A Comparative Study for Using Different Solvents in Pretreatment Fabrics and in Corporation in Printing Paste

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ABSTRACT: A comparative study is carried out to investigate seven different organic solvents in pretreatment and incorporation in printing pastes of polyester, polyester cotton blends, 50/50 and 65/35 fabrics. The substrates are printed with their compatible dyes, disperse and disperse/reactive. The presence of organic solvents increases the suitability of the dye molecules, which facilitates their transfer from the printed film into the fabric during fixation. All the factors influencing the pretreatment and printing efficiency of the substrates are investigated in detail. The *K/S* (the color yield of the printed samples) values of the prints along with the water absorption and tensile strength measurements are also determined. © 2008 Wiley Periodicals, Inc. J Appl Polym Sci 108: 1064–1069, 2008

Key words: organic solvents; plasticizers; substrates; blends; incorporation; tenacity; *k/s*

INTRODUCTION

The basic objective in printing is the almost complete transfer of the dye present in the dried-up thickener film placed on the fabric surface during steaming. Solvents help in the almost complete dissolution of the dyestuff in the printing paste, thereby, ensuring maximum transfer of the dyestuff onto the fabric.[1]

Polyester is generally resistant to organic solvents. Chemicals used in cleaning and stain removal will not damage it, but hot metacresol will destroy the fabric, and certain mixtures of phenol with trichlorophenol or tetra chloromethane will dissolve polyesters. Oxidizing agents and bleaches do not damage polyester fibres.[2] Work on the use of solvents for improved dyeing of polyester has been reported.[3–10]

It has been reported that the pretreatment of fibers with various solvent systems can modify their physical structures in a way that they become presensitized to subsequent dyeing processes.

It has also been reported that[11] cellulose undergoes swelling in solutions of acids, bases, and salts as well as in some organic solvents. Swelling generally involves breaking of intermolecular bonding cellulose, and in many cases, formation of new bonds with the swelling agents to give swelling compounds.

A solvent can be incorporated in the printing paste to overcome or minimize many problems of common occurrence in printing such as (a) uneven blotch prints, (b) fastness in prints, (c) spikiness in prints, (d) streaky prints, (e) dusting of prints, (f) prevention of agglomeration, and (h) to help proper dispersion.

One of the ingredients of the printing paste is the solvent. Solvent dissolves the color and prevents any undissolved particle of the color going into the paste, which later causes the staining of the ground during washing.

In this context, this work has been taken up to compare some selected commercially available solvents on using in pretreatment of fabrics or incorporation in printing pastes.

EXPERIMENTAL

Materials

Fabrics

- Polyester fabric (150 g/m^2). Supplied by Egyptian and developing Co., Cairo, Egypt.
- Polyester cotton fabrics blend 50/50, polyester/cotton fabrics blend 65/35. Supplied by El-Shorbagy for Spinning and Weaving Company, Egypt.

Thickening agents

- Dial gin LV 100, low-viscosity sodium alginate, was kindly supplied by BF Godlish Diamatt GmbH, Munichen, Germany.

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- Daico thic. 1600, Synthetic thickener for reactive printing was kindly supplied by Daico Company.
- Myprogum NP-16, a nonionic chemically modified guar endosperm derivative, was kindly supplied by Meyhall Chemical AG, Switzerland.

Dyestuffs

- Terasil Blue PX-BGE was supplied by Ciba Specialty Chemicals, Cairo (reactive dye).
- Cibacron Turquoise P-GR was supplied by Ciba Specialty Chemicals, Cairo.

Other chemicals

[Dimethyl formamide, B.P. 153°C, nonvolatile, supplied by Fluka, Germany, lot number 41,940, pure reagent 99.6%.
Dimethyl sulfoxide, B.P. 189°C, nonvolatile, supplied by L. A. B. Scan, Doublin, Ireian, lot number 1701/5, pure reagent 99.5%.
Ethyl alcohol, B.P. 87°C, volatile, supplied by ADWIC Company, Cairo, Egypt, lot number 0,015,305, pure reagent 96%.
Glycerol, B.P. 290°C, nonvolatile, supplied by El Nisr Company, Cairo, Egypt, lot number 13,856, pure reagent 99%.
Diethylene glycol, B.P. 127°C, nonvolatile, supplied by Laboratory Rasayan, Russia, lot number 39571, pure reagent, average molecular number weight 380–420.
Acetone, B.P. 56°C, volatile, supplied by ADWIC Company, Cairo, Egypt, lot number 9301, pure reagent 99.5%.
Benzyl alcohol, B.P. 205.3°C, volatile, supplied by Merck, Darmstadi, Germany, lot number 23561, pure reagent 98.7%.]

