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Dyeing of Linen and Blends With Direct, Reactive and Sulphur Dyes

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Tensile strength, moisture absorption, air permeability, "cool-hand" attribute, good comfort, *etc*. properties of linen fibers are better than cotton fiber. The demand for linen and its blends is gaining importance, however, researches conducted on dyeing them is limited in the literature. In this work, dyeing of 100 % linen and 50/50 % linen/viscose, 50/50 % linen/cotton blends with direct, reactive and sulphur dyes by the exhaustion method were studied. The dye exhaustion properties of the direct and reactive dyes were determined and moreover, the fastness properties of dyed materials and the mechanical properties of dyed and undyed materials were compared.

Key Words: Linen fabric, Linen/cotton fabric, Linen/viscose fabric, Linen blend, Reactive dyes, Direct dyes, Sulphur dyes.

INTRODUCTION

Linen may be the oldest fabric known, is an important textile material with different characteristics[1-3]. Linen reduces γ-radiation nearly by half and protects the human organism against solar radiation. Due to its heat transfer, permeability to air, linen fabric is a kind of excellent material for practical applications. Heat conductivity of linen is five times as high as that of wool and 19 times as that of silk, moreover, the tensile strength of linen thread is twice as high as that of cotton and three times that of wool[4]. However, dyeability is the main barrier that unables its wide applications in the real life.

In order to illustrate the material more, linen easily gets wrinkled and has a stiff handle so linen is often used in blends with synthetic or natural fabrics. Stiff handle and inelasticity are undesired properties of linen so most of the studies have been concentrated on softening linen and linen-containing materials or improving dyeability.

A literature review revealed several approaches for the enzymatic treatment of linen fabrics to improve dyeability and its fabric properties[5,6]. Also sevearal techniques such as plasma[7], combination of plasma and enzymatic[8,9], combination of chemical-mechanical and enzymatic technology[10], pretreatment chitosan by microwave oven[11] and ultrasound[12] were applied to improve properties and dyeability of linen and linen containing fabrics.

In this work, dyeing of 100 % linen, 50/50 % linen/viscose and 50/50 % linen/cotton blends with direct, reactive and sulphur dyes by the exhaustion method were studied. Dye exhaustion properties of the direct and reactive dyes were determined. The fastness properties of dyed materials and the mechanical properties of dyed and undyed materials were compared.

EXPERIMENTAL

In this study, 100 % plain woven linen fabric (16 weft/cm, 16 warp/cm, weight 187 g/m^2), 50/50 % linen/viscose plain woven fabric (18 weft/cm, 18 warp/cm, weight 188 g/m^2) and 50/50 % linen/cotton plain woven fabrics (18 weft/cm, 24 warp/cm, weight 153 g/m^2) were used throughout.

Three direct dyes, three reactive dyes and three sulphur dyes were used (Table-1)

A non-ionic surfactant (Sandopur RST [Clariant]), an anionic wetting agent (Uniwett HGA [Alfa Chemistry]), an organic stabilizer (Prestogen P [BASF]), a fixation agent (Indosol E-50 [Clariant]), a reducing agent (Sulfhydrate F [Dystar]), a stabilizer (Stabilisal S [Dystar]) were used. All other chemicals were laboratory grade.

Dyeing methods: 50/50 (%) Linen/viscose fabrics were bleached at 80 ºC, 45 min with 35 % H_2O_2 (8 mL/L), NaOH (1 g/L), Uniwett HGA (0.2 mL/L) and Prestogen P (2 g/L).

In the atmospheric dyeing with direct dyes, the samples of 5 g were dyed. The amount of dye used was 1 % o.w.f. at a liquor ratio of 40:1. The dyeing was started at 40 ºC and sodium sulfate (10 g/L) was added to the dye liquor. The process was continued for 10 min. After 55 min the temperature was raised to 98 ºC. The dyeing was continued for 1 h and the dyed samples were fixed with Indosol E-50 (2 g/L), at

TABLE-1
DYES USED

Type	Commercial names	Supplier	Colour index number
Direct	Indosol Yellow SF-GL160P	Clariant	C.I. Direct Yellow 98
	Indosol Rubin SF-RGN	Clariant	C.I. Direct Red 83:1
	Indosol Navy SF-GLE	Clariant	Mix
Reactif	Drimaren Yellow CL-2R	Clariant	C.I. Reactive Yellow 176
	Drimaren Red CL-5B	Clariant	C.I. Reactive Red 241
	Drimaren Blue CL-2RL	Clariant	–
Sulphur	Cassulfon Yellow GT	Dystar	C.I. Leuco Sulphur Yellow 20
	Cassulfon Olive BBN	Dystar	C.I. Leuco Sulphur Green 9
	Cassulfon Black SR	Dystar	C.I. Leuco Sulphur Black 1

a liquor ratio 40:1 (pH 6.5-7). The dyed and fixed samples were washed out.

