Use of Near Infrared Spectroscopy for Rapid One-Day Analysis of Lignocellulosic Biomass

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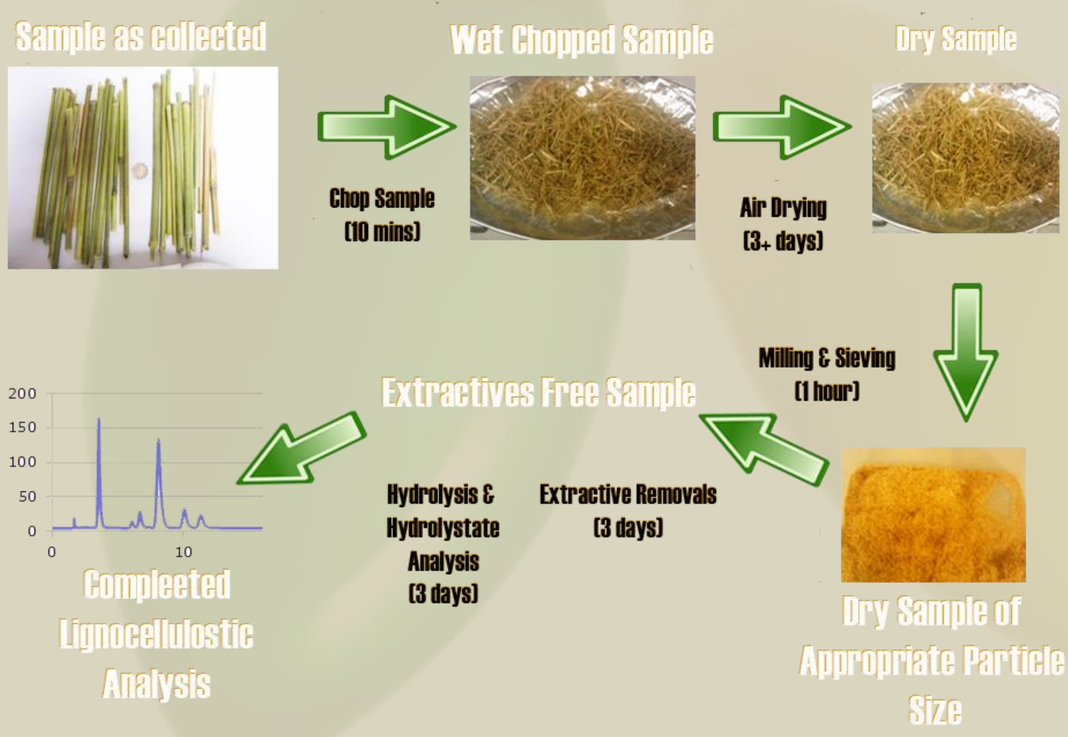
About Celignis

Celignis has been formed as a spin-out company from the University of Limerick to commercialise the progress that was made by the Carbolea Biomass Research Group (www.carbolea.ul.ie) in DIBANET, an FP7 project (www.dibanet.org) that was co-ordinated by the group. Work Package 2 of DIBANET involved the development of near infrared spectroscopy (NIR) as a rapid analysis tool for the characterisation of lignocellulosic biomass.

Need for Rapid Analysis

The flow chart below illustrates the steps involved in characterising biomass for its lignocellulosic constituents (e.g. lignin, cellulose, hemicellulose) by standard wet-chemical methods. It is a costly and laborious process but necessary in order to determine whether biomass can have value for processing in biorefineries. NIR analysis can remove the need for chemical analysis of biomass, providing that suitably robust models can be used to predict composition based on the absorbance spectra of the samples.



Method

Over 700 biomass samples, covering a wide variety of biomass types as detailed in the table below, were collected, prepared (dried and ground) and analysed via standard wet-chemical techniques for the following constituents:

