Hyperspectral imaging analysis of Scots pine wood affected by decay fungi

Arnoud Jochemsen[1,3], Gry Alfredsen[2], Sigrun Kolstad[2], Boyan Yuan[3], Nabil Belbachir[3], Ingunn Burud[1]

[1]Norwegian University of Life Sciences, Department of Science and Technology, Ås, Norway.
[2]Norwegian Institute of Bioeconomy Research, Department of Wood Technology, Ås, Norway.
[3]NORCE Norwegian Research Centre, Department of Technology, Grimstad, Norway.

SUMMARY

Results are shown for early stage research in hyperspectral image analysis of Scots pine wood affected by decay fungi. Three experiments are described:

1. An experiment with a PCA of four images with brown rot mycelium on top of decayed Scots pine wood samples.
2. An experiment in which PLS regression is used to correlate the mass loss in Scots pine due to brown rot decay with the hyperspectral images of the cleaned and dried samples. Three PLS methods are compared.
3. Description of an ongoing time-series experiment, in which two types of decay fungi are analyzed at different stages of decay.

SCOPE OF RESEARCH

To increase the service life of wooden utility poles, the poles are treated with wood preservatives. The main challenge for wooden utility poles in service is failure due to fungal decay ('rot').

The traditional method for inspecting wooden utility poles is manual inspection, where the soil is removed at the base of the pole and a hammer and/or a drill is used to access the level of fungal deterioration. More modern methods can measure non-destructively using acoustic or radio waves but do require direct contact with the pole.

The objective of the research is to find a way to quantify the presence of rot in wooden utility poles by using hyperspectral remote sensing.

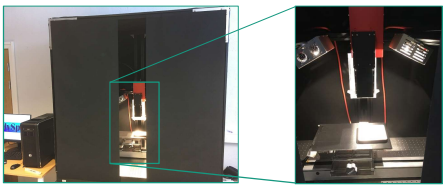
WOOD DECAYING FUNGI

	BROWN ROT	WHITE ROT	SOFT ROT
Type of decay	Basidiomycetes	Basidiomycetes	Various
Degradation	cellulose hemicellulose	cellulose hemicellulose lignin	cellulose hemicellulose lignin
Degradation speed	fastest	fast	slow
Presence on pole	inside	inside	surface

HYPERSPECTAL SETUP

The hyperspectral lab at NMBU in Ås, Norway has several hyperspectral cameras. The hyperspectral camera used in the experiments is the HySpex SWIR-384 of Norsk Elektro Optikk.

Wavelength range	930 - 2500 nm
Spatial pixels	384
Spectral channels	288
Spectral sampling	5.45 nm
FOV	15.88 deg
Lens	30 cm
Pixel size	~0.25 mm



Pre-processing of the image data is performed by the processing steps: radiometric correction, reflectance, absorbance and MSC. The wood sample absorbances (Experiment 1), or the mean spectra of them (Experiment 2), are used in the data analyses.

RESEARCH PARTNERS

NIBIO NORCE agder energi

EXPERIMENT 1 – BROWN ROT MYCELIUM

- Small experiment with two samples with *Coniophora puteana* (a brown rot) after eight weeks of decay. Hyperspectral imaging of the samples with the mycelium still present on the wood samples.
- Four images of the brown rot affected samples and four images of reference samples.
- Computation of Principal Component Analysis (PCA) on the pixels of all eight images.
- Conclusions for the brown rot affected samples:
  - The samples have generally higher absorbance and specifically for the moisture bands around 1450 and 1930 nm.
  - PC1 describes the wood and PC2 describes the mycelium.
  - Further analyses are needed, with more samples and more advanced data analysis methods, e.g. SIMCA, PLS-DA.

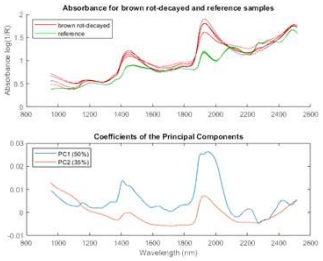


Figure 1: (Up) The absorbance spectra of the four brown rot-decayed samples and the reference samples; (Down) the coefficients of the first two principal components of the images, that together explain around 85% of the variance in the image pixels. The effects of the lowest and highest bands (around 1000 and 2500 nm) is to be investigated.

Figure 2: Two brown rot affected samples after the image acquisitions.

