Characteristics of Xanthosoma sagittifolium roots during cooking, using physicochemical analysis, uniaxial compression, multispectral imaging and low field NMR spectroscopy

To effectively promote the industrial utilization of cocoyam (Xanthosoma sagittifolium) roots for enhanced food sustainability and security, there is a need to study their molecular, mechanical and physicochemical properties in detail. The physicochemical and textural characteristics of the red and white varieties of cocoyam roots were thus analysed by low field nuclear magnetic resonance relaxometry, multispectral imaging, uniaxial compression testing, and relevant physicochemical analysis in the current study. Both varieties had similar dry matter content, as well as physical and mechanical properties. However, up to four fast-interacting water populations were observed in the roots, dependent on the root variety and their degree of gelatinization during cooking. Changes in the relaxation parameters indicated weak gelatinization of starch at approximately 80 °C in both varieties. However, shorter relaxation times and a higher proportion of restricted water in the white variety indicated that this variety was slightly more sensitive towards gelatinization. A strong negative correlation existed between dry matter and all multispectral wavelengths >800 nm, suggesting the potential use of that spectral region for rapid analysis of dry matter and water content of the roots. The small, but significant differences in the structural and gelatinization characteristics of the two varieties indicated that they may not be equally suited for further processing, e.g. to flours or starches. Processors thus need to choose their raw materials wisely dependent on the aimed product characteristics. However, the spectroscopic methods applied in the study were shown to be effective in assessing important quality attributes during cooking of the roots.
Analysis of the production of salmon fillet - Prediction of production yield

The aim was to investigate the influence of raw material variation in Atlantic salmon from aquaculture on filleting yield, and to develop a decision tool for choosing the appropriate raw material for optimized yield. This was achieved by tracking salmon on an individual level (n = 60) through a primary production site. The majority of the salmon exhibited a heavier right fillet compared to the left fillet after filleting. No explicit explanation was found for this observation although the heading procedure was shown to have a large impact. A Partial Least Square model was built to predict the yield after filleting. The model was based on six pre-processing variables and allowed an acceptable prediction of the filleting yield.
with a root mean square error cross validation of 0.68. The presented model can estimate the slaughter yield for a certain batch before ordering from the slaughterhouse. This may facilitate optimal planning of the production of salmon fillets by ordering and assigning the right batch to the right product category to obtain an optimal yield and quality.

**General information**

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Organisations: National Food Institute, Research Group for Food Production Engineering, University of Iceland, Fast-Q

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Laser-light backscattering response to water content and proteolysis in dry-cured ham

Laser backscattering imaging (LBI) is a low-cost technology proposed to determine non-invasively composition and microstructural characteristics of agro food and dairy products. The aim of this work was to define the effect of different acquisition conditions (wavelength, object distance and angle of laser incidence) and to analyse the laser-light backscattering changes caused by additional hot air drying and proteolysis of dry-cured ham slices. The feasibility of the technology to determine water content and proteolysis (which is related to textural characteristics) of commercial sliced dry-cured ham was also evaluated. Results showed that a red laser (635 nm) is more convenient than a green laser (532 nm) to analyse dry-cured ham but no preferable angle or object distance to evaluate dryness or proteolysis was found. Nevertheless, light scattering parameters were modified depending on the acquisition conditions used. Laser backscattering was influenced by both dryness and proteolysis intensity showing an average light intensity decrease of 0.2 when decreasing water content (1% weight loss) and increasing proteolysis (equivalent to one-hour enzyme action). However, a decrease of scattering area was only detected when the water content was decreased (618 mm(2) per 1% weight loss). Changes on scattering of light profiles were only observed when the water content changed. Although there is a good correlation between water content and LBI parameters when analysing commercial samples, proteolysis index has an important effect on the response. This fact hinder estimation of dry-cured ham composition and textural characteristics of dry-cured ham. (C) 2017 Elsevier Ltd. All rights reserved.
Gum tragacanth (GT) exuded from an Iranian Astragalus species was γ-irradiated at 0, 0.75, 1.5, 3, 5, 7, 10 kGy and used to stabilize a model oil in water emulsion system. Stability and physicochemical properties of emulsion samples were investigated with respect to the effect of irradiation treatment on functional properties of gum tragacanth. Particle size distribution, interfacial tension, zeta potential, steady shear and oscillatory rheological measurements were used to characterize and evaluate the emulsion samples and obtain more information about the possible stability mechanism. Emulsions were prepared by homogenizing 10% w/w sunflower oil with 90% w/w aqueous gum dispersions and stored quiescently at 25°C for 120 days. Results indicated that using 1.5 kGy irradiated GT was more effective in providing optimum values of apparent viscosity, number mean diameter, electrosteric repulsion and structure strength for getting maximum emulsion stability. GT significantly reduced the interfacial tension of the oil and water system, but no significant differences were observed among all irradiation treated and non-irradiated samples. This study revealed that, GT acts as a bifunctional emulsifier and irradiation treatment has a great positive influence on its ability to reduce droplets collision frequency and stabilize oil in water emulsion.
Non-invasive volume estimation of fish fillets/cutlets using structured light

General information
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Organisations: National Food Institute, Research Group for Food Production Engineering
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Peelability and quality changes during ice maturation of shrimp (Pandalus borealis)

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Organisations: National Food Institute, Research Group for Food Production Engineering, University of Copenhagen, Royal Greenland A/S, Launis A/S
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Discriminating Yogurt Microstructure Using Diffuse Reflectance Images

The protein microstructure of many dairy products is of great importance for the consumers' experience when eating the product. However, studies concerning discrimination between protein microstructures are limited. This paper presents preliminary results for discriminating different yogurt microstructures using hyperspectral (500-900nm) diffuse reflectance images (DRIs) – a technique potentially well suited for inline process control. Comparisons are made to quantified measures of the yogurt microstructure observed through confocal scanning laser microscopy (CSLM). The output signal from both modalities is evaluated on a 24 factorial design covering four common production parameters, which significantly change the chemistry and the microstructure of the yogurt. It is found that the DRIs can be as discriminative as the CSLM images in certain cases, however the performance is highly governed by the chemistry of the sample. Also, the DRIs shows better correlation to the CSLM images and are more discriminative when considering shorter wavelengths.

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Evaluation of Yogurt Microstructure Using Confocal Laser Scanning Microscopy and Image Analysis

The microstructure of protein networks in yogurts defines important physical properties of the yogurt and hereby partly its quality. Imaging this protein network using confocal scanning laser microscopy (CSLM) has shown good results, and CSLM has become a standard measuring technique for fermented dairy products. When studying such networks, hundreds of images can be obtained, and here image analysis methods are essential for using the images in statistical analysis. Previously, methods including gray level co-occurrence matrix analysis and fractal analysis have been used with success. However, a range of other image texture characterization methods exists. These methods describe an image by a frequency distribution of predefined image features (denoted textons). Our contribution is an investigation of the choice of image analysis methods by performing a comparative study of 7 major approaches to image texture description. Here, CSLM images from a yogurt fermentation study are investigated, where production factors including fat content, protein content, heat treatment, and incubation temperature are varied. The descriptors are evaluated through nearest neighbor classification, variance analysis, and cluster analysis. Our investigation suggests that the texton-based descriptors provide a fuller description of the images compared to gray-level co-occurrence matrix descriptors and fractal analysis, while still being as applicable and in some cases as easy to tune.

Practical Application

Confocal laser scanning microscopy images can be used to provide information on the protein microstructure in yogurt products. For large numbers of microscopy images, subjective evaluation becomes a difficult or even impossible approach, if the images should be incorporated in any form of statistical analysis alongside other measuring modalities or sensory data. Instead, automated image texture analysis can be used to provide objective descriptions of the images, and we provide a comparative study for a broad range of the many image texture analysis available. All of the investigated techniques should be applicable for any type of pseudo homogeneous image structures.

General information

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Non-Invasive Assessment of Dairy Products Using Spatially Resolved Diffuse Reflectance Spectroscopy

The quality of a dairy product is largely determined by its microstructure which also affects its optical properties. Consequently, an assessment of the optical properties during production may be part of a feedback system for ensuring the quality of the production process. This paper presents a novel camera-based measurement technique that enables robust quantification of a wide range of reduced scattering coefficients and absorption coefficients. Measurements are based on hyperspectral images of diffuse reflectance in the wavelength range of 470 to 1020 nm. The optical properties of commercially available milk and yogurt products with three different levels of fat content are measured. These constitute a relevant range of products at a dairy plant. The measured reduced scattering properties of the samples are presented and show a clear discrimination between levels of fat contents as well as fermentation. The presented measurement technique and method of analysis is thus suitable for a rapid, non-contact, and non-invasive inspection that can deduce physically interpretable properties.

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2D Static Light Scattering for Dairy Based Applications
Throughout this thesis we investigate a recently introduced optical technique denoted 2D static light scattering (2DSLS). The technique is remote sensing, non-invasive, highly flexible, and appears to be well suited for in-line process control. Moreover, the output signal contains contributions from several different optical phenomena, which can be utilised to provide information on chemical composition and underlying microstructure of an investigated sample.

The main goal of this thesis is to provide an exploratory study of the 2DSLS technique in relation to dairy based applications. This includes getting an understanding of the various parameters in the setup as well as understanding the output signal in terms of potential and limitations. Furthermore, suitable ways of quantifying the signal are investigated. Here, both established physical models and statistical descriptions of the signal are evaluated and discussed.

There is a major emphasis on using 2DSLS to discriminate between different protein microstructures in yogurt products. This potentially allows for process control, in relation to microstructure, during yogurt manufacture. As microstructure is critical for consumer acceptability, this specific process control can be highly beneficial. To provide suitable reference measures on the actual microstructure, we investigate how to quantify micrographs of yogurts objectively. We provide a comparative study, that includes a broad range of different image texture descriptors.

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DCT-Based Characterization of Milk Products Using Diffuse Reflectance Images
We propose to use the two-dimensional Discrete Cosine Transform (DCT) for decomposition of diffuse reflectance images of laser illumination on milk products in different wavelengths. Based on the prior knowledge about the characteristics of the images, the initial feature vectors are formed at each wavelength. The low order DCT coefficients are used to quantify the optical properties. In addition, the entropy information of the higher order DCT coefficients is used to include the illumination interference effects near the incident point. The discrimination powers of the features are computed and used to do wavelength and feature selection. Using the selected features of just one band, we could characterize and discriminate eight different milk products. Comparing this result with the current characterization method based of a fitted log-log linear model, shows that the proposed method can discriminate milk from yogurt products better.

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Decomposition of Diffuse Reflectance Images - Features for Monitoring Structure in Turbid Media

Light scattering in turbid media can be related to the microstructure of media. Thus, light scattering can potentially be used for process control of products where the structure is a key component. However process control requires robust and sensitive input data to function properly. In this study we investigate different decomposition methods for extracting light scattering information from images of diffuse reflectance. Both well-established theoretical methods and data driven methods are considered and evaluated based on their robustness and sensitivity to changes in light scattering properties.

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Spectral characterisation of dairy products using photon time-of-flight spectroscopy

In this paper, we present, for the first time, the absorption and reduced scattering spectra of commercially available milk and yoghurt products, obtained using photon-time-of-flight spectroscopy. The ability of this technique to separate the contributions from absorption and scattering in the sample provides important information on the chemical composition and micro-structural properties, which are not available with the traditional techniques used in dairy production. The instrument operates in the spectral range from 500 nm to 1030 nm. The reduced scattering coefficient varies from 5 cm\(^{-1}\) for milk with 0.1% fat in the near infrared range, to 60 cm\(^{-1}\) for yoghurt with 3.0% fat in the green wavelength regime. The absorption is within the range of 0.05-0.5cm\(^{-1}\), with only small variation in the absolute value between products. Our results show that the reduced scattering clearly distinguishes milk and yoghurt with the same fat content and can offer a reliable way of monitoring structural formation during milk fermentation.

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Digital Prototyping of Milk Products

Digital prototyping has revolutionised the automotive industry by providing designers and engineers with digital models of their products that enable virtual product design, visualisation, and simulation [1]. However, digital prototyping does not exist in the food industry as the colloidal nature of most foods make them much more challenging to visualise and simulate realistically. We present models and methods that take steps toward digital prototyping of milk products and other food colloids. To simulate the dynamics of liquid products that only exist digitally, we use deformable simplicial complexes with an optimisation-based, linear finite element method [2,3]. Visualisation of products that only exist digitally requires a model for predicting the optical properties of the product materials. The optical properties (absorption coefficient, scattering coefficients, and phase function or asymmetry parameter) are the input needed for a Monte Carlo based graphical rendering. We have developed a model for predicting the optical properties of milk as a function of its fat and protein contents [4]. However, the model has only been validated to a limited extent. We suggest that diffuse reflectance measurements can be used for more extensive validation and for gathering data that can be used to extend our current model such that it can also predict how the optical properties develop during fermentation or acidification of milk to yogurt.

A well-established way of measuring optical properties is by static light scattering measurements. This, however, is an
invasive procedure where a sample must be placed in a relatively small container (like a cuvette) and scanned by a photon detector orbiting the sample. The container must be small enough to ensure that the sample enters the single scattering regime. Diffuse reflectance measurements have the advantage of being noninvasive. However, the analysis becomes more complex as such measurements include multiple scattering effects. To measure optical properties using diffuse reflectance, we capture high dynamic range images of laser at different wavelengths incident on a sample in situ. The wavelength of the laser is easily adjustable as we use an NKT Photonics SuperK laser [5]. This enables us to retrieve spatially and spectrally resolved diffuse reflectance images. We also acquire images with the laser at several angles of incidence to enable oblique-incidence reflectometry. This enables us to use existing techniques [6,7] for retrieving the apparent optical properties of a sample. The validation consists in comparison of measured optical properties with predicted optical properties.

One of our goals is to extend our model for digital prototyping of milk products such that it can also predict how the optical properties develop during gelation of milk to yogurt. The influence of the colloidal aggregation on the optical properties is described by the static structure factor. As our method is noninvasive, we can use our setup for monitoring an acidification process over time. The challenge is to investigate whether we can use the resulting diffuse reflectance images to measure the static structure factor or similar optical properties of gels. We can see some correlation between measured diffuse reflectance and the rheology of the gel. This indicates that some quantity similar to the static structure factor is measurable using spatially resolved diffuse reflectance. There are ways of predicting the static structure factor for different types of colloids [8]. Thus if we succeed in measuring a similar quantity, we can extend our model and validate the extension. This work was (in part) financed by the Centre for Imaging Food Quality project which is funded by the Danish Council for Strategic Research (contract no 09-067039) within the Programme Commission on Health, Food and Welfare. This work was also in part financed by the Digital Prototypes project funded by the Danish Council for Technology and Innovation (Resultatkontrakt).
reflectance properties as well as to demonstrate the relation between the optical parameters and structure formation in milk acidification. These measurements are compared to conventional methods such as pH, oscillatory rheology, confocal laser scanning microscopy, and sensory data.

Regression and Sparse Regression Methods for Viscosity Estimation of Acid Milk From it's Sls Features

Statistical solutions find wide spread use in food and medicine quality control. We investigate the effect of different regression and sparse regression methods for a viscosity estimation problem using the spectro-temporal features from new Sub-Surface Laser Scattering (SLS) vision system. From this investigation, we propose the optimal solution for regression estimation in case of noisy and inconsistent optical measurements, which is the case in many practical measurement systems. The principal component regression (PLS), partial least squares (PCR) and least angle regression (LAR) methods are compared with sparse LAR, lasso and Elastic Net (EN) sparse regression methods. Due to the inconsistent measurement condition, Locally Weighted Scatter plot Smoothing (Loess) has been employed to alleviate the undesired variation in the estimated viscosity. The experimental results of applying different methods show that, the sparse regression lasso outperforms other methods. In addition, the use of local smoothing has improved the results considerably for all regression methods. Due to the sparsity of lasso, this result would assist to design a simpler vision system with less spectral bands.

Classification Methods for CT-Scanned Carcass Midsections: A Study of Noise Stability

Computed tomography (CT) has successfully been applied in medical environments for decades. In recent years CT has also made its entry to the industrial environments, including the slaughterhouses. In this paper we investigate classification methods for an online CT system, in order to assist in the segmentation of the outer fat layer in the mid-section of CT-scanned pig carcasses. Prior information about the carcass composition can potentially be applied for a fully automated solution, in order to optimize the slaughter line. The methods comprise Markov Random Field and contextual Bayesian classification, and are adapted to use neighbourhood information in 2D and 3D. Articial Poisson noise is added to the provided dataset to determine how well each of the methods handles noise. Good noise handling will allow lower dose scannings. The investigated methods did not perform better than the reference model in terms of classification, but the MRF segmentation showed promising results in a case with extreme simulated noise.
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Main Supervisor:
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