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Forest biomass for bioenergy production – comparison of different forest species

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Abstract

Forest biomass is a renewable and sustainable source of energy that can be used for producing electricity, heat, and biofuels. The production of biomass for energy is considered to be an important step in developing sustainable communities and managing greenhouse gas emissions effectively. Biomass properties vary and are commonly associated with plant species. Hence, efficient methods to predict biofuel characteristics will greatly affect the utilization and management of feedstock production. In this paper attempt was made to correlate various chemical characteristics with NIR spectra. Wood chips from various plant species was analyzed for lignin content, heating value, ash content and NIR and the results were evaluated with correlation, PCA and PCR. Initial evaluation showed promising results where chemical components in the wood correlate to NIR spectra. A selection of results will be presented in this paper. Further analysis as well as results from PCA and PCR models will be presented in the full paper version.

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Keywords: biofuel; biomass; heating value; lignin; NIR; wood;

1. Introduction

Bioenergy feedstock includes various types of plant biomasses, from traditional wood to agricultural by-products and waste. Today, forest by-products are among the most used resources for bioenergy and they include logging residues and wood processing residues. The chemical components of wood may vary

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considerably in different wood species and this will greatly affects the utilization of the resource [1]. Therefore, determining various chemical properties such as lignin content and heating value are important. Commonly, these characteristics are determined by using laboratory chemical methods, but these are usually time-consuming, costly, and not ideal for handling large amounts of wood samples. Hence; new, fast, and cost-effective determination methods are needed.

The amount of lignin in wood species is variable ranging from 20% to 40%, and it is the most abundant natural polymer present in nature after cellulose and hemicaelluloses [2]. Hence, lignin is expected to play an important role as raw material for the world's biobased economy for the production of bioproducts and biofuels.

Near infrared reflectance spectroscopy (NIR) is a powerful, in-expensive and rapid tool that can be used for determination of chemical compounds in wood [3]. NIR is non-destructive and may therefore have a great economic influence in a biofuel power plant, since they can be used for real-time monitoring of biomass properties. In the NIR region (700-2700 nm) each constituent of a complex organic mixture has unique absorption properties due to stretching and bending vibrations in molecular bonds [4].

The objective of this paper was to evaluate if NIR spectra can be used to identify lignin content and heating value in wood chips from various forest species. A selection of results will be presented in this paper. Further analysis as well as results from PCA and PCR models will be presented in the full paper version.

2. Material and methods

2.1. Determination of the moisture, ash content, heating value and lignin content

The moisture content was determined using standardized method according to EN 14774-3:2009. The ash content was determined using standardized method according to EN 14775:2009. Heating value was determined according to the standard EN 14918:2009. The higher heating value is calculated from the corrected temperature rise and the effective heat capacity of the calorimeter [5].

For determination of lignin content samples were mixed with 3 mL of 72% of sulfuric acid for 1 hour. 84 mL of deionized water was added and the samples were autoclaved for 1 hour at 121± 3 °C. After cooling and filtering the acid soluble lignin (ASL) was determined by analyzing 25 mL of the eluate spectrophotometrically at 205 nm. The acid insoluble lignin (AIL) was measured by weighing the amount of lignin captured in the filter after drying at 105° C for 2 hours.

Correlation coefficients were calculated using Excel.

3. Results and discussion

In Table 1 some biomass characteristics of the various forest species are presented. The results showed that the lignin content was highest for tops and branches and hybrid larch. Wood lignin contributes to increased mechanical strength properties and lignin generally has a high heating value. However, in our study, the higher heating value (HHV) did not correlate with the lignin content. This is contradictory to results published by other authors who found linear correlations between HHV and lignin content [6]. The HHV is the absolute value of energy at combustion and is affected by primarily total carbon, hydrogen and oxygen content, which is a combination of lignin, cellulose and extractives. This suggests that measuring lignin content is not suitable as sole indicator of the heating value, but needs to be complemented with analyses of other carbon compounds. In the full paper version of this proceeding, Table 1 will be complemented with more data such as cellulose and extractives.

Table 1. Wood chip properties (mean value n=3)

Biomass species	Sum of lignin (*t*)	Higher heating value ($J\ g^{-1}$)	Ash content (*weight %*)
Spruce (stem, bark)	32.3	21564	0.13
Tops and branches	40.2	19355	0.52
Field grown birch	27.5	18297	0.27
Field grown hybrid aspen	20.5	17795	0.68
Fresh maple annual shoots	34.9	17600	1.59
Spruce (stem)	30.4	18041	0.22
Forest oak	27.7	18218	0.67
Hybrid larch (stem)	40.0	18282	0.28
Birch (stem)	29.9	18287	0.68
Spruce (sapwood)	34.4	21877	0.16
Conifers	36.9	19867	0.26
Birch (stem, sapwood)	30.4	18353	0.37
Pine (sapwood)	35.9	18293	0.30

The NIR spectra of seven representatives of wood samples are shown in Figure 1b. Because they are all wood samples, their spectral characteristics are very similar except for the baseline differences among the samples. The baseline shift in the absorbance scale is quite common in NIR spectroscopy and may be due to the sample composition differences and inhomogeneity of the material. According to the literature, bands around 1170, 1600, 1675 and 2200 nm may be assigned to lignin content [7], but these wavelengths numbers do not correspond to visible peaks in Figure 1b. However, all wood samples follow the same spectral characteristics which suggest that the peaks correspond to functional groups present in all samples. For the correlation analysis wavelength selection was done iteratively by comparing wavelength numbers and ranges to lignin content and HHV.

