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A NOVEL ECO-FRIENDLY DYEING OF CATIONIZED POLYESTER FABRICS USING CURCUMIN NATURAL DYE

Wessam El-Zairy*
* Textile printing, dyeing and finishing dept., Faculty of Applied Arts, Helwan University, Giza, Egypt

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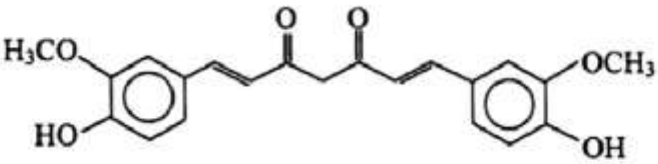
ABSTRACT
Due to the cheap in prize, high production and long life of polyester fabrics, its application is wide in apparel industry. But, concerning to their hydrophobicity and soiling properties it makes the wearer for less comfort. This is because of the absence of water absorbing group in it. This work presents an ecofriendly method for dyeing polyester fabrics with curcumin natural dyes. Firstly alkali treatment of the substrate were done then cationization to activate fibers and improve dyeability of polyester. Fabrics are pretreated with different concentrations of chitosan for different periods of time. Dyeability of the treated samples was investigated in terms of their colour strength expressed as K/S in addition to fastness to washing and light.

KEYWORDS: polyester, alkaline pretreatment, chitosan, curcumin natural dye.

INTRODUCTION
Natural dyes are mostly used to dye natural fibers like, cotton, wool, silk, jute etc. But very little information is available on dyeing of synthetic fibers like polyester with natural dyes. In this study an attempt has been made to dye polyester fabric with curcumin natural dye in absence of mordant. Polyester is one of the synthetic fibers that possess high durability and resistant to wrinkle. However, the fiber is hydrophobic and non-absorbent without chemical modification. Due to its hydrophobicity and high crystallinity, polyester is difficult to dye. Since it have no active-site, it is impossible to be dyed with majority of dyestuff. [1,2]

Normally polyester is dyed using disperse dyes at temperature of 130 º C. In the current study, to facilitate the dyeing process, the polyester fabric was firstly treated with sodium hydroxide then with chitosan to improve the affinity between curcumin natural dye and polyester fabric followed by applying the dyeing process at low temperature.

MATERIALS AND METHOD
Materials
Natural Dye Source
Curcumin were purchased from Riedel de Haen Ag Seelze Hannover Company, Germany, and were used as natural dyes.



Figer 1 Chemical structure of soluble curcumin

Chemicals
Chitosan (medium molecular weight, deacetylation 82.9% Dalton,Vanson Inc.Co.USA) and sodium hydroxide were used throughout this investigation.

Substrates

Scoured and bleached polyester fabric (200 g/m^2) was used in this study.

Methods

Alkali Treatment

The polyester samples were firstly treated with aqueous solution of NaOH (12%) at L.R 1:50 at 60 ^{O} C for 90 min. [3,4]

Theory of Alkali Hydrolysis of polyester fabrics: Two separate kinds of chain cleavage may occur. The first may involve the reaction of single hydroxide ion with the chain to produce a carboxylate anion and hydroxyl end groups of the shortened chain. This reaction does not produce a weight loss directly but may increase the weight due to the addition of hydroxide ion. The second reaction involves the attack of two hydroxide ions essentially simultaneously some distance apart along the same polymer chain backbone. In this case, a low molecular weight segment of the chain is removed as a single unit, resulting in a loss in weight from the polymer. Further reaction of these low molecular weight segments occur in liquid phase and do not contribute further to the weight loss of polyester, but it does contribute to depletion of the caustic concentration of the solution. Both of these reactions occur at the interface between the caustic solution (liquid phase), and the fibre surface (solid phase). At the moment of reaction, molecular solvation of the polymer must be minimal. Accordingly, this step of the reaction must be slow. Another kind of reaction is a scission of an already cleaved chain at the carbonyl group distal to the free end group of the chain. The free end groups consist of either terephthalate anion or the hydroxyl ethyl group. The reactions leading to elimination of the terephthalate dianion or ethylene glycol by "un- zippering" (i.e., the progressive reaction of the chain with hydroxide ion, beginning at a free end group) occur at locations that may be solvated, and hence can be expected to have rates that are faster than the rates of chain cleavage. Hydrolysis at the end group produces one molecule of either ethylene glycol or the terephthalate dianion for the reaction of each hydroxide ion. The result is the formation of terminal hydroxyl and carboxylate groups on the fibre surface. Hydrolysis is believed to increase the number of polar functional groups at the fibre surface.[5]

