Cloud-shadow removal for Unmanned Aerial System multispectral imagery based on tensor decomposition methods

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Cloud-shadow removal for Unmanned Aerial System multispectral imagery based on tensor decomposition methods
Multispectral images acquired on board of Unmanned Aerial Systems (UAS) provide unprecedented opportunities to monitor vegetation status and functioning at spatial scales compatible with field instrumentation and field management. UAS such as hexacopters acquire overlapping images that are mosaicked into larger images to produce ortho-photomaps. Frequently, especially in northern latitudes, the images to be mosaicked have been acquired under varying irradiance conditions due to moving clouds that create artifacts in the detected signal unrelated to physical changes in vegetation properties. In order to exploit the full potential of UAS, correction methods should be developed to provide ortho-rectified images that can provide robust estimates of vegetation properties. We applied a Tucker tensor decomposition method to reconstruct images using a four-way factorization scheme. By doing so, this study succeeded to remove the cloud shadow effects and image noise in UAS imagery providing normalized reflectance. The comparison between the corrected and uncorrected images shows a significant improvement for reflectance estimation in the shadow areas. Further, analysis of vegetation indices e.g. normalized difference vegetation index derived from the corrected and un-corrected images also showed improvement. This method could also have the ability to resolve artifacts, such as temporary objects (e.g. humans, tractors etc.) from the vegetation background.

General information
**Imaging for monitoring downstream processing of fermentation broths**

In relation to downstream processing of a fermentation broth coagulation/flocculation is a typical pretreatment method for separating undesirable particles/impurities from the wanted product. In the coagulation process the negatively charged impurities are destabilized by adding of a clarifying agent thereby neutralizing the charges on the particles. Particles thus agglomerate. Larger agglomerates are formed in the flocculation process by adding a polymer, which forms bridges between the particles. The operation of coagulators, flocculators and clarifiers requires trained operators implying the human factor to play a major risk with regard to performance. Better process monitoring will provide the means for improved control giving higher yield, better quality, and minimize the consumption of water. In particular, the optimal separation of biomass from a soluble enzyme phase is often dependent on an initial coagulation of the biomass and a final flocculation of the solids just prior to separation. We investigate flocculation processes at Novozymes facilities so that the response time and risk of error is minimized. We use oCelloScope [1], an automated microscope, for imaging samples from the flocculation process and subsequently we extract image features for qualitative and quantitative image characterization. The processing include image morphology, image segmentation and image quantification. The aim is to correlate image information to “quality” of the separation process. Here we report our initial finding. [1] M.Fredborg et al. Journal of Clinical Microbiology Vol 51 Number 7 p. 2047–2053 (2013); http://www.biosensesolutions.dk

**Oxidation of lignin in hemp fibres by laccase: effects on mechanical properties of hemp fibres and unidirectional fibre/epoxy composites**

Laccase activity catalyzes oxidation and polymerization of phenols. The effect of laccase treatment on the mechanical properties of hemp fibres and hemp fibre/epoxy composites was examined. Laccase treatment on top of 0.5% EDTA + 0.2% endo-polygalacturonase (EPG) treatments increased the mechanical properties of hemp fibres and fibre/epoxy composites. Comparing all fibre treatments, composites with 0.5% EDTA + 0.2% EPG + 0.5% laccase treated fibres had highest stiffness of 42 GPa and highest ultimate tensile strength (UTS) of 326 MPa at a fibre volume content of 50%. The thermal resistance of hemp fibres increased after laccase treatments, as the maximum degradation temperature increased about 5 °C. Oxidation of phenolic hydroxyls in lignin by laccase was observed. Cross-linking of hydroxyphenylates by laccase was not observed. We suggest that the increased mechanical properties of laccase treated hemp fibres and their composites were due to laccase catalyzed polymerization of lignin moieties in hemp fibres.
Prediction of Pectin Yield and Quality by FTIR and Carbohydrate Microarray Analysis