Methods

Pretreatment of fabric with solvents

Polyester, polyester/cotton blends were subjected to organic solvent pretreatment using a liquor ratio (the ratio between the fabrics and solution) of 1 : 40 at different temperatures and times in water bath. After that, the fabrics were washed with water and finally rinsed and dried by dry air. The pretreated fabrics were printed with different thickeners.

Incorporation of solvents in the printing paste

For each substrate, seven printing pastes were prepared. Different solvents were used for each printing paste. A printing paste with the same recipe, but without any solvent was also prepared.

The composed printing paste for each substrate is as follows in the table.

	Polyester	Polyester/ cotton 65/35	Polyester/ cotton 50/50
Disperse dye	30	19.48	15
Reactive dye		10.52	15
Urea		50	50
Sodium carbonate		15	15
Acetic acid 30%	20		
Thickening agent	600	600	600
Water	×	×	×
	1000	1000	1000

Application

The printing pastes were applied to the fabrics through a screen printing technique.

Fixation

Fixation was carried out by thermal treatment of polyester fabrics for 1 min at 180°C. For polyester/ cotton blends, fixation of dyes was carried out for 30 min at 120°C.

Washing

Washing of the fixed printed goods was carried out through various steps according to the procedures recommended by the dyestuff manufacturer.

Measurements

The color strength[12]

The color strength of the printed samples expressed as K/S was evaluated by high reflectance technique. Reflectance measurements of the printed fabrics were performed on PERKIN–ELMER Lambda 3B, UV/V Spectrophotometer. The color strength expressed as K/S was assessed by applying the Kubelka Munk equation as follows:

$$K/S = (1 - R)2/2R - (1 - \mathrm{RO})2/2\mathrm{RO}$$

where R, RO are decimal fractions of the reflectance of the printed and unprinted fabric, respectively, K = absorption coefficient, S = scattering coefficient.

Evaluation of the tensile strength and elongation[13]

Four samples were treated for the evaluation of the tensile properties before printing. Fabrics and one untreated sample (a control) were selected. An Uster single-yarn strength tester was used for this purpose (Asano Machine Meg. Co., Ltd, Japan).

TABLE I
Effect of Treatment Temperature of Different Solvents on the Color Strength of the Polyester, Polyester/Cotton 50/50, and Polyester/Cotton 65/35

Type of solvent	Temperature (°C)	Color strength K/S for the printed fabrics using: Polyester	Polyester/cotton 50/50	Polyester/cotton 65/35
Untreated		5.14	3.86	3.81
Dimethyl sulfoxide	50	6.5	3.03	3.85
	70	6.61	3.19	4
	90	5.65	4.88	3.13
Dimethyl formamide	50	6.1	3	4.6
	70	5.97	3.19	5.07
	90	4.93	3.97	4.41
Ethyl alcohol	40	5.7	3.6	3.6
	50	5.14	4.2	3.77
	60	6.08	3.9	4.37
	60	6.96	4.2	3.95
Glycerol	80	6.5	3.86	4.05
	100	6.39	3.81	4.3
Diethylene glycol	60	5.98	2.41	4.26
	80	6.39	2.39	3.91
	100	6.39	3.52	3.09
	40	5.9	3.64	3.71
Acetone	50	4.79	3.95	4.2
	60	4.26	3.95	3.91
Benzyl alcohol	50	5.14	4.66	4.16
	70	5.14	3.23	3.6
	90	6.08	3.3	3.64

Water repellency

Water repellency of the samples was determined on a spray tester (water repellency tester) model No. BS 370 21 SO 4920.

RESULTS AND DISCUSSION

It has been reported that[14] pretreatment of fabrics with various solvent systems can modify their physical structure in such a way that they become presensitized to subsequent dying process and improved dyeability is achieved through these swelling and/or plasticity action of the solvents. Hence, it is of a great interest to investigate the effect of some solvents either by pretreatment or incorporation in the printing paste on the printability of polyester, polyester/cotton blends.

Solvent application by pretreatment of fabrics

The previously mentioned substrates were pretreated using the seven solvents with L.R 1 : 40, separately. Samples were then washed thoroughly, rinsed with distilled water, dried, and printed as previously mentioned in the experimental part to investigate the following factors.

Effect of pretreatment temperature

Table I represents the effect of using different temperatures for each solvent in pretreatment of the three substrates on the K/S values of print along with their compatible dyes.

It can be concluded from the figures that, for polyester fabrics, the best result could be obtained when the fabric was pretreated at 70, 50, 60, 60, 80, 40, and 90°C using dimethyl sulfoxide, dimethyl formamide, ethyl alcohol, glycerol, diethylene glycol, acetone, and benzyl alcohol, respectively, as the increases were 28.59, 18.67, 18.28, 35.40, 24.31, 14.78, and 18.28%, respectively, compared with the K/S of untreated printed fabrics which was 5.14.

For polyester/cotton blend 50/50% fabrics, it is apparent that the best results could be obtained when the fabric was pretreated at 90, 100, 50, 60, 100, 50, and 50°C using dimethyl sulfoxide, dimethyl formamide, ethyl alcohol, glycerol, diethylene glycol, acetone, and benzyl alcohol, respectively. The increases of K/S were 27.21, 2.98, 20.72, 8.80, 7.61, 3.63, and 20.72%, respectively compared with the K/S of untreated polyester/cotton 50/50, which was 3.86. While for polyester/cotton 65/35 fabrics, the best color values were obtained through pretreatment of the substrate at 70, 70, 60, 100, 60, 50, and 50°C for the previously mentioned solvents, respectively. The increases of K/S were 4.9, 33.07, 14.69, 6.29, 11.81, 10.23, and 9.18%, respectively compared with the K/S of the untreated polyester/cotton 65/35, which was 3.81.

The previous increases in the color yield of the prints are attributed to the plasticizing effect of the solvent.

TABLE II
Effect of Treatment Time of Different Solvents on the Color Strength of the Polyester, Polyester/Cotton 50/50, and Polyester/Cotton 65/35

		Color strength K/S for the printed fabrics using		
Type of solvent	Time (minutes)	Polyester	Polyester/cotton 50/50	Polyester/cotton 65/35
Untreated		5.14	3.86	3.81
Dimethyl sulfoxide	30	6.21	4.31	3.95
	60	6.61	4.88	4
	90	5.53	4	4.15
	120	5.31	3.77	4
Dimethyl formamide	30	6.08	3.56	4.15
	60	6.1	3.97	5.07
	90	5.79	3.91	4.37
	120	5.64	3.81	4.86
Ethyl alcohol	30	5.37	4.05	3.03
	60	6.08	4.2	4.37
	90	6.08	4.48	4.15
	120	5.92	4.26	3.3
Glycerol	30	5.7	4.05	4
	60	6.97	4.2	4.3
	90	5.98	4.26	4.05
	120	6.28	4.15	4.73
Diethylene glycol	30	6.28	3.48	3.95
	60	6.39	3.52	4.26
	90	6.2	4.42	4.31
	120	5.7	4.15	4.2
Acetone	30	4.95	3.6	4
	60	5.9	3.95	4.2
	90	5.29	3.81	4.31
	120	5.89	3.85	4.2
Benzyl alcohol	30	5.98	3.37	3.95
	60	6.08	4.66	4.16
	90	6.73	4.05	3.77
	120	6.39	4.2	3.77

Moreover, the solvents may act as molecular lubricants and many cause reduction of the internal stress, permitting the movement of the polymer chains. The crystallinity of the polyester substrate enhanced due to solvent pretreatment, affecting the amorphous region by increasing the disorientation and creating new voids. The number of created voids seemed to depend on the swelling abilities of the solvents used on the polyester substrate.[15]

Effect of pretreatment time

To study the effect of pretreatment time, the optimum temperature of every type of substrate was chosen, application and the fabric were subjected for different periods of pretreatment time, which are 30, 60, 90, and 120 min.

From the results obtained, which appear in Table II, it is clear that pretreatment had no effect on the color yield values of the prints using the variety of solvents and substrates, which corresponds with the literature. According to these figures, treatment of the substrates using the seven solvents was chosen to last for 60 min as an optimum time as it gave best K/S values.

Effect of thickener type

To study the effect of thickener type, the optimum solvent temperature and time were chosen for every type of substrate.