The dyeing with reactive dyes, the samples of 5 g were dyed. The amount of dye used was 1 % o.w.f. at a liquor ratio of 40:1. The dyeing was continued for 2 h at 60 ºC. Sodium carbonate (10 g/L) and sodium chlorite (40 g/L) were added to each reactive dye liquor for all-in method. The dyed materials were washed with Sandopur RST.

The dyeing with sulphur dyes, the samples of 5 g were dyed. The amount of dye used was 1 % o.w.f. at a liquor ratio of 40:1. The dyeing was started at 40 ºC. The process was continued for 10 min. After 24 min the temperature was raised at 98 ºC. The dyeing was continued for 45 min. Sodium chloride (25 g/L), Sulfhydrate F (5 mL/L) and Stabilisal S (3 mL/L) were added to each reactive dye liquor for all-in method. At the end of the dyeing, the dyed samples were removed, rinsed thoroughly in tap water and were oxidized with H_2O_2 (1.5 mL/L) at 4.5-5.0 pH (adjusted with CH_3COOH).

Measurements and standards: The colour measurements of the materials were carried out by Datacolor SF 600+ spectrophotometer (Illuminant D_{65}, specular reflection included mode, 10º Standart Observer and LAV 30 mm measuring plate). The dye uptake values (E %) were calculated by the use of a UV-visible spectrophotometer (Shimadzu UV-1200) measuring the absorbance at the wavelength of maximum absorption (λ_{max}) of Indosol Navy SF-GLE and Drimarene Red CL-5B dyes in accordance with eqn. 1.

$$E\ (\%) = 100\left[\frac{(C_0 - C_t)}{C_0}\right] \quad (1)$$

In eqn. 1, C_0 and C_t indicate the concentration of the dye initially used in the dyebath and residual amount of dye at time t (minute) during dyeing, which were calculated from the absorbance values measured at λ_{max} of the dye, respectively.

The fastnesses of the dyeings to washing and to wet and dry rubbings were determined in accordance with ISO 105 C06 method (A1S) and ISO 105-X12, respectively. The tensile strength properties (tenacity and elongation at break) of dyeings were tested in accordance with TS EN ISO 13934-1 and the Elmendorf tear strength were also tested in accordance with ASTM 1424-8.

RESULTS AND DISCUSSION

The CIELab and K/S values of dyed samples with direct, reactive and sulphur dyes are given in the following tables.

Table-2 shows that the colour strength (K/S, 9.16) of 100 % linen dyed with Indosol Yellow SF-GL 160 P was slightly higher. The colour was yellower and redder (as evidenced by the higher b* and a* values). The K/S (9.53) value of % linen dyed with Indosol Rubin SF-RGN was higher, but the colour was duller (as shown by the lower C* value). In the case of Indosol Navy SF-GLE, the K/S value of 50/50 (%) linen/viscose was higher. The colour was brighter (as indicated by the higher C* value).

Table-3 shows that the colour strength (K/S value, 9.04) of 100 % linen dyed with Drimarene Yellow CL-2R was higher and the colour yellower and redder (as evidenced by the higher b* and a* values) than the others. In addition, the depth of the shade of linen was greater (as shown by the lower L* value) and brighter (as indicated by the higher C*value). In the case of the other reactive dye, Drimarene Red CL-5B, the colour strength of K/S (8.24) value of 50/50 % linen/viscose was higher and the depth of the shade was greater (as shown by the lower L* value) and brighter (as indicated by the higher C* value). In case of the other reactive dye, Drimarenen Blue CL-2RL, the colour strength (K/S, 9.55) of 50/50 % linen/viscose was higher. The colour of fabric has more blue shade

