

Improving light fastness of reactive dyed cotton fabric with antioxidant and UV absorbers

P Thiagarajan¹ & G Nalankilli^{2, a}

¹Department of Textile Technology, Anna University, Coimbatore 641 013, India

²Sri Raaja Raajan College of Engineering and Technology, Karaikudi 630 301, India

Received 29 November 2011; revised received and accepted 10 May 2012

Cotton fabrics have been dyed with C. I. Reactive Yellow 84, C. I. Reactive Red 22 and C. I. Reactive Blue 19 dyes and the effect of some commonly used antioxidants and UV absorbers is studied in order to improve light fastness property. The antioxidants such as gallic acid, vitamin C and caffeic acid, and the UV absorbers such as 2-hydroxybenzophenone and phenyl salicylate have been applied on reactive dyed cotton fabric by exhaust method. Treated samples are then tested for fastness properties as per international standards. The results show no change in colour depth during after treatment. In all the cases, the use of UV absorbers or antioxidants improves the light fastness of dyed fabrics. The most effective light fastness improvement is found by the application of vitamin C.

Keywords: Antioxidant, Cotton fabric, Dyeing, Light fastness, Reactive dyes, UV absorbers

1 Introduction

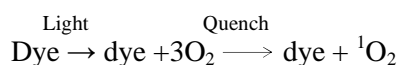
Resistance of the material to a change in its color characteristic on its exposure to sun light or an artificial light source is called light fastness. The fading of colored textiles upon exposure to light is a well-known phenomenon, and has been an active area of research for nearly 200 years¹. The mechanisms by which dyes undergo photo degradation are thought to be complex process². However, most of the studies suggest that UV light-induced unimolecular decomposition and visible light-induced photo-oxidation are the two most important pathways of fading, as shown below:

Dye + UV light → Bleaching

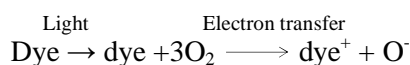
Dye + O₂ + Light → Bleaching

Many authors studied the chemistry and reactive species involved in photo-fading. Notably, Egerton and Morgan³ in a series of papers showed that reactive oxygen species (ROS) were produced by irradiation of dyed fabrics which were capable of destroying dyes. The nature of the ROS, i.e. singlet oxygen, hydrogen peroxide, superoxide radicals, hydroxyl radicals or peroxy radicals was not defined. Subsequently a large amount of work has been done on how these species might be formed during

irradiation and the damaging effect on dyes. Most attention has been paid to singlet oxygen (¹O₂) which can be formed by the quenching of excited states of dyes by the triplet ground state of oxygen⁴, as given below:



Many model studies have shown that singlet oxygen is very reactive towards dyes^{5,6}, although its importance is unclear. Recent quantitative work has suggested that its role in photo-fading of azo-dyes is quite small^{7,8}. The quenching of excited states of dyes by oxygen has also been shown to lead to the formation of the superoxide radical and destruction of the dye⁹, as shown below:



The so-formed superoxide could then react and destroy further dye molecules³. Clearly, the exact mechanism of a dye photo-fades will critically depend on the dye and fibre type. Therefore, it has become necessary to understand the relative importance of UV and visible light plus the various possible ROS's to photo-fading.

UV absorbers are additives used to prevent the photodegradation of polymeric materials by UV-rich sunlight and artificial light. These additives absorb UV radiation and reemit it as fluorescent or infrared

^aCorresponding author.
E-mail: gnalankilli@yahoo.com

radiation. The energy of the excited molecules which causes photodegradation is released as thermal energy¹⁰. Researchers have investigated the usefulness of UV absorbers in reducing color alteration using two general methods namely (i) direct application of UV absorbers to fabrics and (ii) use of UV filtering materials¹¹. The major classes of commercial ultraviolet-radiation stabilizers include derivatives of 2-hydroxybenzophenone, 2-(2H-benzotriazol-2-yl)-phenols, phenyl esters, substituted cinnamic acids and nickel chelates. Gordon *et al.*¹² studied the use of ultraviolet light absorbers for protection of wool against yellowing.

