Utilization of woody biomass and residues for production of energy products and high-value natural compounds

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ABSTRACT

This project addresses basic research challenges in the different steps of biomass treatment and use to provide a validated basis for developing a lignocellulosic woody biomass biorefinery that is suitable for the conditions specific to Western Norway. This is a strategic and interdisciplinary PhD project within the UiB priority research area Climate and Energy Transition. The project constitutes a collaboration between the departments of Chemistry and Biosciences.

Figure 1: Coastal forest in Nordhordaland

Biomass is developing as the primary renewable source of organic carbon compounds to replace petroleum-based products in a future circular economy. Biomass can be converted to liquid fuels, and into bulk and fine chemicals to replace products that at present are produced form fossil carbon sources. However, even with a great potential for future sustainable use, the economics of production and refining at present is a barrier for the development of biomass use in the overall economy. Thus, research is needed to provide economically viable and sustainable biomass valorization concepts.
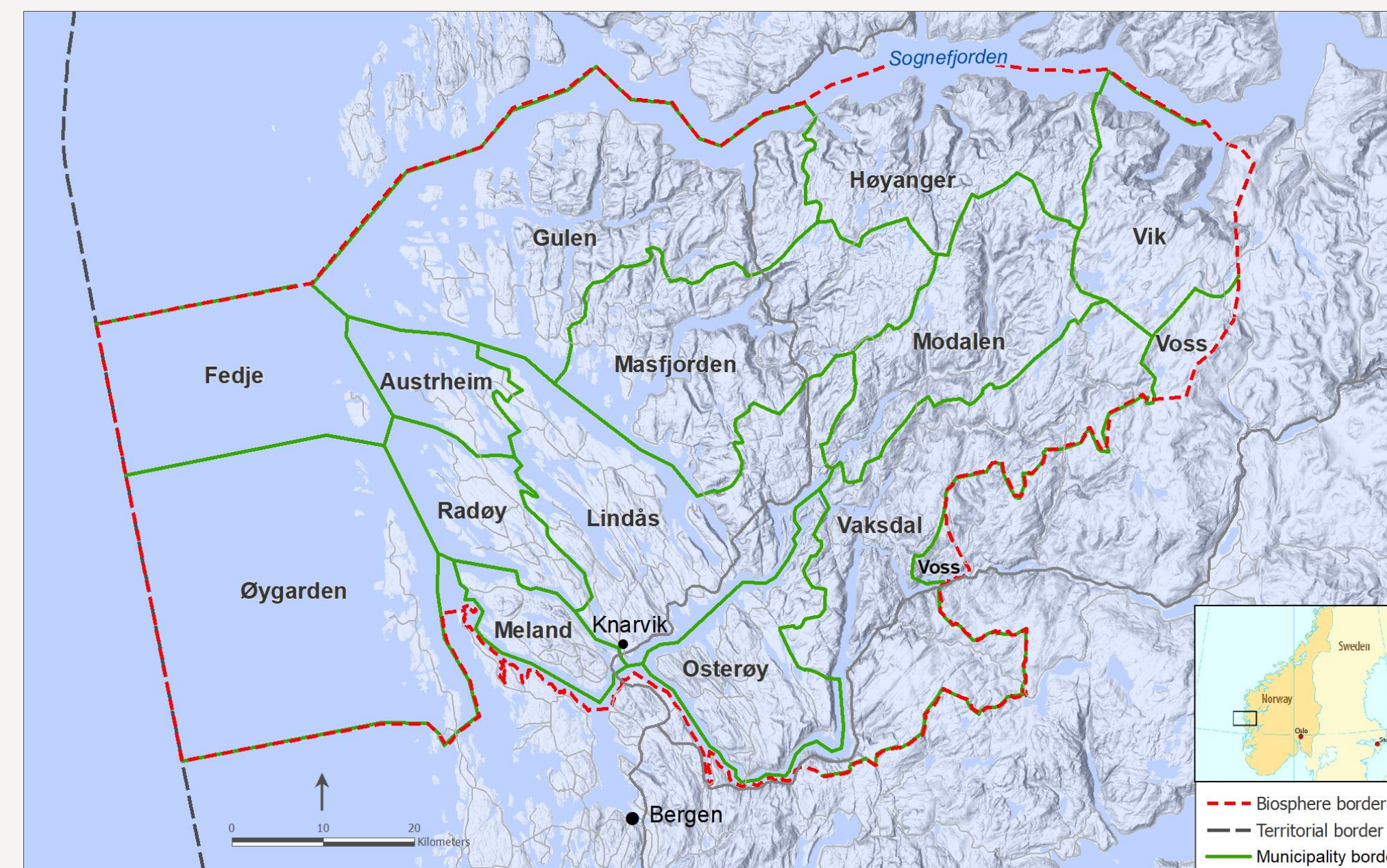
Figure 2: Map of the Nordhordaland Biosphere Reserve

Nordhordaland is part of the UNESCO biosphere program and has been defined as a biosphere reserve.[1] Within Nordhordaland there are a lot of forestry, particularly of Sitka spruce. Biosphere reserves are sites for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity. They include terrestrial, marine and coastal ecosystems. Each site promotes solutions reconciling the conservation of biodiversity with its sustainable use.

Figure 3: Coarsly ground samples of heartwood, bark, needles and twigs.

One of the challenges concerning lignocellulosic biomass lies in its heterogenous nature. The chemical compositions may vary according to species, location, harvest season and botanic fractions. Therefore, it is crucial to assess the composition prior to any biofuel conversion method. The conventional assessment procedure of lignocellulosic biomass includes decomposing the sample, which is time consuming, labor-intensive, expensive and destroys the sample. Vibrational spectroscopy has proven effective to predict the composition of lignocellulosic biomass based on a calibration set.[2][3].
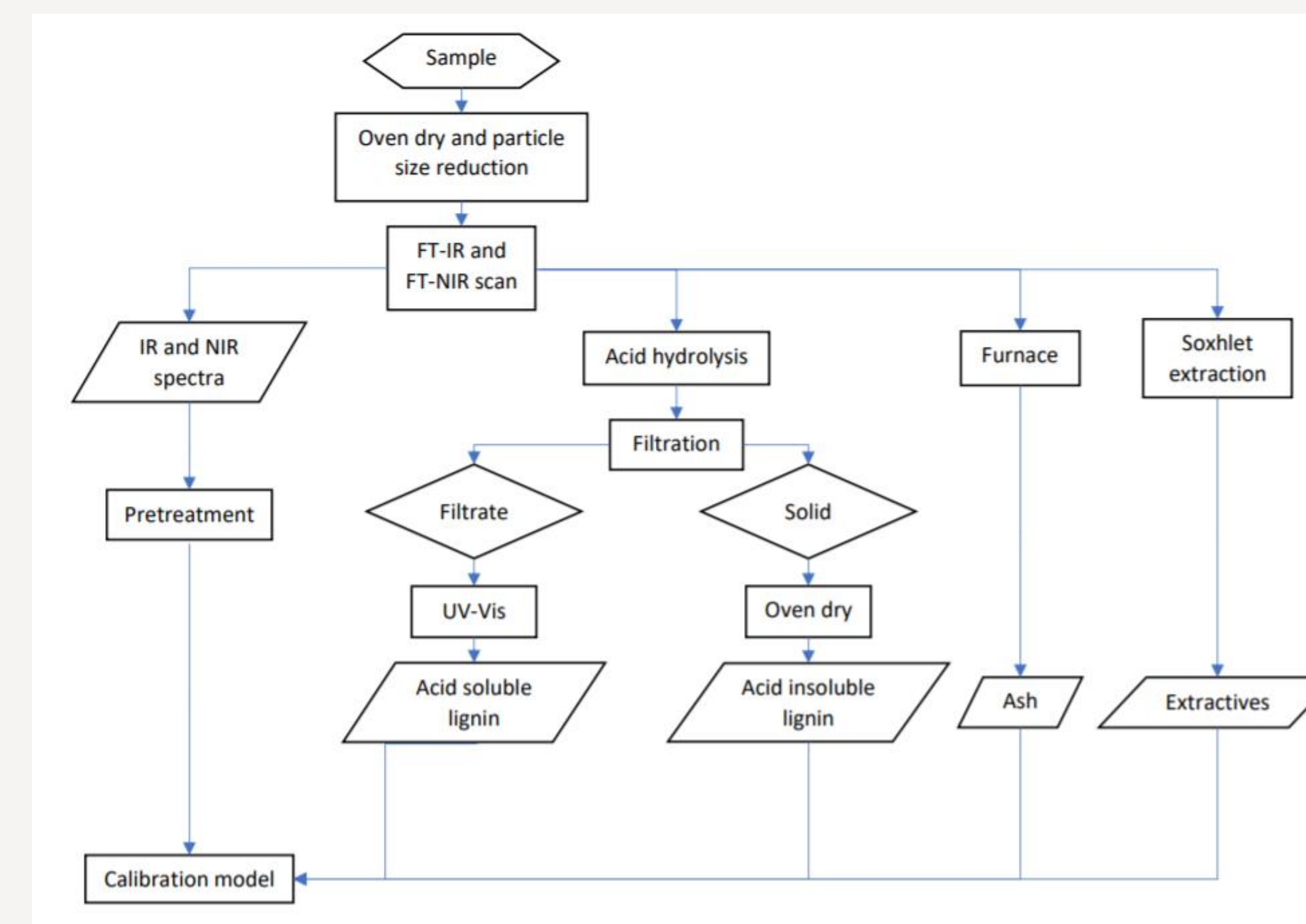
Figure 4: Flowchart of the preperation procedre