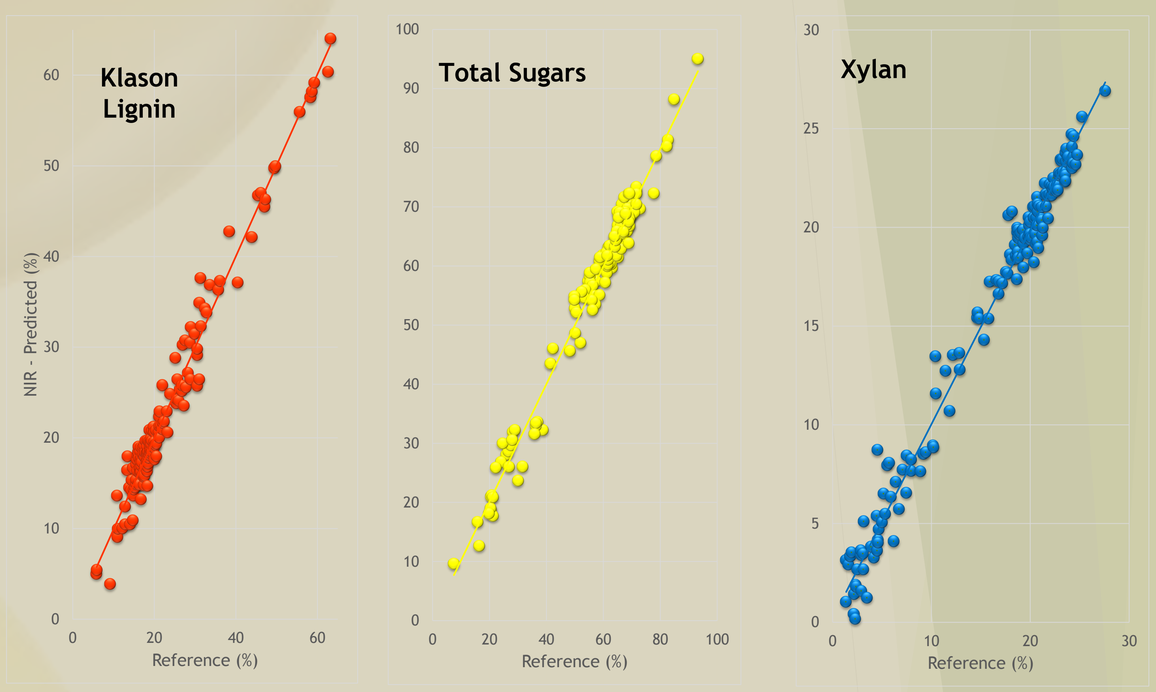
- Lignocellulosic sugars (glucose, xylose, mannose, arabinose, galactose, rhamnose).
- Lignin (Klason and acid-soluble).
- Ethanol-soluble extractives and ash.

The NIR spectra of these samples were also collected, at various points in the sample preparation process (ranging from wet-unground, to dry-unground, and dry-ground samples). Partial least squares (PLS1) regression was then used to develop models linking the variation in composition with spectral variation so that compositional predictions could be made from spectra alone.

Energy Crops	Agricultural Residues	Municipal Wastes
Miscanthus	Straws	Paper/cardboard
Other grasses	Animal manures	Green wastes
Hardwoods	Sugarcane bagasse	Black/brown bins waste
Softwoods	Forestry residues	Composts
Pretreated biomass	Mushroom compost	

Results

The Figure below provides regression plots for some compositional parameters for the independent validation set that was used to test the models. This set included a number of samples (25% of the total) that were not used to develop model parameters. The Table below provides regression statistics for this validation set. It can be seen that there is a good predictive accuracy for the main constituents of biomass. For example, the Root Mean Square Error of Prediction (RMSEP) for the total sugars content is 2.4% (providing an R^2 of 0.979).



Constituent	Range (%)	R^2 (%)	RMSEP
Total Sugars	7.5-100.0	0.979	2.413
Gluclose	3.8-84.8	0.972	2.010
Xylose	0.6-27.6	0.978	1.138
Klason Lignin	0.8-72.2	0.972	1.825
Mannose	0.0-14.0	0.956	0.605
Arabinose	0.0-6.2	0.903	0.353
Ash	0.2-59.4	0.914	2.479
Acid Soluble Lignin	0.5-7.7	0.899	0.338
Extractives	0.0-33.2	0.882	1.725
Rhamnose	0.0-1.6	0.861	0.096
Galactose	0.1-5.0	0.783	0.375

The accuracy of prediction tended to vary with the type of biomass being analysed. For example, the NIR models tended to be able to predict homogenous feedstocks (such as energy crops like Miscanthus) with a higher accuracy than heterogeneous feedstocks (such as municipal wastes). Nevertheless, the models demonstrated utility in the analysis of all samples.

As well as the global models detailed in this poster, feedstock-specific NIR models have been developed for Miscanthus, peat, straws, waste papers/cardboards, composts, pre-treated biomass and animal manures. These models tend to have lower RMSEPs than the global models.

Conclusion

NIR has been shown to allow rapid and accurate analysis of lignocellulosic biomass for properties relevant to utilisation in biorefineries. Approximately 20 person-years of work have been used to develop these models. NIR has now become the primary means of analysis at Carbolea and Celignis and has allowed analysis of many more samples than would otherwise be possible. The models are continually being improved with additional samples and analytes for prediction.

Hayes, D. J. M (2012), Development of near infrared spectroscopy models for the quantitative prediction of the lignocellulosic components of wet Miscanthus samples, Bioresource Technology 119:393-405

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