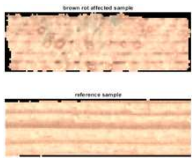


Figure 3: A brown rot affected and a reference sample in SWIR RGB. The pixels represent radiances.

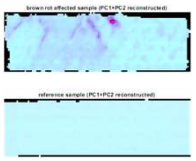


Figure 4: The same samples of Fig 3 in the PC1+PC2 reconstructed RGB. The pixels represent MSC corrected absorbances.

EXPERIMENT 2 – MASS LOSS DUE TO BROWN ROT DECAY

- Small experiment with *Rhodonia placenta* (a brown rot) on Scots pine sapwood.
- 27 samples with decay at different temperatures (21, 23.5, 30 °C) and durations (6, 8 and 10 weeks). The mass loss is in the range from 5.4% to 60.8%. See Figure 1.
- PLS regression using X = average spectra of the samples and y = mass loss. Three methods are compared in Figure 3:
  - SIMPLS, by DeJong (1993);
  - Modified kernel algorithm #2, by Dayal and MacGregor (1997);
  - Bidiag2, by Bjorck and Indahl (2016).
- Preliminary conclusions of the analysis:
  - The resulting PLS model can predict well the mass loss due brown rot decay from the average sample spectrum (R^2_{cal} = 0.981, R^2_{val} = 0.903). See Figure 2.
  - The spectral peaks found in the major PLS model component (Figure 5) deserve further analysis. Recorded physical (surface) effects need to be isolated and removed to be able to analyze the chemical changes to the wood sample.
  - The SIMPLS method is the better PLS method if the minimization of the validation residuals is the measure for model performance. See Figure 3.

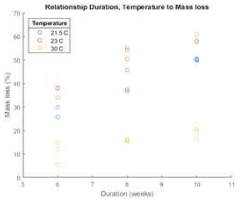


Figure 1: Shows how experiment duration and temperature affect how much mass of the wood samples is consumed by the brown rot.

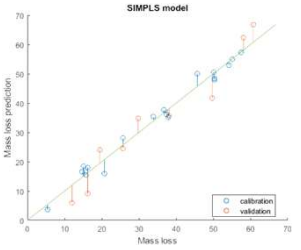


Figure 2: The true mass loss and the mass loss predicted by the SIMPLS model, for the observations in the calibration set (18 observations) and the validation set (9 observations).

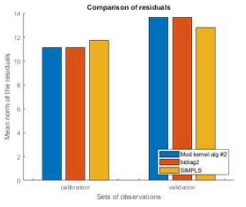


Figure 3: The mean value of the residuals for 100k models with random selections of calibration and validation observation sets.

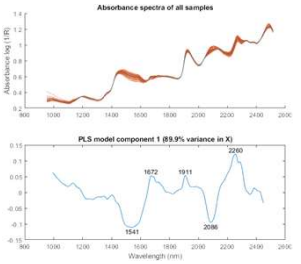


Figure 5: The absorbance spectra of the 27 samples (up) and the first PLS model component (down).

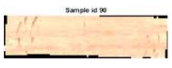


Figure 4: A SWIR RGB image of a wood sample with ~50% mass loss.

EXPERIMENT 3 – TIME SERIES (ONGOING)

- Petri-dishes with Scots pine sapwood (*Pinus sylvestris L.*) samples on a malt agar medium.
- Infected with two types of decay fungi, a brown rot (*Rhodonia placenta Fr.*) and a white rot (*Trametes versicolor L.*).
- The wood samples are scanned at different stages of rot progression to create a time series of the effect of the wood-decay for a period of up to sixteen weeks.
- The primary variables to be monitored in this experiment are wood sample weight and spectra before and after fungal decay.

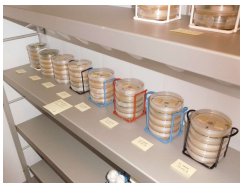


Figure 1: The dishes with wood samples in the climate room at NIBIO at the start of the experiment.

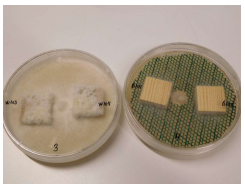


Figure 2: Two petri dishes with each two samples of Scots pine sapwood after two weeks; the left one with Trametes versicolor and the right one with Rhodonia placenta.

This work is supported by the project RIWUP, running under Research Council of Norway grant agreement nr 281018 and co-funded by both RCN and Nettpartner. (www.remote-inspection.info)

Norwegian University of Life Sciences

The Research Council of Norway Nettpartner