Original article

Stability of natural dyes under light emitting diode lamps

Laura Degani a, Monica Gulmini a, Gabriele Piccablotto b, Paola Iacomussi c, Daniela Gastaldi d, Frederica Dal Bello d, Oscar Chiantore a

a Università degli Studi di Torino, Dipartimento di Chimica, via Giuria, 5, 10125 Torino, Italy
b Politecnico di Torino, Dipartimento Architettura e Design, Laboratorio LAMSA, corso M. D’Azeglio, 42, 10125 Torino, Italy
c Istituto Nazionale di Ricerca Metrologica, Strada delle Cocce, 91, 10135 Torino, Italy
d Università degli Studi di Torino, Dipartimento di biotecnologie molecolari e scienze per la salute, Via Nizza, 52, 10124 Torino, Italy

1. Introduction and research aims

Natural dyes are among the most fugitive materials and were used for decorative purposes in the past. The conservation and the display of historical and archaeological objects require particular attention if natural dyes are present. Lighting shall render the original colours of the displayed objects, and also must meet the conservation issues for photosensitive molecules. Several studies on the light sensitivity of natural dyes employed for colouring fabrics and yarns are available, and they highlighted that the stability of the natural dye is affected by a number of factors [1–6]. The chemical structure of the molecules that are responsible for the colour is an important intrinsic factor that influences light-fastness. Both the skeleton structures of the various chemical families of dyes and the position of auxochromic substituents determine the degradation pathway upon light exposure. External factors, such as temperature and humidity, can also affect the degradation reactions [2–5], although the energy distribution and the intensity of the illumination are the principal external factors that must be considered when displaying historical textiles [6–9].

In the last decade, the use of white light emitting diodes (LEDs) has largely increased, firstly because they are among the most energy-saving light sources, and also because of their negligible UV and infrared components in the emission spectra. White LEDs are therefore replacing fluorescence and incandescence lamps in many museums and art galleries, but only a few systematic studies on the effects of white LED emission on historical textiles dyed with natural dyes are available [10,11].

This work aims at evaluating the suitability of LED lighting for illuminating historical textiles in display cases. Both the colour changes (i.e. the variation of colour coordinates) and the modifications that occurred in the concentration of the various colouring molecules were determined on silk cloths dyed in the laboratory.

Samples were obtained by dyeing silk clothes with plants (or insects) selected among the materials that have been most widely used in the past for dyeing [12,13]. Two chemical families of dyes were considered: flavonoids (from weld, old fustic, logwood and brazilwood) and anthraquinones (from cochineal and madder). The samples, therefore, represent common situations that can be encountered when displaying ancient coloured textiles. Such textiles also allowed us to investigate the response of the different types of molecular structures under the LED lighting.

The following samples were considered for the investigation: yellow silk dyed with weld or old fustic; blue-violet silk dyed with logwood; red silk dyed with brazilwood, cochineal or madder.
The samples were exposed to three types of white LED lamps, with the same white light emission technology (i.e. blue LED with phosphor coating), but with different Correlated Colour Temperature (CCT). The provided light dose at the end of the experiment was equivalent to more than 1000 years under museum controlled lighting as requested by the Italian Cultural Heritage Preservation Act (50 klx h/year light dose) [14]. Such a high light dose was chosen for our experiments in order to amplify the fading, with the aim of enhancing the possibility of recording detectable differences among the three lamps when measuring the colour coordinates and of obtaining significant colour variations that would enable a direct comparison between colourimetric and chromatographic data. Samples dyed with weld, old fustic, cochineal and madder were in fact considered in order to determine the variation induced by the LED in the concentration of the colouring molecules. High-performance liquid chromatography coupled with photo-diode array and mass spectrometric detectors (HPLC–PDA–MS) was used to this aim. The dyes extracted from the fabrics were analysed at the beginning and at the end of the fading experiment.

2. Methods

2.1. Materials and instruments

Hydrochloric acid (HCl), methanol (MeOH), ethylenediaminetetraacetic acid disodium salt dihydrate (EDTA), aluminum potassium sulfate dodecahydrate (alum), formic acid (FA); dimethylformamide (DMFA), acetonitrile (CH3CN) alizarin, carminic acid, apigenin, luteolin, morin, kaempferol and purpurin were purchased from Sigma-Aldrich (Milano, Italy). Madder (Rubia tinctorum L. roots), cochineal (Dactylopius coccus Costa dried insects), weld (dried leaves and stems of Reseda luteola L.), old fustic (extract of Chlorophora tinctoria L.) and logwood (extract of Haematoxylum campechianum L.) were purchased from Kremer Pigmente (Aichstetten, Germany). Brazilwood (extract of Caesalpinia echinata Lamark) was purchased from Critt Horticole (Rochefort/Mer, France). The structures of the main colouring chemical species associated with the considered natural dyeing materials are shown in Fig. 1.

The illuminance levels in the fading experiment were checked by a Gigahertz-Optik P9710 class A luxmeter [15] and the reflectance spectra of the samples during the exposition to LED light were collected by an UV–Vis–NIR Perkin Elmer Lambda 900 double-beam spectrophotometer measuring the spectral reflectance of each sample as follows: measurement range ~ 250–2500 nm, 1 nm step, 8° of incidence and diffuse reflectance (8/d). As the samples showed a diffuse behaviour, the specular component was also included in the measurements. The CIE 2° standard observer and the equi-energy spectrum (illuminant E) were used for calculating the colourimetric data. An Ultimate 3000 Dionex HPLC instrument coupled with a PDA detector and a LTQ-Orbitrap analyzer (Thermo Scientific) was used for the target molecules. The separation (20 μL injected) was carried at 30 °C. The column (C18-bonded silica, 150 x 2.1 mm, 3 μm particle size by Phenomenex) was eluted at a flow rate of 0.2 mL/min with CH3CN (A), and 0.05% (v/v) FA (B) with gradient elution from 95% A, 5% B to 5% A, 95% B in 30 min. The mass spectrometer was run in positive and negative ion mode and data were processed with the Excalibur 2.0.7 Software.

For the Electrospray Ionization (ESI) source, the temperature was set at 275 °C, the ion spray voltage at +4.5 kV. For the

![Fig. 1. Structures of the molecules discussed in the text: a: Apigenin; R2 = OH. Luteolin; R2=OH; R3 = OH. Morin: R1 = OH; R2 = OH; R4 = OH. Kaempferol: R2 = OH; R4 = OH; b: carminic acid; c: Purpurin; R = OH; Alizarin: R = H; d: Munjistin; e: Brazilin: R = H; Haematoxylin: R = OH; f: Brazililein: R = H; Haematein: R = OH.](image)
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات