INTRODUCTION

The use of wood outdoor is widespread in various applications from ancient times. Nowadays, untreated wooden surfaces are frequently utilized as cladding in modern buildings. To ensure optimal choices of wood species, and increasing demand for a better understanding of the deterioration mechanisms of wood during the outdoor exposure is necessary. Wood subjected to weathering is degraded by various environmental agents such as solar radiation, cyclic wetting, atmospheric temperature and relative humidity changes, environmental pollutants and certain micro-organisms. The characteristic grey patina visible after few months of exposures is mostly caused by photodegradation of lignin in middle lamella by UV radiation\(^1\). The elements of facades made of wooden often present a non-uniform degradation patterns such as shown in Fig. 1. Various architectonical solutions and different degradation of wood species are the main reasons for heterogeneous appearance.

Near infrared spectroscopy and hyperspectral imaging are perfect scientific tools for rapid and non-destructive characterization of wood surfaces\(^2,3,4\). The great advantage of both techniques is the possibility of determining both chemical and physical properties of a large number of samples.

The goal of this work was to assess the degradation of weathering and to model its kinetics on the base of thin wood samples exposed outdoors by means of NIR hyperspectral imaging. The work is part of the pan-European Round Robin experiment established within the COST Action FP1006.

KEYWORDS: hyperspectral imaging, transmission, wood weathering, degradation kinetic

ABSTRACT

Untreated wooden surfaces degrade when exposed to varying doses of natural weathering. In this study thin wood samples were exposed outdoors for time intervals from 0 to 28 days. The collected samples were then imaged with hyperspectral camera in NIR wavelengths in transmission mode to study degradation effects. Spectra of earlywood and latewood were extracted from the hyperspectral images using a PCA based masking algorithm. The degradation were modelled with a rating determined from a PLS regression model of the spectra. A PLS prediction of $R^2 = 0.798$ was obtained using solar radiation as response value when half of the data set was used for calibration and the other half as independent test set. The results from the study is a first step towards a weather dose model determined by temperature and moisture content on the wooden surface in addition to the solar radiation.

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MATERIALS AND METHODS

Experimental samples were prepared from one piece of Norway spruce wood (Picea abies) on a slicing planner (Marunaka) to a thickness of ~100µm, and a surface of 30mm x 35mm. Sets of 12 samples were exposed outdoors at 18 different locations with identical setup. One sample was collected from the set after 0, 1, 2, 4, 7, 9, 11, 14, 17, 21, 24 and 28 days of weathering. Hyperspectral images in NIR wavelengths (1000 – 2500 nm) were obtained from the samples with a linescan camera (Specim, SWIR). The hyperspectral image acquisition was carried out in transmission mode using a custom setup; backside illumination with halogen lamps below a semi opaque glass plate, and another transparent glass plate transmitting NIR radiation above the samples. A set of samples and the hyperspectral imaging setup for transmission mode is shown in Fig. 2.

The images were analysed to study the evolution of earlywood and latewood as a function of weather degradation doses by using PLS regression techniques and PLS-DA classification. MATLAB (Mathworks) and PLS Toolbox (Eigenvector) were used as software platforms.

Results and Discussion

Spectra corresponding to the earlywood and latewood zones of samples at varying degradation stages were extracted from hyperspectral images using a PCA based masking procedure. Changes in the spectra were assessed separately (for early- and latewood) due to significant differences to the morphological, chemical and physical structures of these woody constituents.

The deterioration progress due to weathering was modelled by means of a custom algorithm based on PLS and considering mean spectra from early- and latewood for each sample. The PLS model has been established for two extreme samples exposed for 0 and 28 days. The reference values of the degradation index were 0 and 1000 respectively. The model was then applied to predict the degradation indexes for all the other mean spectra. It was expected that the degradation progress was be strongly related to UV radiation. Therefore, a separate PLS model was also performed with the cumulated direct solar radiation on the model predictor. The differences in solar radiation as noticed in San Michele (Italy) in the four directions (North, East, South and West) are shown in Fig. 4. The amount of solar radiation on a wooden surface in these directions was simulated.
using the technique described in 5. The PLS regression results for modeling the solar radiation on the base of earlywood spectra of 48 samples collected from that location are summarized in Fig. 4. Spectra from half of the samples were used to calibrate the model and the other half was used as independent test set to model validation. Determination coefficients $R^2 = 0.969$ and $R^2 = 0.798$ were obtained on the calibration and validation data sets respectively. It was concluded that the degradation is clearly correlated to the solar radiation, however, a total weather dose including temperature and moisture on the surface should also be taken into account in order to improve the model. It was in agreement with the state-of-the-art knowledge assuming that kinetics of wood weathering depends on UV radiation but also on the moisture and temperature conditions.  

![Figure 4.](image)

**CONCLUSION**

NIR hyperspectral imaging in transmission mode was successfully applied to analyse the short term weathering process of very thin samples of wood. The hyperspectral imaging allowed us to segment spectra of earlywood and latewood which makes it possible to model the weathering kinetics independently for both constituents. The results presented will be utilized together with other complementary multi-sensory measurements within the Round Robin experiment to develop a weather-dose model of the degradation of the wooden surfaces. Such models will be used to simulate the future performance wooden surfaces exposed to varying doses of natural weathering.

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**References**