The role of Raman spectroscopy in meat processing

Benefits at a glance

- In-line analysis improves processes to valorize residual meat on chicken carcasses
- Raman spectroscopy provides a non-contact, specific, and representative measurement in the laboratory or processing plant, with potential to serve as feedback-control of processes

Introduction

There are a variety of laboratory applications of Raman spectroscopy for food authenticity, product quality, and product understanding. Translating the technology to a plant environment can be facilitated through industry-government partnerships or consortia. The Norwegian Institute of Food, Fisheries and Aquaculture Research (Nofima) is a food research institute and have reported on spectroscopic analyses in food. Two papers described extension of a "toolbox" approach by Nofima researchers, using different spectroscopy techniques to control industrial food processes, identify residual bone, and measure product quality.[1,2]

Materials and methods

The two described studies apply various spectroscopy techniques for in-line fat, protein, and ash weight identification, including near-infrared (NIR), fluorescence, and Raman spectroscopy. For the Raman measurements, a hybrid variant of a Raman Rxn2 analyzer operating at 785 nm was equipped with a Rxn-20 large volumetric probe. The configuration of the large volumetric probe provided a non-contact, focus-free, and representative measurement for the heterogeneous food solids. Raman-derived parameters were compared against reference laboratory measurements. Protein, fat, and ash were measured using Nordic Committee on Food Analysis standard procedures.

A hybrid configuration of the Raman Rxn2 analyzer was used for measurements of meat byproducts

Results and discussion

The 2018 paper by Wubshet et al describes the use of NIR imaging, micro NIR, fluorescence, and Raman spectroscopy to measure fat, proteins, and ash weight of meat byproducts as received and after enzymatic hydrolysis under simulated process conditions. The end goal of these studies was integration of spectroscopic analysis as a feed-forward control basis for enzymatic hydrolysis of byproducts. There was no single technique that could predict molecular weight and total protein, and each of the techniques could predict a set of parameters well. An understanding of the underlying chemistry and how each technique can measure that chemistry gives context to the paper's major findings.

Raman spectroscopy was found to predict ash weight better than NIR or fluorescence because of the strong symmetric stretch of bone's carbonated apatite phosphate group at ~ 960 cm^{-1}. Raman was sensitive

to differences in molecular weight because the amide III and amide I envelopes reflect differences in molecular structure. A combined NIR and fluorescence approach was the best approach for predicting protein yield because of collagen-specific fluorescence emission at 440 nm and a CH overtone at 1200 nm in the NIR.

An additional study in 2019 by Wubshet et al used the Raman experimental approach developed for meat byproducts to predict calcium and ash weight in mechanically deboned chicken meat.[2] During the deboning process, small pieces of bone may be produced and these are an undesirable component of deboned meat. Calcium and ash are used as surrogates for the presence of bone, and they are typically measured using acid extraction and atomic absorption, titration, or incineration. Raman spectroscopy is an excellent tool for measuring bone and is an established technique for understanding bone composition in health and disease.[3,4] The carbonated apatite mineral has two main Raman bands: $nu_1\ PO_4^{3-}$ at ~960 cm^{-1} and $nu_1\ CO_3^{2-}$. The phosphate band at 960 cm^{-1} is very strong, unique to bone in musculoskeletal tissues, and provides good contrast between bone and unmineralized soft tissue. Thus, the authors hypothesized that Raman spectroscopy could be used to non-destructively identify residual bone in mechanically deboned chicken meat. Mixtures of mechanically deboned chicken meat and deboning residue were prepared to mimic various amounts of bone content. Large volumetric Raman spectra were collected in all 79 samples and compared to reference measurements of calcium and ash weight. Raman-based partial least squares regression of ash and calcium yielded a model with an R^2 of 0.894 and prediction error of 0.634 g/100g for % ash and R^2 of 0.775 and prediction error of 0.333g/100g for % calcium. These promising initial results establish feasibility of Raman spectroscopy in meat valorization applications.

Conclusions

Food products are complex and chemically heterogeneous, and their analysis requires a “toolbox” approach whether the analysis is performed in the laboratory or directly in a process. As a molecular spectroscopy technique, Raman spectroscopy provides highly specific information on chemical composition and molecular structure. Raman’s specificity and lab-to-process compatibility with existing process hardware enable real-time measurements of important meat quality parameters such as fat and protein content and the presence of residual bone. The papers by Wubshet et al represent the first known paper describing in-line spectroscopy to control an industrially relevant process, and speak to a growing acceptance of Raman spectroscopy in the food industry for laboratory or process analysis.

References

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