Results: Chemical degradation of the samples shows that the biggest variation in the chemical composition lies between fractions more than tree species. Principal Component Analysis (PCA) for the IR and NIR spectra made the fractions highly distinguishable, and no particular groupings for tree species. Partial Least Squares (PLS) calibration models for prediction of lignin based on IR and NIR spectra give reasonable results. The root mean square error of cross validation (RMSECV) of the calibration using IR and NIR spectra are 7,60 w/w% and 6,42 w/w% respectively, giving NIR a slight edge.
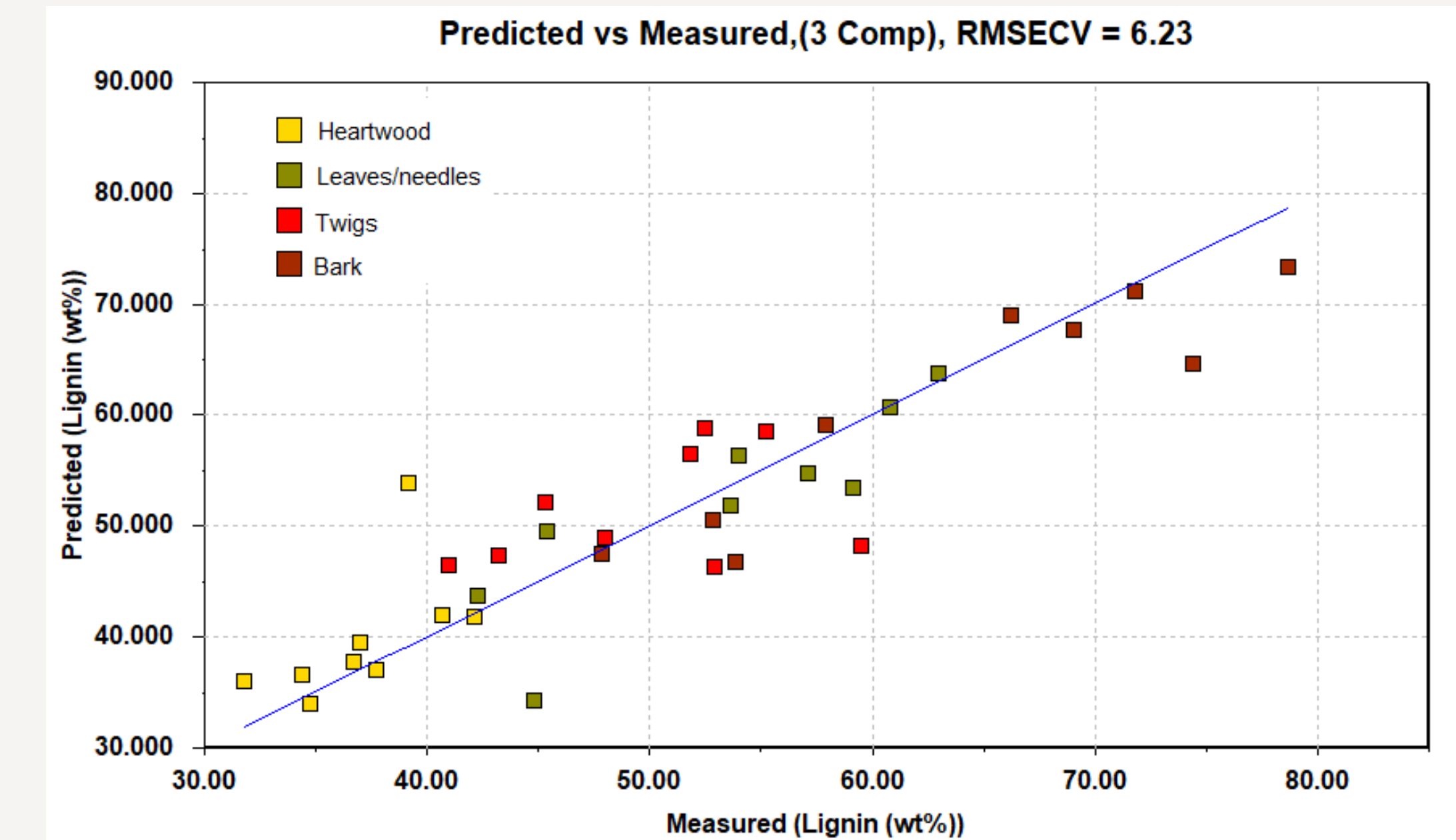
Predicted vs Measured,(3 Comp), RMSECV = 6.23

Figure 5: Predicted value plotted against measured value of lignin content for NIR spectra based on PLS regression.

Discussion: Particle size shows to have great impact of results regarding the chemical degradation and IR/NIR spectra. Particles sized too big and too small yields a higher content of lignin, which is not accurate. Particle sizes too big will also make the samples heterogenous, making the spectra vary for the same sample. A calibration model will show higher accuracy the more samples included. 36 samples may not be sufficient foundation for an accurate model, but for the purpose of comparing spectroscopic techniques it is acceptable.

Conclusion: Both calibration models based on IR and NIR spectra to predict the chemical composition of lignocellulosic biomass samples proves to be very promising for prediction of biomass composition. The calibration model based on NIR holds a slight edge in predictive power with a lower RMSECV of 6,42 w/w%. This may be the consequence of a larger surface area on the NIR-probe but needs to be studied further.

REFERENCES
1. Nordhordaland biosphere reserve. http://www.nordhordlandbiosphere.no/kva-er-eitbiosfaereomraade.353323.nn.html (accessed 17.02.20).
2. Templeton, David W. et al. Assessing corn stover composition and sources of variability via NIRS, (2009) CELLULOSE, 16 4 621-639
3. Liu L, et al. Variability of biomass chemical composition and rapid analysis using FT-NIR techniques, (2010) Carbohydrate Polymers, 81 4 820-829

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