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Photochemical Colour Changes on Chestnut Wood Surface

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Abstract

The aim of this work is to study the surface colour and chemical modifications in chestnut wood samples as a consequence of irradiating in a controlled environment. The changes were investigated by reflectance spectrophotometry in a totally non-invasive modality, and further deepened by Fourier transform infrared spectroscopy and hyperspectral imaging, in order to obtain forecast models to describe the phenomenon. The statistical elaboration of the data allowed to validate the measurements and to obtain models enabling to relate the investigated parameters; the elaboration of the hyperspectral images by chemometric methods allowed to study the changes in the spectra. A result of great importance is the possibility to correlate the lignin alteration with the colour changes. This result is relevant in the field of cultural heritage and in general in the control processes of wooden materials.

Introduction

Colour measurement represents a widely diffused and consolidated method to evaluate the surface modifications in wood both in cultural heritage and material science. It is a rapid, economic, and above all non-invasive method to evaluate a surface treatment on a real object without the necessity to take samples. For this reason it was chosen as possible non-invasive method to study the surface modifications, due to photo-irradiation, on chestnut wood. The choice of chestnut (*Castanea sativa* Mill.) was due to its wide use in Central Italy especially for the construction of external doors. The colour data were statistically validated and correlated with those obtained by other spectroscopic techniques in order to gain a modelling of the changes [1]. The chestnut wood was never studied before according to the statistical and chemometric methodology presented in this work.

Materials & Methods

Flat wood samples (slice of 1 cm diameter) were obtained by a board of chestnut, cut in the heartwood. The radial surface was used for the measurements. The accelerated ageing of the samples was performed in a Model 1500E Solar Box equipped with a 2.5 kW xenon-arc lamp and an UV filter that cuts off the spectrum at 280 nm. The samples were exposed from 0 to 504 h at 550 W/m^2 and 55°C. Colour was measured using an X-Rite CA22 reflectance spectrophotometer according to CIELAB colour system. Infrared spectra were obtained using a Nicolet Avatar 360 Fourier transform spectrometer. Peak heights were measured to evaluate the chemical modification of wood constituent. The data were analyzed with the Statistica 2010 advanced statistics software. HyperSpectral Imaging (HSI) was carried out in the wavelength interval 1000-2500 nm (i.e. SWIR range), adopting a the SISUChema XL analytical unit, equipped with a 31 mm lens allowing the acquisition of wood samples with a resolution of 300 micron/pixel. The spectral resolution was 6.3 nm. Calibration was performed acquiring the images of certified black and white standards. Spectral data (i.e. hypercubes) analysis was carried out adopting standard chemometric methods [2, 3], by the PLS_Toolbox running inside Matlab. The spectra preprocessing was preliminary performed [1]. A 2nd order Detrend, Standard

Normal Variate (SNV) and Mean Centering preprocessing was applied. A Principal Component Analyses (PCA) was carried out to identify correlation existing among samples detected features, by classical analyses, and corresponding collected hyperspectral features. Finally a Partial Least-Squares Discriminant Analysis (PLS-DA) classification was applied.

Results & Conclusions

The study of colour changes in chestnut samples showed that greatest colour changes occur within the first 24 hours of exposure and that the irradiation causes the photo-degradation of lignin. FTIR spectroscopy allowed investigating the rate of photo-degradation of wood surface due to lignin oxidation. The rate of photo-degradation was investigated by studying the lignin/carbohydrate intensity ratio (I_{1507}/I_{1377}) as function of time [1]. The results highlighted that this ratio decreased to about 50% of its original value after 168 hours of exposure. The statistical elaboration of the experimental data allowed to validate the measurements and to obtain models enabling to relate the exposure time with the colour changes, the exposure time with the photo-degradation of lignin, and the colour variations with the photo-degradation of lignin. An important result was that the colour changes, expressed as L*, a*, b* coordinate variations, can be correlated to the photo-degradation of lignin obtained by FTIR analysis. In fact, the regression analysis gave a second degree equation (R^2adj.=0.609) whose coefficients have an high statistical significance ($p<0.01$).

Hyperspectral analysis allowed to identify the different samples characteristics according to the different irradiation times and the corresponding samples photo-degradation. The potentialities of the methods are well evidenced analyzing the results outlined in Fig. 1 and Fig. 2, where PC1-PC2-PC3 score plot and wood samples classification, according to irradiation time, are reported, respectively.

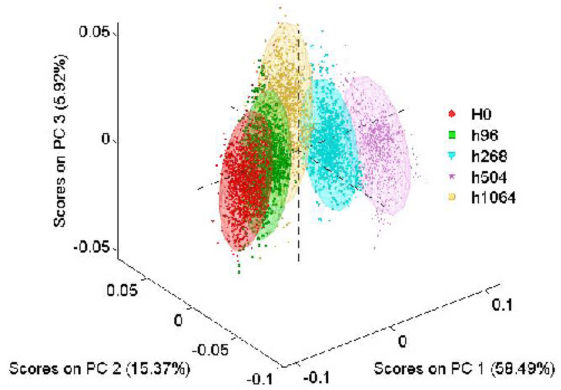

Fig.1. PC1-PC2-PC3 score plot of the wood sample subjected to a different irradiation time (H0: not irradited samples and h96, h268, h504 and h1064 samples irradiated for 96, 268, 504 and 1064 hours, respectively).

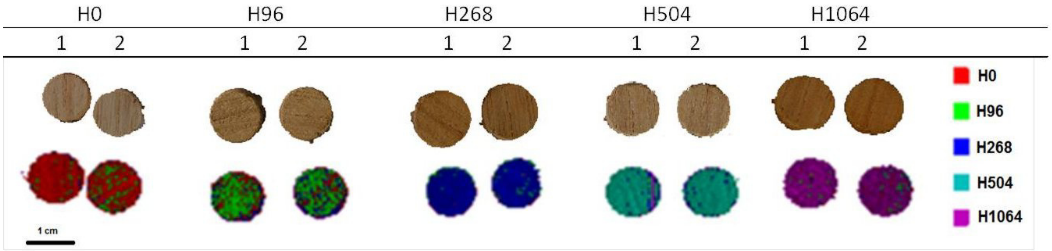

Fig.2. Class prediction membership as resulting from the application of Partial Least-Squares Discriminant Analysis (PLS-DA) classification to the different irradiated samples.

References

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