Cationization using Chitosan

The alkali pre-treated polyester fabrics were then cationized with chitosan (0-20%) o.w.f. at L.R. 1:50, at (30-90 ^{O} C) for (30-90) min. pH 5.5.

Dyeing

The pre-treated fabrics were dyed in a solution contains the natural dye with different concentrations (1-5%), at (30-100) ^{o} C, for (30-90)min. ,at L.R 1:20.[6-7]

TESTS AND ANALYSES

The colour strength of dyed polyester samples were measured by using reflectance spectrophtometer model Data color Spectrophotometer SF600+Datacolor Company, U.S.A.

The colour strength expressed as K/S values was assessed by applying the Kubelka Munk equation

$K/S= (1- R) 2 /2R$

Where K and S are the absorption and scattering coefficient respectively, and R is the reflectance of the dyed fabric.

Fastness properties of dyed samples were tested according to ISO standard methods. The specific tests were: ISOX12 (1987), colour fastness to washing; and ISO 105-E04, colour fastness to perspiration: Furthermore the dyed samples were subjected to tests, for fastness to light by AATCC test method 16-1993.

RESULTS AND DISCUSSION

Cationization of polyester fabrics:

Effect of chitosan concentration on polyester fabrics pre-treated with alkali

First the samples were treated in a solution contains NaOH (12%) at L.R. 1:50 for 90 min. at 60 ^{O} C [3,4], then the fabrics were thoroughly washed with warm water then with cold water and finally squeezed and air dried. Hence cationization using chitosan were applied on the fabric before post dyeing with curcumin natural dye. Table 1 clear that, the K/S of the alkali treated polyester fabrics is higher than untreated fabrics that due to the possible increase in the number of hydrophilic groups on the fiber surface caused by chain scission after the fabric was treated with alkaline.[8]

The results show that the color strength, K/S values, of all chitosan-pre-treated fabrics had higher values than the untreated as well as than the alkali treated sample. The K/S values increased gradually by raising the chitosan concentration. It is obvious that, chitosan at 15 % concentration was selected to be the more suitable concentration that attains the highest color yield (K/S) value. Chitosan treatment on fabric provided more dye sites than untreated fabric. Polyester, like most solid surfaces is slightly negatively charged. The mean reason for the adsorption of chitosan on weakly anionic surfaces is often electrostatic interaction. The electrostatic interaction favor a flat configuration of a cationic polymer on a negatively charged surface, and that explain the improvement in the color strength of polyester fabric after the cationization but in this study chitosan sorption on the alkali treated polyester is found to be due to ionic interaction between the negative charges of carboxylic groups in the broken chain of polyester and the protonated amino groups of chitosan, and possible due hydrogen bonding between hydroxyl groups in alkali treated polyester and similar groups in chitosan.

Table 1. Effect of chitosan concentration on the K/S values of the cationized polyester fabrics.

Chitosan conc. (%), (on the alkali pre-treated samples)	K/S
Untreated sample either with alkali nor with chitosan	4.76
0	5.64
5	7.24
10	8.69
15	9.31
20	8.84

Cationization temperature of the alkali pre-treated polyester fabrics

It can be concluded from table 2, that the temperature is the prime factor that greatly influence the K/S values due to the increased rate of diffusion, adsorption and penetration of chitosan into the substrate. By raising temperature there was gradually increasing on K/S of dyed fabrics. Cationization at 60°C was the optimum degree, noticed that with increasing temperature above 60°C significant decrease in K/S values happened.

Table 2. Effect of Cationization temperature on the K/S values of the cationized polyester fabrics.

