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Improving light fastness of natural dyes on cotton yarn

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Abstract

The objectives of this study were to evaluate the light fastness of selected natural dyes (madder, weld and woad) and the effect of some commonly used antioxidants and UV absorbers on the light fastness of these dyes.

The photofading rate curves of madder and weld fixed on cotton correspond to type II fading rate curves described by Giles. These results are in concordance with those of Cox-Crews. The woad presents a type III fading rate curve, similar to the indigo fading rate curve presented by Cox-Crews.

A poor light fastness of the three natural dyes in comparison with synthetic ones is established beyond question. Nevertheless, the use of some additives can improve this default of natural dyes. In all the cases, the use of UV absorbers or antioxidants improved the light fastness of dyed fabrics. The most effectives were the vitamin C and the gallic acid.

Keywords: Madder; Weld; Woad; Light fastness; Antioxidants; UV absorbers; Natural dyes

1. Introduction

Since prehistoric times, natural dyes have been used for many purposes such as the coloring of natural fibers wool, cotton and silk as well as fur and leather. The dyes were also used to color cosmetic products and to produce inks, watercolors and artist's paints.

The use of natural dyes to color textiles declined rapidly after the discovery of synthetic dyes in 1856, until they were virtually unused by 1900. Most natural dyes have poor to moderate light fastness, while synthetic dyes represent the full range of light fastness properties from poor to excellent. The first systematic tests of the light fastness of dyes were made by Dufay about 1730. The modern system for the light fastness testing was introduced by the Deutsche Echtheiskommission in 1914, who adopted the principle, now in use in many countries, of exposing the test pattern alongside a set of standard patterns of graded fastness.

The light fastness is influenced by internal factors: the chemical and the physical state of dye, the dye concentration, the nature of the fibers, the mordant type.

- *The chemical structure* of a dye molecule is divided in two parts: the main skeleton (chromophore) and the substituent groups (auxochromes). In general, the skeleton seems to determinate the average light fastness properties of a dye, while substituent groups usually alter the light fastness properties of a particular dye within a class in minor ways.

  The analysis of the natural dyes listed in Color Index revealed that almost 50% of all natural dyes used to color textiles are flavonoid compounds. Most of the remaining natural dyes fall within three chemical classes – anthraquinones, naphtoquinones and indigoids. Although flavonoid compounds are not very light fast, anthraquinones and indigoids are

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noted for their excellent light fastness. However, the light fastness of anthraquinones is decreased as the number of hydroxyl substituent groups is increased. Other aspects of chemical structure may affect the light fastness, such as the symmetry of the dye molecules: symmetrical dye molecules usually exhibit greater light fastness than non-symmetrical dye molecules, and larger dye molecules generally provide faster dyeing than smaller ones.

- *The physical state of dye* is generally more important than the chemical structure. The more finely dispersed the dye is within the fiber, the more rapidly it will fade. Fibers with large aggregates of dye are more light fast, since a smaller surface area of the dye is exposed to air and light.

A useful way of probing the interrelationship between the physical state of a dye within a fiber and its light fastness is by examination of fading rate curves. In 1965, Giles [1] described five types of fading rate curves which are typical of synthetic dyes (Fig. 1). Type I is a fading rate which decreases steadily with time, but rarely occurs in practice; the dye is probably molecularly dispersed throughout the fiber. Type II fading initially occurs at rapid rate followed by slower fading at a constant rate; dyes are present in aggregates inside the fiber substrate. Most synthetic dyes exhibit a type II fading rate curve. Type III is a fading rate curve characterized by a linear or constant rate of fading. This type of fading occurs most often with pigments and fast dyes that form larger aggregates inside the fibers. Type IV is a fading rate initially darken, followed by a slow fading rate. This type of fading occurs in a few fast dyes. Type V is a fading rate that steadily increases with time and is observed occasionally with azo dyes on cellulose; there is a continued breakdown of large dye particles to small dyes particles. Fading rate curves can be useful because they can give qualitative information about the physical state of dye within the fiber. They may also be useful in determining colorant formulation or dye concentration necessary to match faded materials. For these reasons, the fading rates of numerous synthetic dyes and some pigments have been studied. However, quantitative fading rate curves for most natural dyes have not been established. In 1987, Cox-Crews [2] studied the fading rate curves of some natural dyes, such as cochineal, fustic, madder, weld, turmeric and indigo. The fading rate curves were constructed from color difference measurements made using a tristimulus colorimeter. The 12 dye/mordant combinations evaluated in this study exhibited fading rate curves similar to either type II or type III described by Giles; type II: fustic (alum or tin mordant), madder (alum or tin mordant), turmeric (alum or tin mordant), weld (alum or tin mordant); type III: cochineal (alum or tin mordant), fustic (chrome mordant), indigo.

- The light fastness of a dyed fiber usually increases with increasing *dye concentration*, the main cause being an increase in average size of the submicroscopic particles which the dye forms in the fiber [1].
- Light fastness of dyes textiles is related to *the chemical structure and physical characteristics of the fiber* itself. Cumming et al. [3] attributed the fading on cellulose to an oxidative process, whereas on protein fibers the process has a reductive nature. Padfield and Landi [4] stated that indigo is much more light resistant on wool than on cotton; the reverse is true for madder. An oxidative pathway is involved in the fading of indigo dyed cotton. As fading on non-protein substrates is reductive, the indigoid chromophore which is resistant to photoreduction shows high fastness on wool [5].
- The fastness of a mordant dye depends on *the mordant and mordanting method*, because different metal dye complexes are formed, which may differ in their stability to light and also because the metal may have a positive or negative catalytic effect on the photochemical degradation of the dye [6].
  Cox-Crews [7], in a study on 18 yellow natural dyes, concluded that the mordant is more important than the dye itself in determining the light fastness of colored textiles. Use of tin and alum mordant results in significantly more fading than when chrome, iron or copper ones are used.

External factors such as the source and the intensity of illumination, the temperature and the humidity, the atmospheric pollution, can affect the reaction as well.

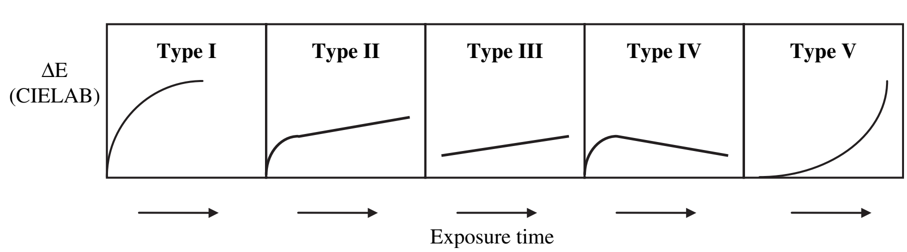

Fig. 1. Giles' diagrams of fading rate curves (percent change in concentration versus time).