for red cottons are larger than those for blues, therefore, there is a greater degree of color overlap. Our results confirm this. An ellipse overlap means that some of the fibers in one sample are the same color as some of the fibers in the other sample. It does not, however, mean that they are dyed with the same dye.

Spectra only allow determination of color. They cannot be used to identify dyes as the same dye will give different spectra under different dyeing conditions, and dyes with widely different dyeing characteristics and chemical structure can exhibit very similar absorption spectra. Absorption spectra recorded from single fibers do not allow determination of whether or not the dye in question is a mixture. There is no certainty that two samples are from the same textile even if the spectral curves are very similar; we can only be certain that they do not have a common origin if the spectra are different (Ciba-Geigy: personal communication). In a casework situation, samples having common origin will have been dyed under the same conditions and will therefore match both visually and spectrally.

Because of the large degree of overlap of error ellipses, retrieval from a data bank based on complementary chromaticity coordinates to obtain frequency estimates for cottons may give misleading results if color and generic type are the only searching parameters being used. The number of "hits" generated may include many that are actually nonspectral matches or nonvisual matches or both because a different dye mixture has been used or because of a dye concentration difference. Our results indicated this to be particularly common among black cottons. It would be desirable, but possibly not practical, to recheck the visual and spectral appearance of all supposed matches.

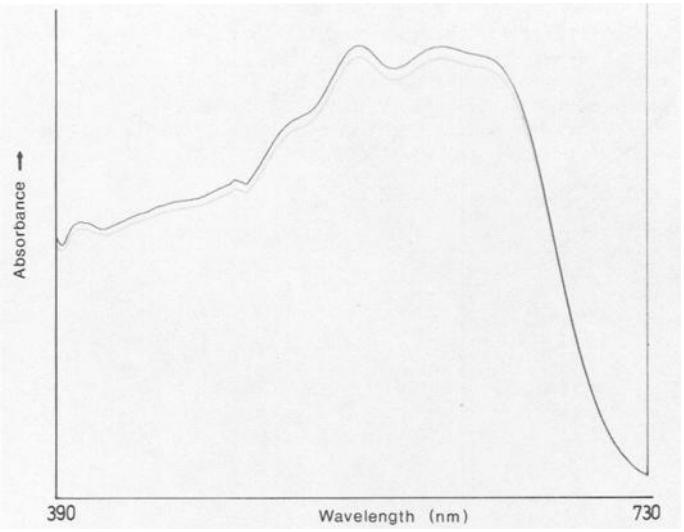

FIG. 5—*Characteristic absorption spectra recorded from two pairs of black cotton underpants marketed by the same company, Marks & Spencer PLC, in the United Kingdom during 1981 to 1982.*

Different dye mixtures that produce the same absorption spectrum may be separable by chromatography, provided they can be extracted from the fiber, which can be a definite problem for cotton. No system currently devised can successfully store this information even if it can be obtained. Analytical laboratories associated with the dye industry can identify dyes with the aid of thin-layer chromatography and high pressure liquid chromatography [*8*], but the amounts of material required are far in excess of that normally available to forensic scientists. Because of this, they are able to employ alternative methods for dye extraction. If thin-layer chromatography cannot be used in a comparison of cotton fibers, because of dye extraction difficulties, it would be useful to have an idea of how frequently matching spectra are produced by different dyes used to produce cotton fibers of the same color. It would also be interesting to examine the extent of spectral variation within cotton samples dyed with a known dye. Further research will investigate these topics and the results will be published in due course.

Acknowledgment

The authors wish to thank The Home Office Forensic Science Service Central Research Establishment, Aldermaston, England for the use of their computer software for color calculations.

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Erratum

In the recent paper "An Assessment of the Value of Blue, Red and Black Cotton Fibers as Target Fibers in Forensic Science Investigations" by M. C. Grieve, J. Dunlop, and P. Haddock in this *Journal* (Vol. 33, No. 6, Nov. 1988, pp. 1332-1344), the reproduction of Fig. 1 was not faithful to the original. So that readers can interpret this figure correctly according to the caption, this figure has been reprinted.

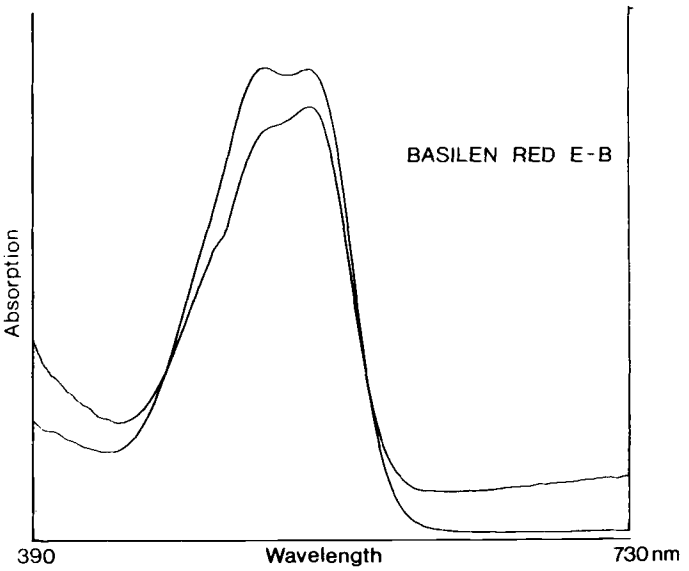

FIG. 1—*Absorption spectra recorded from cotton fibers taken from cloth dyed with BASF Basilen Red E-B, showing alteration of peak ratio.*