Cationization temperature °C	K/S
30	6.24
45	8.69
60	9.31
90	8.41

Cationization time of the alkali treated polyester fabrics

Table 3 reveals the effect of cationisation time on the K/S values of the alkali treated polyester fabrics. As is evident, table 3, increasing the treatment time from 30 to 60 min leads to an increase in the K ⁄ S values. It was noted that that the better K/S values for that cationized fabric was attained after 60 min. so the optimum cationisation time for the dyed fabrics is 60 min . It may be concluded, from the results, the most suitable time for cationization process reach 60 min. During this treatment time a sufficient amont of chitosan was adsorbed and fixed on the fibers which may be attributed to great ionic attraction between chitosan and the negatively charged fiber surface.

Table 3. Effect of cationization time on the K/S values of the cationized polyester fabrics.

Cationization time (min)	K/S
30	4.78
45	7.87
60	9.29
90	9.31

DYEING OF CATIONIZED POLYESTER FABRICS

Effect of dye concentration

The cationized fabrics were dyed using curcumin natural dye with different concentrations (1-5%) (o.w.f) under fixed dyeing conditions.It is clear from table 4 that generally, within the range examined, an increase in dye concentration is accompanied by an improvement in K / S values. After 4 % of the natural dye concentration, almost stable K / S values were observed because there is no further increase in the K / S after saturation was observed even although more dye was available at a higher dyebath concentration. In polyester natural dyeing, it is known that, natural dyes molecule are very small and hydrophobic in nature which should make them substantive to hydrophobic fiber where the mechanism of dyeing polyester with natural dyes is similar to that of synthetic disperse dyes. In current study, we can add that, a reaction happened between the amino groups (ammonium cations) in the cationized polyester and hydroxyl groups (hydroxyl anions) in curcumin natural dye which explain the increase in the K/S values.

Table 4. Effect of dye concentration on the K/S values of the cationized polyester fabrics.

Dye conc. (%)	**K/S**
1	3.64
2	5.74
3	7.96
4	9.37
5	9.41

Effect of the dyeing temperature

Table5 shows that, the K/S values increase by raising the dyeing temperature. It is known that raising dyeing temperature improve the dye uptake on the fabrics. 60 ^{o} C .was chosen to be the optimal dyeing temperature. Farther increase in temperature led to slight decrease in K/S values. That higher temperature may cause dye fading and reducing the diffusion of the dye.

Table 5. Effect of dyeing temperature on the K/S values of the cationized polyester fabrics.

Dyeing Temp. ^{o}C	**K/S**
20	6.84
40	8.24
60	9.38
80	9.21
100	9.15

Effect of the dyeing time

Results of table 6 signify the effect of the dyeing time on the K / S values of the cationized polyester fabrics. It was seemed that the color strength gradually increased as the time increase .This can be attributed to the slight diffusion with short dyeing time. Because coloring component attained equilibrium from dye bath to fabric, which increases with time.90 min was chosen to be the optimal dyeing time.

Table 6. Effect of dyeing time on the K/S values of the cationized polyester fabrics.

Dyeing time min.	**K/S**
30	7.17
45	8.31
60	8.83
75	9.19
90	9.38

FASTNESS PROPERTIES

The results of fastness properties of dyed pre-alkali/cationized polyester fabrics via curcumin natural dye are illustrated in table 7. These data showed that there was a marginal effect of cationizing treatment in improving fastness properties. The results of the fastness ranged very good to excellent.

Table 7. Colour fastness properties of cationized polyester fabrics dyed with curcumin natural dyes

Polyester fabrics	**Washing Fastness**	**Prespiration Acidic Cotton**	**alkaline wool**	**Light**
Untreated samples	3	3	3	3
Alkali pre-treated samples	3-4	3-4	3-4	5
Alkali pre-treated/ Cationized samples	4-5	5	5	6-7

CONCLUSION

Polyester fabrics were dyed using curcumin natural dye. The fabrics were pre-treated using chitosan after alkali treatment. The fabrics were treated in a solution contains (15%) chitosan, at 60 °C for 60 min. The pre-treated fabrics were then post dyed in solution contains 4% natural dye (curcumin) , at 60 º C for 90 min., L.R 1:20.

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