Antioxidants, also called inhibitors of oxidation, are organic compounds that are added to oxidizable organic materials to retard autooxidation and, in general, to prolong the useful life of the substrates. Antioxidants are classified as either radical trapping (chain breaking) or peroxide decomposing, terms that describe the mechanism by which they function¹³. The antioxidant absorbs free singlet oxygen and reduces the photo fading. This activity of antioxidant is measured by the unit of oxygen radical absorbance capacity (ORAC)¹⁴. Works carried by researchers concentrated on dyes' chemical structure, dyeing properties and condition of light fastness testing on light fastness properties. Antioxidant has been used only on natural dyed fabric for light fastness improvement. In this work, antioxidant and UV absorbers have been applied on reactive dyed materials for improving light fastness properties.

2 Materials and Methods

2.1 Materials

2.1.1 Fabric Particulars

The plain cambric cotton ready-for-dyeing fabric of the following constructional parameters was used:

Warp count	: 60Ne
Weft count	: 60Ne
Ends/inch	: 120
Picks/inch	: 103
Areal density	: 80 g/m ²
CIE whiteness index	: 68.0
Absorbency	: <3 s

2.1.2 Reactive Dyes

Commercially used reactive dyes namely C. I. Reactive Yellow 84, C. I. Reactive Red 22 and C.I. Reactive Blue 19 were used without any purification.

2.1.3 Antioxidant and UV Absorbers

The antioxidants (gallic acid, vitamin C and caffeic acid) and the UV absorbers (2-hydroxybenzophenone

and phenyl salicylate) were used for treating the cotton before exposure to irradiation. They were obtained from commercial sources (Acros Organics, Sigmae, Aldrich, Fluka). Caffeic acid (CAS no. 331.39.5), gallic acid (CAS No 149-91-7), vitamin C (ascorbic acid, CAS No. 50.81.7), phenyl salicylate (CAS No.118.55.8), and benzophenone (CAS No. 117.99.7) were used. Chemical structure and other details of these can be obtained from CAS index¹⁴.

2.2 Methods

2.2.1 Dyeing

Dyeing of the scoured fabrics was performed at 60°C using C. I. Reactive Yellow 84, C. I. Reactive Red 22 and C. I. Reactive Blue 19, each 1.0% by exhaustion with sodium sulphate (30 g/L) for 30 min and fixation with soda ash (10 g/L) for 45 min. After dyeing, the samples were rinsed in distilled water, soap solutions, rinsed again in distilled water and then dried.

2.2.2 Application of Antioxidants and UV Absorbers

The antioxidants (gallic acid, vitamin C and caffeic acid) and the UV absorbers (2-hydroxybenzophenone and phenyl salicylate) each 1 g/L concentration were applied by treating the dyed cotton fabric in a solution at 70° C, with 30 min stirring. For gallic acid, vitamin C and caffeic acid, aqueous solutions and for the others water/ethanol mixture (9/1 v/v) were used. After treatment, the samples were washed and then air dried¹⁴.

2.2.3 Light Fastness Testing

The dyed fabric was exposed separately for 1, 2, 6, 12, 24 and 36h at 40°C under artificial light source (day light B01, James H Heal and company, Hamifax, England), equipped with xenon arc and mercury-tungsten florescent, whose wave length was similar to that of sunlight. The change was compared with original specimen and assessed by Data color CIE Lab dE value¹⁵.

3 Results and Discussion

3.1 Light Fastness Properties

Figure 1 shows that for dyed fabric the fading increases progressively with duration of light exposure. The light fastness (36 h exposure) of dyed samples treated with antioxidants (gallic acid, vitamin C and caffeic acid) and UV absorbers (2-hydroxybenzophenone and phenyl salicylate) has

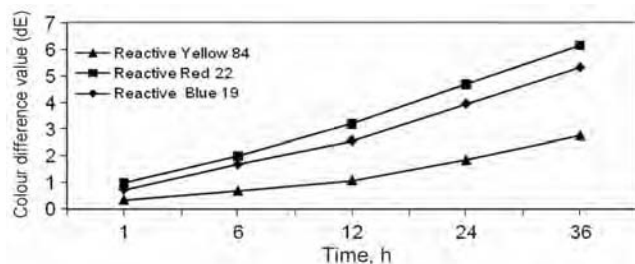


Fig. 1—Fading rate curves

has been studied. C. I. Reactive Yellow 84 (dE 2.76) dyed fabric shows good light fastness than C. I. Reactive Red 22 (dE6.35) and C. I. Reactive Blue 19(dE5.32) dyed fabrics.

The application of these additives must not change the color of the dyed samples. In general, the treatment brings certain changes in brighter and bluer direction. The fading rate curves of the treated samples look alike to the fading rate curve of the untreated dyed cotton fabric.

It is observed that the antioxidants are more effective than the UV absorbers for C I Reactive Yellow 84 dyed fabric. The colour difference is measured by keeping dyed sample as standard and faded samples as batch. Colour difference of dyed sample after 36 h fading is found to be dE 2.76, vitamin C treated sample dE 1.76, caffeic acid treated sample dE 1.90, galic acid treated sample dE 1.95, phenyl salicylate treated sample dE 2.52 and benzophenone treated sample dE 2.33. The fact that the UV absorbers are inefficient on yellow dyed cotton suggests that this dye is very susceptible to fading by the visible light.

Colour difference of C.I. Reactive Red 22 dyed sample after 36 h fading is found to be dE 6.35, vitamin C treated sample dE 4.12, caffeic acid treated sample dE 5.35, galic acid treated sample dE 5.64, phenyl salicylate treated sample dE 5.45 and benzophenone treated sample dE 5.39. Red dyed sample treated with vitamin C shows very less fading as compared to other treatments.

Colour difference of C.I. Reactive Blue 19 dyed sample after 36 h fading is found to be dE 5.32, vitamin C treated sample dE 2.54, caffeic acid treated sample dE 3.45, galic acid treated sample dE 3.96, phenyl salicylate treated sample dE 4.12 and benzophenone treated sample dE 4.01. Both the antioxidant and UV absorber treated samples show less fading and the most efficient additive after 36 h of exposure is vitamin C treated sample.

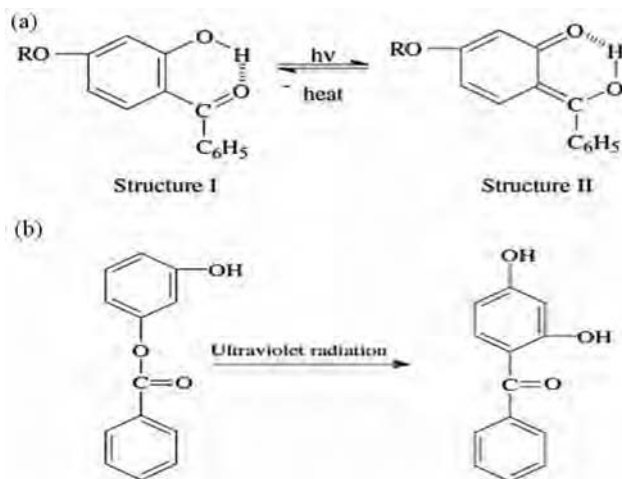


Fig. 2—Photochemistry of (a) 2-hydroxybenzophenones and (b)phenyl salicylate

3.2 Effect of Antioxidant on Light Fastness

Visible light requires oxygen to degrade the dyes. Usage of antioxidant like gallic acid, vitamin C and caffeic acid absorb the oxygen radicals available for photo degradation. Oxygen radical absorbance capacity of ascorbic acid is more than that of gallic acid and caffeic acid, this is the reason for good results of ascorbic acid (ORAC value 12.5) then caffeic acid (ORAC value 9.5) and galic acid (ORAC value 11.7)¹⁵.

3.3 Effect of UV Absorbers on Light Fastness

The photochemistry of the 2-hydroxybenzophenones (Fig. 2a) has been more extensively studied than that of the other classes of ultraviolet absorbers. It is known that structure I is rapidly converted to a “photoenol” (structure II) by absorption of light, and that structure II reverts to structure I with loss of energy as heat, showing almost 100% efficiency. The existence of the intra molecular hydrogen bond in both I and II structures accounts for the rapid and efficient photo automerism.

