On-line near infrared technique for biorefinery process monitoring

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Introduction

Incoming biomass to biorefineries varies in chemical content. In order to obtain tailor-made feedstocks for the production of high value-added products it is of importance to monitor and control rapid material streams in industrial processes.[1] Therefore an experimental design was conducted to characterise biomaterials–specifically wood species origin in blends–in a process stream, using a fast near-infrared (NIR) diode array on-line spectrometer with built-in camera.

The main objective was to construct NIR prediction models for three biomass origins of different blends, but also calibration models for moisture content.

Materials and methods

Experimental

The experimental set-up was a factorial mixed design, using blends of wood species with three different origins of the raw materials, and further with three moisture content levels, giving 19 experiments. The target values of the design were 8%, 10% and 12% in moisture content and blends of 10%, 30% and 50% (volume basis) of chipped energy wood, either in a mixture of two softwood species in the same volume ratio, or in one of the softwood species. This means that the expected values for the different components in the blends were: 0%, 10%, 25%, 30%, 35%, 50%, 70% or 90%. These blends were mixed and dried, and ground into wood powder by the industrial process.

Each experiment was run for 30–40 minutes after steady state process values were reached for each set-point. A total of 6,439 NIR average spectra were collected.

NIR spectroscopy

An on-line diode array spectrometer (Perten Instruments AB, Sweden) was used to collect NIR reflectance spectra from the wood powder, Figure 1.

Average spectra between 950–1650 nm were collected at 5 nm increments every 6 seconds. A built-in video camera delivered 40 images (640×480 pixels, red-green-blue colour channels) per

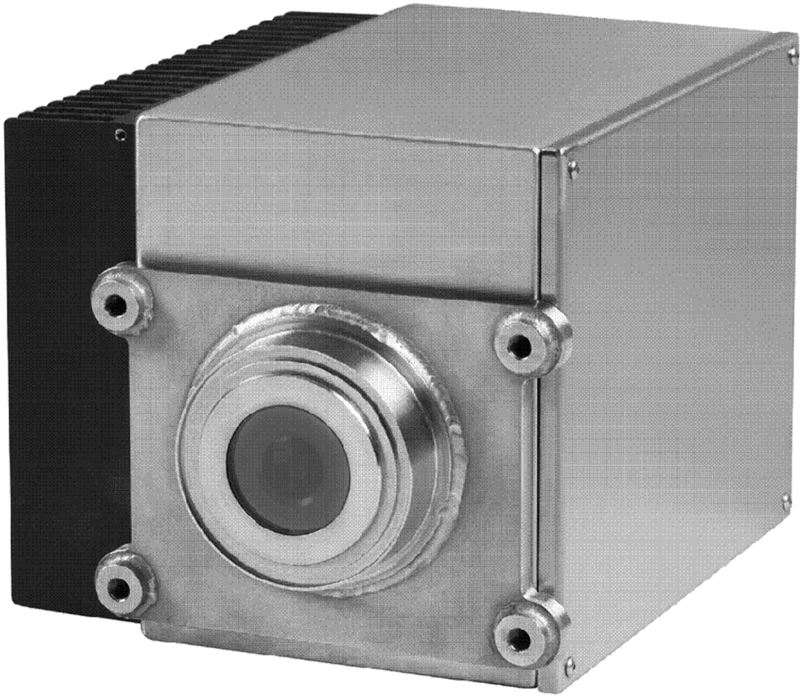

Figure 1. On-line NIR instrument (950–1650 nm) with sapphire glass window and built-in red-green-blue colour camera system.

minute and correlations between consecutive images. The instrument was positioned on the side of a U-shaped container with a screw (Θ ca. 50 cm) feeding dried and ground wood powder to the biorefinery process of an industrial plant. The distance from the sapphire glass window (Θ 50 mm) to the outer part of the screw wing was about 4 cm, and this distance was filled with wood powder.

Reference variables

Reference variables were:

- percentage (volume basis) of each of the different tree wood raw materials in the blends
- moisture content based on the standardized oven method at 105°C and percentages were calculated on wet weight.

