Non-destructive spectroscopic methods for the assessment of the natural durability

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The objective of this work was to seek spectroscopic methods for the evaluation of the natural durability (wood decay tests according to EN 350-1 and EN 113 standards), of four species technically and economically important. Sampling was carried out while trying to favour the variability of heartwood natural durability within each species. Two spectral zones were studied: the visible and the near infrared domain. Colour measurements were performed on dried wood sample with a Microflash data color spectrophotometer. FT-NIR spectra were recorded on a BRUKER FT-IR spectrometer (Vector 22/NI). Partial Least Squares (PLS) regression models were established and validated by cross- and test set validation.

Standardised test samples coming from various parts of oak after exposure to *Coriolus versicolor* during 16 weeks.

Prediction for Douglas

The test results of the natural durability tests for Douglas prove that this species can be classified as not very durable according to the European classification (EN 350-1). The correlations obtained by using the colorimetric components do not make it possible to predict in a reliable way the mass loss due to fungi attack. On the other hand, near infra-red spectroscopy (NIRS) makes it possible to develop exploitable calibrations to discriminate the performances (Table 1 and Figure 1). However they must be improved in order to develop robust predictive models. A set of complementary samples taken on different ecological and genetic criteria would probably result in extending the scattering of mass loss values and thus in improving the quality of the predictive models. In addition, the acquisition technique of the spectra must be improved as well as the effect of the density which could have an impact on the natural durability which is not completely taken into account in the spectral information.

Species	Fungi	Total number samples	Number of calibration samples	Mean	SD	R^2	RMSECV	SEL	SEP	SD/SEP	Rank	Spectral data Pre-processing
Teak	CP	101	94	0.11	0.21	**0.25**	0.18	0.26	-	-	3	multiplicative scatter correction
	CV	101	91	1.25	0.58	**0.66**	0.34	0.51	0.27	**2.15**	6	vector normalization (VN)
Chesnut	CP	128	119	1.77	1.04	**0.54**	0.70	1.01	0.59	**1.76**	8	First derivative + VN
	CV	128	98	1.46	0.29	**0.34**	0.24	0.34	-	-	4	First derivative + VN
Douglas fir	CP	117	105	27.56	4.74	**0.63**	2.89	1.94	1.65	**2.88**	2	multiplicative scatter correction
	PP	117	107	17.68	2.83	**0.32**	2.31	1.65	-	-	7	vector normalization (VN)
Oak	CP	80	70	3.01	6.31	**0.75**	3.16	1.75			8	First derivative + VN
	CV	80	66	7.19	10.6	**0.95**	2.35	2.07	3.01	**3.50**	7	First derivative + VN

Fungi: CV: *Coriolus versicolor*; CP: *Coniophora puteana*; PP: *Poria placenta (only for softwood)*
Mean: Mean **mass loss** for the set of calibration
SD: Standard error for the set of calibration
R^2: Determination coefficient from **cross-validation**
RMSECV: Root Mean Square Error of Cross Validation
SEL: Standard Error of Laboratory
SEP: Standard Error of Prediction
Rank: Number of model factors

Table 1. Best calibrations from Partial Least Squares (PLS) regression models for the mass loss results.

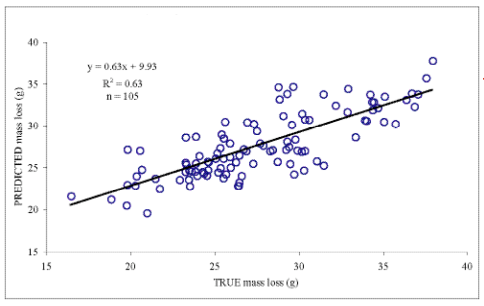

Figure 1. Relationship between the actual x-values obtained from wood decay tests on Douglas and the y-values predicted by NIRS in the cross-validation step (*Coniophora puteana*, LR plane).

Prediction for Teak and Chestnut

For very durable species such as Teak or the chestnut (Table 1), it is possible to obtain by NIRS discriminating predictive models from the mass loss obtained by the standardised test of natural durability (Figure 2 and 3).

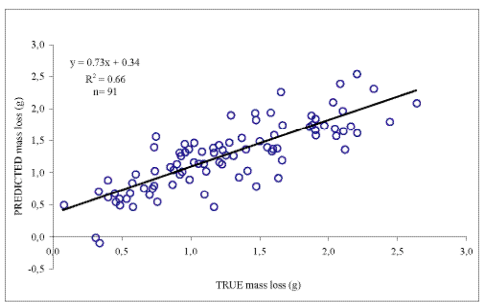

Figure 2. Relationship between the actual x-values obtained from wood decay tests on Teak and the y-values predicted by NIRS in the cross-validation step (*Coriolus versicolor*, LR plane).

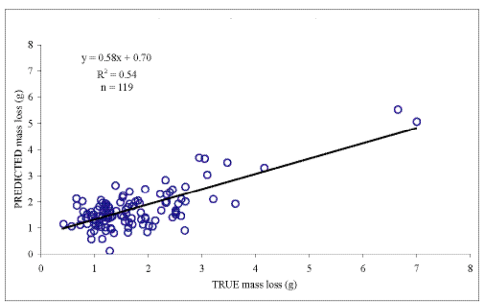

Figure 3. Relationship between the actual x-values obtained from wood decay tests on Chestnut and the y-values predicted by NIRS in the cross-validation step (*Coniophora puteana*, LR plane).

The possibility of obtaining exploitable calibrations is thus shown; however the current procedure of test leads to very weak fungi attacks. The latter have unfavourable consequence on the error of measurement and a relatively narrow range over the actual values which generate a very poor capacity of discrimination. The use of the colorimetric components does not make it possible to develop exploitable predictive models. For these two species, widening the variability of the natural durability within the set of calibration is essential by a judicious choice of the samples.

Prediction for Oak

The oak constitutes a particular case in the study since samples containing sapwood were knowingly used. It is advisable however to note that certain trees have a natural durability definitely lower (one in our batch). This choice contributed to develop particularly powerful calibrations (Figure 4). They prove that it is possible to obtain predictions of natural durability completely exploitable if a judicious choice of samples for the set of calibration is carried out. This artifice cannot replace a set of calibration only made up of samples from heartwood and covering a wide range of variability.

The colorimetric components do not make it possible to establish an exploitable prediction.

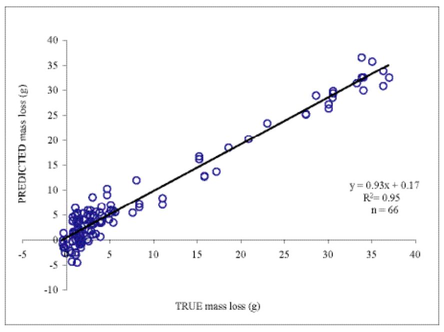

Figure 4. Relationship between the actual x-values obtained from wood decay tests on Oak and the y-values predicted by NIRS in the cross-validation step (*Coriolus versicolor*, LR plane).

Conclusion

In all the cases, the colorimetric method does not constitute a relevant approach for the indirect evaluation of natural durability. The reasons are multiple but are more particularly dependent on the low penetration depth of the visible radiation and its physical origin (electronic transitions) which is sensitive to the history of the wood (for example moisture content or ageing).

NIRS appears to be the technique the most adapted to the indirect evaluation of natural durability for theoretical and practical reasons. NIR spectrometers tend to be widespread in industry which involves a price reduction of the equipment. The industrial request for measurements in real time increases, including the best accuracy possible and long-term stability under the industrial conditions. This implies that the robustness of the system of measurement is the principal criterion in the development of each method. The application of NIRS is largely widespread in the field of quality control, particularly in the food industry. It allows the qualitative and quantitative study of various types of products starting from the spectral information combined with the multivariate models of calibration. This technique improves the performances of quality control of the product, by reducing the time and the production cost. Many portable NIRS spectrometers are available for the industrial use at a relatively low cost.

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