TABLE-2
CIELAB AND K/S VALUES OF DYED SAMPLES WITH DIRECT DYES

Direct dyes	Fabrics	CIELab colour values				K/S
		L*	a*	b*	C*	
Indosol Yellow SF-GL 160 P (C.I. Direct Yellow 98)	100 % Linen	81.96	5.99	72.93	73.18	9.16
	50/50 % Linen/Viscose	81.82	4.63	68.52	68.68	8.17
	50/50 % Linen/Cotton	83.51	3.69	67.99	68.09	7.20
Indosol Rubin SF-RGN (C.I. Direct Red 83:1)	100 % Linen	36.51	34.82	-7.83	35.96	9.53
	50/50 % Linen/Viscose	39.79	35.57	-8.74	36.63	7.76
	50/50 % Linen/Cotton	42.12	34.84	-11.56	36.71	6.30
Indosol Navy SF-GLE	100 % Linen	35.64	-2.72	-15.50	15.74	7.19
	50/50 % Linen/Viscose	36.01	-4.09	-18.12	18.58	8.07
	50/50 % Linen/Cotton	40.13	-4.79	-17.74	18.38	6.15

TABLE-3
CIELAB AND K/S VALUES OF DYED SAMPLES WITH REACTIVE DYES

Direct dyes	Fabrics	CIELab colour values				K/S
		L*	a*	b*	C*	
Drimarene Yellow CL-2R (C.I.Reactive Yellow 176)	100 % Linen	73.14	29.95	75.57	81.29	9.04
	50/50 %Linen/viscose	76.73	24.79	69.95	74.21	5.66
	50/50 % Linen/cotton	76.89	24.46	70.24	74.38	5.72
Drimarene Red CL-5B (C.I.Reactive Red 241)	100 % Linen	48.71	55.94	-5.94	56.25	7.03
	50/50 %Linen/viscose	46.72	56.77	-7.87	57.31	8.24
	50/50 % Linen/cotton	53.44	52.07	-10.70	53.16	4.44
Drimaren Blue CL-2RL	100 % Linen	38.79	0.88	-32.65	32.66	8.68
	50/50 %Linen/viscose	38.87	0.91	-34.58	34.59	9.55
	50/50 % Linen/cotton	46.49	-0.85	-31.81	31.82	5.02

(as evidenced by the higher -b* value) and brighter (as indicated by the higher C* value).

The results in Tables 2 and 3 demonstrate that 50/50 (%) linen/cotton fabric has the lower K/S values than the other fabrics for direct and reactive dyes.

Table-4 shows that colour strength of dyed materials were low values with the exception of the black dye. For Cassulfon Yellow GT dye, the colour of the 100 % linen was yellower and brighter (as indicated by higher b* and higher C* values). In the case of Cassulfon Olive BBN dye, the colour strength of K/S (1.82) value of 50/50 % linen/cotton was little higher but the colour was duller (of lower chroma). In the case of Cassulfon Black SR dye, the colour strength of K/S (3.63) value of 50/50 % linen/cotton was little higher but the colour was brighter (of higher chroma).

The dye uptake properties of linen and its blends were also studied with Indosol Navy SF-GLE direct and Drimarene Red CL-5B reactive dyes under atmospheric conditions and the exhaustion curves are given in Figs. 1 and 2.

As shown in Figs. 1 and 2, the maximum exhaustion values of the Indosol Navy SF-GLE direct dye for 100 % linen, 50/50 % linen/viscose, 50/50 % linen/cotton were 86, 98 and 91 % and maximum exhaustion values of Drimarene Red CL-5B reactive dye for 100 % linen, 50/50 % linen/viscose, 50/50 % linen/cotton were 55, 72 and 55 %, respectively. The highest dye uptake results (for direct dye 98 % , reactive dye 72 %) were obtained in 50/50 % linen/viscose fabric. It might be attributed partially to the viscose the most absorbent fiber in the cellulosics fibers. Viscose has higher dye affinity than cotton[13].

The colour change values were found between "4-5" and "5" for direkt and reactive dyes, "2-3" and "4" for sulphur dyes. The staining test results of adjacent multifiber were generally found "4-5" and "5" for direkt and reactive dyes, "3-4" and "5" for sulphur dyes. The colour fastness to rubbing

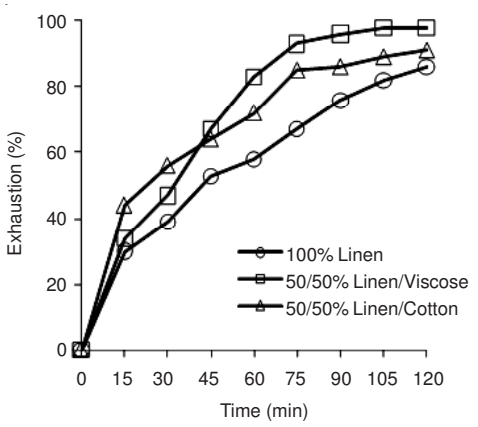

Fig. 1. Dyeing rates for Indosol Navy SF-GLE

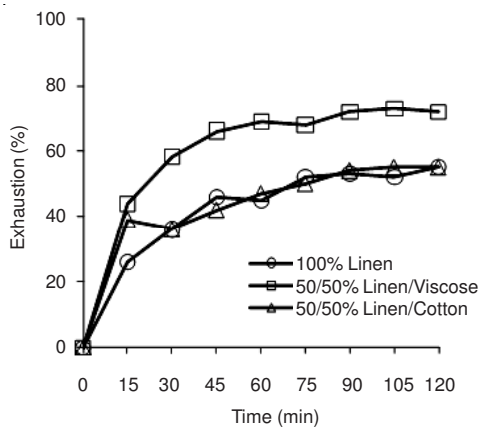

Fig. 2. Dyeing rates for Drimarene Red CL-5B

TABLE-4
CIELAB AND K/S VALUES OF DYED SAMPLES WITH SULPHUR DYES

Direct dyes	Fabrics	CIELab colour values				K/S
		L*	a*	b*	C*	
Cassulfon Yellow GT (C.I.Leuco Sulphur Yellow 20)	100 % Linen	94.19	-5.43	21.07	21.76	0.37
	50/50 %Linen/Viscose	93.56	-4.88	16.52	17.22	0.24
	50/50 % Linen/Cotton	94.86	-4.89	8.38	9.70	1.64
Cassulfon Olive BBN (C.I.Leuco Sulphur Green 9)	100 % Linen	65.73	-6.25	7.64	9.88	1.5
	50/50 % Linen/Viscose	73.47	-5.56	7.76	9.55	0.74
	50/50 % Linen/Cotton	71.27	-3.83	1.11	3.99	1.82
Cassulfon Black SR (C.I.Leuco Sulphur Black 1)	100 % Linen	44.83	-0.97	-3.35	3.48	2.75
	50/50 %Linen/Viscose	41.46	-1.16	-3.35	5.55	3.50
	50/50 % Linen/Cotton	46.28	-0.61	-6.75	6.78	3.63

TABLE-5
TENSILE STRENGTH, ELONGATION AND ELMENDORF TEAR STRENGTH TEST VALUES OF LINENAND ITS BLEND FABRICS (THE NUMERICAL DATA IN THE TABLE REPRESENTS THE AVERAGELOSSES IN PENCENTAGES BETWEEN UNDYED AND DYED MATERIALS)

Fabric	Tensile strength (%)			Elongation (%)			(Elmendorf) tear strength (%)		
	Direct dye	Reactive dye	Sulphur dye	Direct dye	Reactive dye	Sulphur dye	Direct dye	Reactive dye	Sulphur dye
100 % Linen	5-7	5-6	6-8	6-8	6-8	9-10	6-9	7-9	11-13
50/50 % Linen/viscose	6-9	6-8	11-13	11-12	8-10	10-13	9-11	7-10	10-14
50/50 % Linen/cotton	8-11	6-7	13-16	5-7	6-8	8-11	6-8	5-6	7-10

values of the direct and reactive dyed samples were "4-5" and "5" , the sulphur dyed samples were "3-4" and "4".

A slightly decrease was observed in mechanical strength of the dyed materials in reference to undyed ones. Highest decrease was noticed in sulphur dyed materials and this decrease can be attributed from the sulphur dyeing procedure.

Conclusion

Uniform and level dyeings were obtained with the reactive and direct dyes for all materials. But the colour of the sulphur dyed materials were dull and the colour strength of sulphur dyes were low. The highest dye uptake results (for direct dye 98 % , reactive dye 72 %) were obtained in 50/50 (%) linen/viscose fabric. Viscose is the most absorbent of all cellulosic fibers even more so than cotton and linen so its high absorbency applies equally to dyes[3,13-15]. Lively and brightly coloured materials were produced by the reactive dyes and also the reactive dyes are more popular for cellulosic materials. In addition to this, the good colour yields and dye exhaustions were achieved with the direct dyes. Therefore, the direct dyes will become increasingly important for dyeing linen fabrics. The good wash fastness (4-5) results were obtained with the reactive and direct dyes. On the other side, the wash fastness results of the sulphur dyed materials were moderate. The results of rubbing fastness in dyed fabrics are very good with the exception of the sulphur dyes. The value of 4/5 or 5 in the gray scale was obtained for direct and reactive dyed materials. The dyed material compared to that of the undyed materials, a slight decrease was observed in the strength values.

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