Modelling and diagnostics

All data were arranged in a mathematical matrix with matching reference values and absorption spectra. Only centred values were used in the modeling. The multivariate calibration models based on partial least squares regression were calculated using SIMCA software (Umetrics AB, Sweden).

Results and discussion

The outcome of the design was a moisture content that on an average for all experiments varied between 6.3 and 12.8%, with a total mean value of 9.4% and a standard deviation of 1.9%. This was within a close range to the preset values of the design.

The video camera images were useful to follow the process stream in real time and to detect any possibly contaminating layer on the detector sapphire glass window. This camera was therefore also used to detect product flow, besides collecting NIR spectra. If the product is standing still, the correlation between e.g. pixel gray values of two consecutive images will be high, >0.9. If the product is moving the correlation will become low, normally <0.1. This technicality can also be used to detect an anomaly such as window contamination. If the correlation is higher than for a normal flow, say 0.4 instead of 0.9, then a significant portion of the product is not exchanged. This can indicate a glass window contamination and can trigger an alarm. The camera also allows for a visual inspection of the glass to confirm the reason for such an alarm. However, no such contamination was detected over a two-week period.

The multivariate prediction model for wood origin explained 94.9% of the variation with a standard deviation of 3.8%, based on mean values for each experiment. For individual spectra

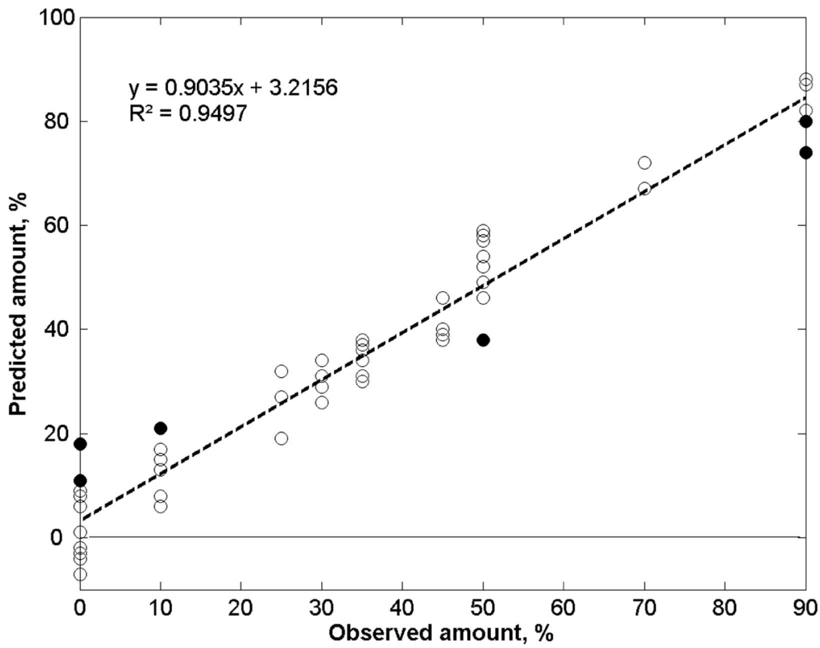

Figure 2. Mean prediction values (%) of wood origin in 19 blends. Filled circles indicate mistakes in the industrial blending process in relation to target values.

this deviation increased to 5.6%. The predictions deviated in some cases too much (>1.96 times standard deviation) from target values according to the experimental design, indicating errors in the blending of the wood raw materials, see Figure 2.

The NIR calibration model for moisture content gave its customary excellent predictions, with low errors of about 0.5% within the observed variation range in moisture. The results illustrate the possibilities for better monitoring and control of biorefinery processes in industrial plants.

Conclusion

The conclusions are that:

- the NIR technique is a powerful tool to characterize biomass and supervise processes.
- on-line NIR techniques facilitate excellent calibrations and real time predictions, and designed tailor-made feedstocks for biorefinery and energy combine processes.

Reference

1. T.A. Lestander, B. Johnsson and M. Grothage, *NIR Bioresource Technol*. **100,** 1589 (2009).