Three different thickeners, which are sodium alginate, Meypro gum, and synthetic thickener, were used in printing the substrates using the previous conditions that are illustrated in Figure 1. It is apparent from the figure that the pretreatment of the fabrics had a good effect on the K/S values of the prints, which means better fastness of the dye due to solvent treatment. For polyester and both polyester/blends, best results are obtained using synthetic thickener in printing as increases of 64.59, 43.26, and 56.69%, respectively, are obtained.

These results prove the theory of enhancing dye fixation on the substrates under the influence of solvent pretreatment.

The opening up of the fiber structure takes place by lowering the T_g, thereby increasing the chain mobility inside the fiber to make it more accessible for dyeing. The presence of certain solvents in the dye bath helps to bring about these changes.[16]

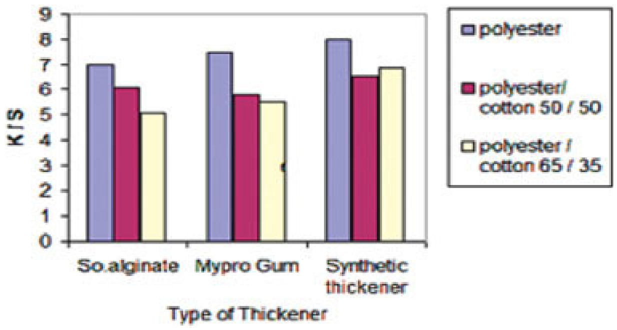

Figure 1 Effect of thickener type on the K/S of the three substrates of printed fabrics (polyester, polyester/cotton blends 50/50, and 65/35) with their compatible dye using different thickeners. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

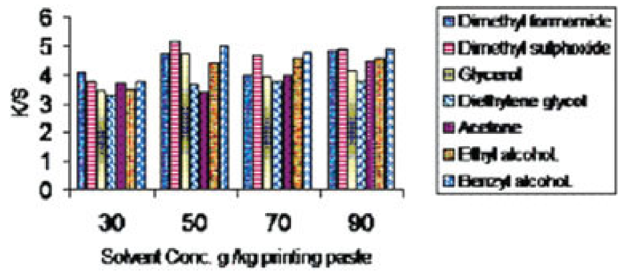

Figure 3 Effect of the seven solvents concentration, incorporated in printing paste of polyester/cotton 50/50, on the K/S values of the prints with their compatible. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Incorporating solvents in printing pastes

Effect of solvent concentration

The same seven solvents were incorporated separately in the printing paste with different concentration (30, 50, 70, 90 g solvent/kg printing paste) to be printed on the same three substrates to study the influence of adding these solvents to the printing pastes on the K/S values of the prints, which is illustrated in Figures 2–4. It is apparent from the previous figures that optimum increases in the K/S values of the prints can be obtained by adding glycerol with 50 g/kg in printing polyester substrate, dimethyl sulfoxide with 50 g/kg in polyester/cotton 50/50 blend, dimethyl formamide with 50 g/kg in polyester/cotton 65/35 blend as they enhanced the K/S values of the prints with 30.93, 20.72, and 25.72, respectively, when compared with conventional printing without adding solvents.

These results are considered very good baring in mind that no staining happened as on alternative to pretreatment or incorporating the solvents in the printing pasts these.

Increases in K/S values are due to using solvents which dissolve color paste and help in the almost complete dissolution of the dyestuff in the printing paste, thereby ensuring maximum transfer of the dyestuff on the fabric.

This transfer can take place only when the dye is present in the form of molecules or ions. These solvents by themselves split up the dye particles into dye molecules.

The best solvent concentrations used in printing the three substrates, which gave the optimum K/S values, are incorporated in the printing paste along with synthetic thickener to study its effect on dye fixation. It is found that using the synthetic thickener enhanced the K/S values of the prints markedly by 17.46, 20, and 20.3% for polyester, polyester cotton 50/50, and polyester/cotton 65/35, respectively, compared with the same conditions of printing with sodium alginate.

Tensile strength and water absorption

Tables III and IV represent the effect of pretreatment of the three substrates using the previously studied optimum conditions before printing on the tensile strength and water absorption of the fabrics.

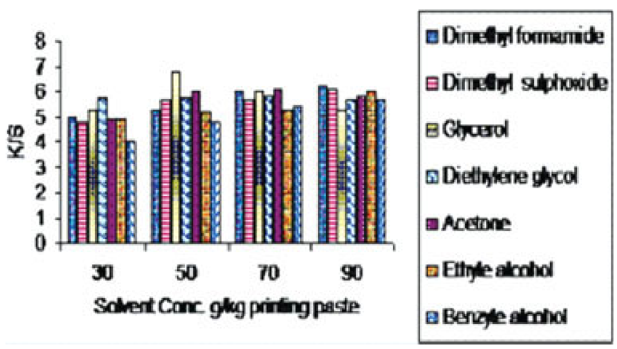

Figure 2 Effect of the seven solvents concentrations, incorporated in printing paste of polyester, on the K/S values of the prints with their compatible. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

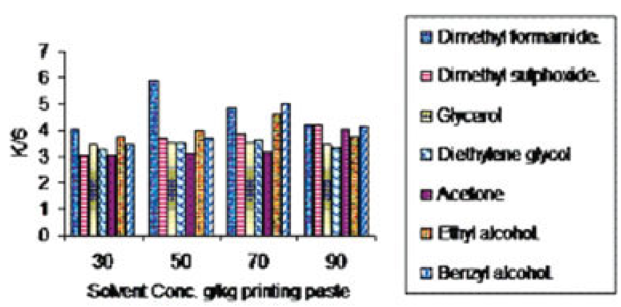

Figure 4 Effect of the seven solvents concentrations, incorporated in printing paste of polyester/cotton 65/35, on the K/S values of the prints with their compatible. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

TABLE III
Tensile Strength and Elongation Measurements of Treated and Untreated Fabrics at the Optimum Condition

	Measurements			
Conditions of fabrics	Tensile strength	Elongation (%)	Change in strength (%)	Change in elongation (%)
Untreated polyester	102	52	−11.7%	5.7%
Pretreated polyester	90	55		
Un treated polyester/cotton 50/50	45.5	23	−11.36	8.3%
Treated polyester/cotton 50/50	39	25		
Un treated polyester cotton 65/35	71	48	−14.28	8.6%
Treated polyester cotton 65/35	63	52		

As shown in Table III, the pretreatment of polyester, polyester/cotton 50/50, and polyester/cotton 65/35 decreased the tensile strength slightly. However, the loss of density is found 11.7, 11.36, and 14.28%, respectively, based on control fabric.

It is also clear that the treated fabrics showed ∼ 5.7–8.6% increase in their elongation.

The pretreatment of the substrates with the studied solvents is found to increase the absorption of the fabric as shown in Table IV. Increases of 20, 40, and 50% were obtained on treating polyester, 65/35 and 50/50, respectively, compared with the untreated fabrics.

CONCLUSIONS

In the present work, pretreatment of polyester, polyester/cotton blends 50/50, and 65/35 was carried out using seven different organic solvents and subsequently printed with disperse or disperse/reactive dyes. The same organic solvents are also incorporated in printing the same substrates to compare their effect in pretreatment and printing on the *K/S* values of the prints. Optimum results are obtained on using glycerol, dimethyl sulfoxide, and dimethyl formamide in pretreatment of polyester, polyester/cotton 65/35, and polyester/cotton 50/50, respectively, as increases of the *K/S* values of the prints are obtained by 35.40, 27.71, and 33.07% compared with the untreated fabrics printed under the same conditions. Incorporation of the same solvents in the printing paste enhanced the *K/S* of the prints with lower degree, because it increased the *K/S* by 30.93, 20.72, and 25.72% on printing polyester, polyester/cotton 50/50 and 65/35, respectively. These results are due to the dissolution of dye molecules and swelling effect of the plasticizers/organic solvents, also decreasing the T_g of the fabric. The use of organic solvents increased water absorption of the pretreated unprinted fabrics by 20, 40, and 50% for polyester, polyester/cotton 50/50, and 65/35, respectively, while it has a reverse but limited effect on the tensile strength of the same fabrics.

It could be concluded that incorporation of glycerol, dimethyl sulfoxide, dimethyl formamide in the printing pastes of polyester, polyester/cotton 50/50, and polyester/cotton 65/35 gives the best results in *K/S* and minimizes many problems of common occurrence in printing.

TABLE IV
Effect of Pretreatment Polyester, Polyester/Cotton 50/50, and Polyester/Cotton 65/35 on the Water Repellency of the Fabrics

	Water repellency	
Condition	Absorption	Repellency
Untreated polyester	30	70
Treated polyester	50	50
Un treated polyester/cotton 50/50	60	40
Treated polyester/cotton 50/50	100	0
Un treated polyester/cotton 65 /35	50	50
Treated polyester/cotton 65/35	100	0

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