Pectin production is complex, and final product quality assessment is generally accomplished at the end of the process using time-consuming off-line laboratory analysis. In this study, pectin was extracted from lime peel either by acid or by enzymes. Fourier transform infrared spectroscopy and carbohydrate microarray analysis were performed directly on the crude lime peel extracts during the time course of the extractions. Multivariate analysis of the data was carried out to predict final pectin yields. Fourier transform infrared spectroscopy (FTIR) was found applicable for determining the optimal extraction time for the enzymatic and acidic extraction processes, respectively. The combined results of FTIR and carbohydrate microarray analysis suggested major differences in the crude pectin extracts obtained by enzymatic and acid extraction, respectively. Enzymatically extracted pectin, thus, showed a higher degree of esterification (DE 82 %) than pectin extracted by acid (DE 67 %) and was moreover found to be more heterogeneously esterified when probed with the monoclonal antibodies JIM5, JIM7, and LM20. The data infer that enzymatic pectin extraction allows for extraction of complex, high DE pectin, and that FTIR and carbohydrate microarray analysis have potential to be developed into online process analysis tools for prediction of pectin extraction yields and pectin features from measurements on crude pectin extracts.

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Industrial fermentation processes are monitored using a variety of sensors. Typically, measurements are taken throughout the entire production process. Production may be carried out under supervision of different operators (operator variation), on different sites (global variation), in different buildings and/or in different tanks (local variation). However, up to now processes are mainly controlled according to traditional recipes and experience.

Oxidation of lignin in hemp fibres by laccase: effects on mechanical properties of hemp fibres and unidirectional fibre/epoxy composites

Rapid quantification of casein in skim milk using Fourier transform infrared spectroscopy, enzymatic perturbation, and multiway partial least squares: Monitoring chymosin at work

In this study, we introduce enzymatic perturbation combined with Fourier transform infrared (FTIR) spectroscopy as a concept for quantifying casein in subcritical heated skim milk using chemometric multiway analysis. Chymosin is a protease that cleaves specifically casein. As a result of hydrolysis, all casein proteins clot to form a creamy precipitate, and whey proteins remain in the supernatant. We monitored the cheese-clotting reaction in real time using FTIR and analyzed the resulting evolution profiles to establish calibration models using parallel factor analysis and multiway partial least squares regression. Because we observed casein-specific kinetic changes, the retrieved models were independent of the chemical background matrix and were therefore robust against possible covariance effects. We tested the robustness of the models by spiking the milk solutions with whey, calcium, and cream. This method can be used at different stages in the dairy production chain to ensure the quality of the delivered milk. In particular, the cheese-making industry can benefit from such methods to optimize production control.
Descriptive and predictive assessment of enzyme activity and enzyme related processes in biorefinery using IR spectroscopy and chemometrics

Enzyme technology provides key strategies to green chemistry as many processes have undergone re-design to serve increasing demands towards being sustainable. While the population is rapidly increasing on our planet it is leading to accumulative problems in terms of production of waste, depletion of natural fossil resources and increasing demands for food and energy.

Biorefinery, in particular, deals with related challenges, as it is defined to deal with the conversion of biomass using enzyme technology to produce renewable energy, in terms of heat, power and fuel. Furthermore, biorefinery intends to extract value-added compounds from biomass to avoid downcycling effects prior to e.g. biofuel production. Those value-added compounds are highly attractive to be utilized as food ingredients, bio-chemicals or precursors for pharmaceutical products and represent high market potentials for related industries.

However, as biorefinery concepts are implemented in many industrial processes an increasing demand for Process Analytical Technology (PAT) evolves to monitor, understand and steer processes optimally. Biomasses can be very diverse and are usually of complex chemical nature. Conventional univariate analytical methods therefore require time-consuming sample preparation which is mostly cumbersome to analyze biomass conversion related processes. Throughout this project alternative approaches will be presented to deal with the individual challenges. As outlined it seems obvious that more advanced techniques are necessary to monitor such difficult reactions as enzymatic biomass degradations. Such techniques should be of multivariate nature to capture and understand complex patterns in comparison to univariate techniques which can only capture information in a highly specific sense which does not allow interference of information. Vibrational spectroscopy (e.g. infrared) represents such multivariate techniques and is mostly used throughout the project. Data is analyzed by chemometric methods to extract the underlying patterns from the complex datasets.

Hence, this project focuses on chemometric approaches utilizing mostly Fourier Transform Infrared (FTIR) spectroscopic data to provide descriptive and predictive insights into biomass conversion related processes. Two main study fields are introduced to the reader. First, two-way chemometric methods are used to establish Process Analytical Technology (PAT) solutions for prediction of monosaccharide release efficiency of pretreated destarched corn bran using Near Infrared (NIR) spectroscopy (PAPER 1). Throughout this study predictive and descriptive models were established to evaluate the pretreatment effect without the need to perform the subsequent enzymatic hydrolysis itself. Furthermore, the efficiency (and quality) of differently extracted pectin from lime peel could be predicted from measuring FTIR spectra (PAPER 2). The prediction models were compared to results retrieved from carbohydrate microarray analysis which additionally enhanced the understanding of the structural properties of the extracted pectin.

