Identification of The Juvenile Wood in Sawn Wood Products by NIR Spectroscopy and Chemometrics

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ABSTRACT

The early detection of wood quality by using non-destructive methods is a research area under continuous exploration and of a great interest for the forest sector. The aim of the study was to develop a rapid and simple method for the detection of juvenile wood present in the radial and transversal sections of the raw material used to manufacture wood products (window frames). Two near-infrared (NIR) instruments (laboratory and portable) were used for the purpose of this research. Experimental samples included industrially manufactured window profiles, including juvenile and adult wood. In total, 1860 spectra were collected with both instruments on radial and cross sections in a conditioned environment (65% RH and 20 °C). The preliminary results show that it was possible to develop robust chemometric models on the basis of NIR spectra associated with chemometric analysis. Detection of juvenile and adult wood by NIR measurement might therefore support quality sorting of sawn wood products.

INTRODUCTION

Natural wood variability is a great technical challenge for wood processing industries. One of the most important quality features is the presence of juvenile wood, which should be minimal in a high-quality product, such as window frames. Juvenile wood is a tissue present in the inner part of the trunk near the pith, corresponding to the bulk of the tree that was rapidly rising along with tree life. Juvenile wood characteristics undergo progressive changes in successively older growth rings, until finally becoming adult wood. Juvenile wood has a cellular structure with lower tracheid length, lower density, lower stiffness and cellulose/lignin ratio, higher spiral grain and microfibril angle, and, usually, wider yearly rings (Ruano Sastre et al. 2016). Above mentioned characteristics have deep negative effects on physical-mechanical and technological properties of the material. To ensure proper quality, it is necessary to identify and quantify the presence of juvenile wood. However, the current procedure used for that purpose relies mainly on visual verification. This fact makes necessary the development of an alternative procedure capable of identifying the presence of juvenile wood with higher accuracy and by quick and easy measurements. Some studies have been conducted to determine the boundaries between juvenile and adult wood using specific gravity in combination with mathematical regressions or discriminant analysis, measuring the differences in the cellulose microfibril angles or using X-ray based methods to create density profiles with good accuracy (Alteyrac et al. 2006). However, these methods require long and careful sample preparation and are not applicable *in situ*.

METHODS AND MATERIALS

Materials: Sets of glued wood joints composed of three different boards of Scots pine (*Pinus sylvestris* L) were randomly selected for the NIR measurements. The radial and transversal surfaces of each piece were sanded before measurements and kept conditioned at 20 °C and 65% RH in a dark room before and during the measurements. Zones of the juvenile, adult, as well as reaction and heartwood were identified, marked, and measured by both instruments. Spectra were collected on cross and radial sections. In total, 1500 spectra were collected with microNIR and 360 with FT-NIR instrument.

Spectroscopy: Near-infrared spectra were collected using two different instruments: laboratory and portable. A Vector N-22 Fourier-transform NIR spectrometer, produced by Bruker Optics GmbH (Ettlingen, Germany), was equipped with a fibre optic probe and operated in the measurement range between 12000 cm^{-1} to 4000 cm^{-1} (833 to 2500 nm). The spectral wavenumber interval was 3.85 cm^{-1} with zero-filling equal to 2. The spectral resolution was 8 cm^{-1} and 32 internal scans were averaged at each spectrum. A Portable MicroNIR Pro 1700 spectrometer by VIAVI Solutions Inc. (Santa Barbara, USA), integrated with a tungsten lighting lamp and 128-pixel InGaAs photodiode array detector, was used as an alternative instrument. Spectra were acquired with a scanning frequency of 80 Hz, allowing 12.5 ms of the integration time. The effective spectral range covered by the senor was 950-1650nm (10526 – 6060 cm^{-1}).

Analysis: The data analysis from both instruments was carried out with PLS Toolbox software (Eigenvector Research, Inc.). The pre-treatments applied were normalization (Normalization, SNV), filtering (EMSC, derivatives (Savitzky-Golay 1st and 2nd derivative)), scaling (Mean Centre), and removal of some wavelength regions. Then different analyses were performed in order to obtain the most suitable model for our goal. The classification was done by PLS-DA, SVM, KNN, and SIMCA methods.

RESULTS

SNV as pre-processing with Support Vector Machine (SWM) was identified as the optimal combination that provides the highest discrimination between juvenile and adult wood. The juvenile-adult wood classification success obtained from FT-NIR and MicroNIR using these chemometric models were 83% and 92.7%, respectively. The independent validation set included spectra collected from diverse wood samples that were used for calibration.

A high accuracy of juvenile wood (100%) and adult wood (81.3%) discrimination was observed when extending models with spectra of reaction and heartwood. In that case, the reaction wood was discriminated with 100% success, while only 45.5% of the heartwood spectra were correctly identified. Even with that, the preliminary results prove a high feasibility for NIR spectroscopy in the discrimination of juvenile and adult wood. The ongoing research is to implement laboratory methodology for *in-situ* measurements and allow automatic wood quality assessment in the industrial environment.

CONCLUSIONS

The use of a portable NIR spectrometer for discrimination of juvenile and adult wood is a promising alternative for fast evaluation of wood quality. SWM classification algorithm provides satisfactory results for the discrimination of both wood types; however, the model developed has to be extensively validated to deal with other sources of wood variability as related to the provenance, defect presence, or drying history.

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