The application of benzophenones is only useful for dyes which are not sensitive to visible light and even then, the improvement is in general not greater than one grade of fastness. Our study shows that the 2-hydroxybenzophenone is not an efficient UV absorber for the three chosen reactive dyed cotton fabrics. Nevertheless, the 2,2-dihydroxy-4,4-imethoxybenzophenone seems to be more efficient than the 2-hydroxybenzophenone in the case of Reactive Blue dyed cotton yarn. The difference between the 2,2-dihydroxy-4,4-dimethoxybenzophenone

and the 2-hydroxybenzophenone activities may be explained by the differences in adsorption. The 2,2-dihydroxy-4,4-dimethoxybenzophenone presents a strong absorption in the near ultraviolet, attributed to a conjugate chelation between the ortho-hydroxy and the carbonyl group. The phenyl salicylate presents a very low absorption in the solar ultraviolet region. However, after a short exposure to sunlight, it shows an increase in absorption in the 290-400 nm regions, and after sufficient exposure, its spectrum resembles those of 2-hydroxybenzophenones.

The phenyl salicylate shows its effectiveness to a light-catalyzed rearrangement that converts it to 2-hydroxybenzophenone (Fig. 2b). Unfortunately, other products are also formed, and the conversion to effective stabilizers is only 50-70% efficient. Our study shows that the phenyl salicylate is inefficient in all the given cases. The poor light fastness of the three reactive dyes is established beyond question. Nevertheless, the use of some additives can improve this default of reactive dyes.

The UV light is an important cause in the fading of practically all dyes, in the weakening of fibres and fabrics, and in the photodegradation of many other substances. UV absorbers and antioxidant molecules have been applied to many substances and are found successful in many cases in neutralizing the destructive attack of UV light. However, many more studies on their application to fibres will be necessary before maximum effectiveness can be attained.

4 Conclusion

Fading rate curves for color difference measurements of C. I. Reactive Yellow 84, C. I. Reactive Red 22 and C. I. Reactive Blue 19 dyed samples show that fading increases progressively with time of light exposure. The application of UV

absorbers and antioxidants gives the colour change of the dyed samples in brighter and bluer direction. The most efficient additive for C.I. Reactive Yellow 84 and C.I. Reactive Red 22 dyes samples is vitamin C. For C.I. Reactive Blue 19 dyed samples, all the UV absorbers and antioxidants show a great improvement in the light fastness. The treatments on C.I. Reactive Yellow 84 and C.I. Reactive Blue 19 dyed samples show significant improvement in fading as compared to C.I. Reactive Red 22 dyed fabric. The effect of combined application of UV absorber and antioxidant on light fastness will be studied later.

References

- 1 *Physico-chemical Principle of Color Chemistry*, edited by N Kuramoto, A T Peter & H S Freeman (Blackie A&P, London), 1996.
- 2 Oakes J, *Rev Prog Color*, 31 (2001)21.
- 3 Egerton G S & Morgan A G, *J Soc Dyers Colour*, 89(1971)268.
- 4 Wilkinson F, Helman W P & Ross A B, *J Phys Chem Ref Data*, 22(1993)113.
- 5 Wilkinson F, Helman W P & Ross A B, *J Phys Chem Ref Data*, 24(1995)663.
- 6 Griffiths J & Hawkins C, *J Chem Soc Perk*, 2(1977)747.
- 7 Jansen L M G, Wilkes I P, Wilkinson F & Worrall D R, *J Photochem Photobiol Chem*, 125 (1999) 99.
- 8 Yamaguchi S & Sasaki Y, *J Photochem Photobiol Chem*, 142 (2001) 47.
- 9 Bandara J & Kiwi J, *New J Chem*, 23 (1999) 717.
- 10 Lappin G R, *Encyclopedia of Polymer Science and Technology*, Vol.14 (Interscience Publishers, New York), 1971, 125.
- 11 Woepfel L & Crews P, *Text Chem Color*, 22 (1990) 31.
- 12 Gordon Rose W, Walden M K & Moore J E, *Text Res J*, 31(1961)495.
- 13 Castera-Rossignol A & Bosque F, *Oleagineux Corps Gras Lipides*, 1(1994)131.
- 14 Daniela Cristea & Gerard Vilarem, *Dyes Pigm*, 70 (2006) 238.
- 15 Md.Samsul Alam, Arifuzzaman KhanG M, Abdur Razzaque S M, Jamil Hossain M & Minhaz-ul-Haque M, *Indian J Fibre Text Res*, 33 (2008) 58.