Secondly, enzyme kinetics of biomass converting enzymes was examined in terms of measuring enzyme activity by spectral evolution profiling utilizing FTIR. Chemometric multiway methods were used to analyze the tensor datasets enabling the second-order calibration advantage (reference Theory of Analytical chemistry). As PAPER 3 illustrates the method is universally applicable without the need of any external standards and was exemplified by performing quantitative enzyme activity determinations for glucose oxidase, pectin lyase and a cellolytic enzyme blend (Celluclast 1.5L). In PAPER 4, the concept is extended to quantify enzyme activity of two simultaneously acting enzymes, namely pectin lyase and pectin methyl esterase. By doing so the multiway methods PARAFAC, TUCKER3 and NPLS were compared and evaluated towards accuracy and precision.
Enzyme activity measurement via spectral evolution profiling and PARAFAC

The recent advances in multi-way analysis provide new solutions to traditional enzyme activity assessment. In the present study enzyme activity has been determined by monitoring spectral changes of substrates and products in real time. The method relies on measurement of distinct spectral fingerprints of the reaction mixture at specific time points during the course of the whole enzyme catalyzed reaction and employs multi-way analysis to detect the spectral changes. The methodology is demonstrated by spectral evolution profiling of Fourier Transform Infrared (FTIR) spectral fingerprints using parallel factor analysis (PARAFAC) for pectin lyase, glucose oxidase, and a cellulase preparation.
Simultaneous measurement of two enzyme activities using infrared spectroscopy: A comparative evaluation of PARAFAC, TUCKER and N-PLS modeling

Enzymes are used in many processes to release fermentable sugars for green production of biofuel, or the refinery of biomass for extraction of functional food ingredients such as pectin or prebiotic oligosaccharides. The complex biomasses may, however, require a multitude of specific enzymes which are active on specific substrates generating a multitude of products. In this paper we use the plant polymer, pectin, to present a method to quantify enzyme activity of two pectolytic enzymes by monitoring their superimposed spectral evolutions simultaneously. The data is analyzed by three chemometric multiway methods, namely PARAFAC, TUCKER3 and N-PLS, to establish simultaneous enzyme activity assays for pectin lyase and pectin methyl esterase. Correlation coefficients $R^{2}_{pred}$ for prediction test sets are 0.48, 0.96 and 0.96 for pectin lyase and 0.70, 0.89 and 0.89 for pectin methyl esterase, respectively. The retrieved models are compared and prediction test sets show that especially TUCKER3 performs well, even in comparison to the supervised regression method N-PLS.
Rapid near infrared spectroscopy for prediction of enzymatic hydrolysis of corn bran after various pretreatments

Efficient generation of a fermentable hydrolysate is a primary requirement in the utilization of fibrous plant biomass as feedstocks in bioethanol processes. The first biomass conversion step usually involves a hydrothermal pretreatment before enzymatic hydrolysis. The purpose of the pretreatment step is to increase the responsivity of the substrate to enzymatic attack and the type of pretreatment affects the enzymatic conversion efficiency. Destarched corn bran is a fibrous, heteroxylan-rich side-stream from the starch industry which may be used as a feedstock for bioethanol production or as a source of xylose for other purposes. In the present study we demonstrate the use of diffuse reflectance near infrared spectroscopy (NIR) as a rapid and non-destructive analytical tool for evaluation of pretreatment effects on destarched corn bran. NIR was used to achieve classification between 43 differently pretreated corn bran samples using principal component analysis (PCA) and hierarchal clustering algorithms. Quantification of the enzymatically released monosaccharides by HPLC was used to design multivariate calibration models (biPLS) on the NIR spectra. The models could predict the enzymatic release of different levels of arabinose, xylose and glucose from all the differently pretreated destarched corn bran samples. The present study also demonstrates a generic, non-destructive solution to determine the enzymatic monosaccharide release from polymers in biomass side-streams, thereby potentially replacing the cumbersome HPLC analysis.

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