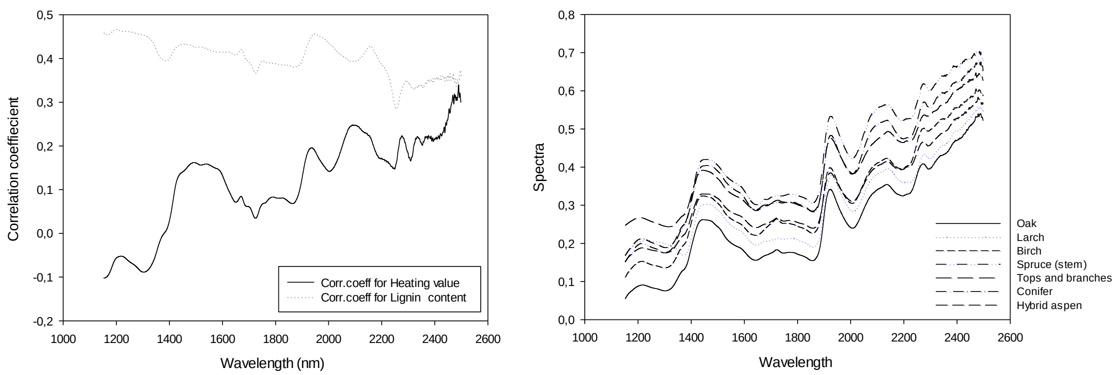

Fig. 1. (a) Correlation coefficients for NIR spectra vs heating value and lignin; (b) Comparison of NIR spectra for a selection of the wood samples analysed in the study

A correlation was performed for each specific wavelength and HHV and lignin content. The general idea was to evaluate if individual wavelengths numbers or ranges can be used to predict HHV or lignin. The correlation coefficients for NIR spectra vs. HHV and lignin content, respectively, are shown in Figure 1a.

Generally, the lignin content showed better correlation to specific wavelengths than HHV although the correlation is weak (r<0.5). However, both lignin and HHV showed peaks in correlation around the wavelength range 2000-2200 nm. In addition, after a dip, their correlation increased with wavelengths higher than 2300. This indicates that these wavelength ranges may be useful in further analyses. Wood is a complex organic material and interpretation of the NIR spectrum may be complicated. Prediction of specific chemical or physical properties by using NIR spectra may be significantly improved by first decomposing the dataset by principal component methods. Preliminary results from a principal component regression (PCR) showed that NIR successfully predicted heating value and lignin content (data not shown). Similar results have been shown Fang et al. [8] who proposed enhanced predictions of wood properties using hybrid models of PCR and PLS with high-dimensional NIR spectral data.

In conclusion, the preliminary results showed that NIR spectra may be a useful tool in predicting the heating value and the lignin content. In the full paper version, more extensive data will be presented along with principal component analysis (PCA) and principal component regression (PCR).

References

[1] Vassilev SV, Baxter D, Andersen LK., Vassileva CG. An overview of the chemical composition of biomass. *Fuel* 2010;**89**:913–933.

[2] C. Telmoa, The explained variation by lignin and extractive contents on higher heating value of wood. Biomass and Bioenergy Volume 35, Issue 5, May 2011, Pages 1663–1667

[3] He W, Hu H. Rapid Prediction of Different Wood Species Extractives and Lignin Content Using Near Infrared Spectroscopy. *Journal of Wood Chemistry and Technology* 2013; **33**:52–64

[4] Wetzel DL. Near-infrared reflectance analysis: sleeper among spectroscopic techniques. *Analytical Chemistry* 1983;**55**:1176A– 1665A.

[5] CEN EN 14918:2009 Solid biofuels – Determination of calorific value.

[6] Tillman DA. *Wood as an energy resource*. New York Academic Press, 1978

[7] PRG Hein, Campos ACM, Mendes RF, Mendes LM,·Chaix G. Estimation of physical and mechanical properties of agro-based particleboards by near infrared spectroscopy. *European Journal of Wood Production* 2011;**69**:431–442

[8] Fang Y, Park JI, Jeong YS, Jeong MK, Baek SH, Cho HW. *Enhanced predictions of wood properties using hybrid models of PCR and PLS with high-dimensional NIR spectral data. Annals of Operations Research* 2009;1–13.

Biography

Anders Avelin is a PhD student at Mälardalen University, Sweden. He holds a master's degree in Energy Engineering from Mälardalen University, Sweden. Currently he is studying how to build soft sensors of the characteristics of biomass to complement traditional sensors for robust and effective simulation, optimisation and control.