Multi-attribute salmon quality monitoring using Raman spectroscopy

Benefits at a glance

- Taste, color, and texture are three quality attributes of salmon fish meat
- Laboratory measurements of fish quality involve destructive sample preparation, time-intensive wet chemical or chromatographic analysis, and are not compatible with processing plant speeds
- Raman spectroscopy provides information on all three fish quality attributes non-destructively and rapidly, and can be performed in the laboratory or in the processing plant

Introduction

There is high consumer demand for salmon worldwide. This demand has created a need for efficiency from the raising of salmon to its processing in the plant. Rapid measurements of fat, color, and firmness, the three main attributes of fish quality, can help achieve the goal of efficient processing. Fat content is associated with taste and mouth feel.[1] Salmon meat color influences consumer perception of fish quality, and consumers prefer a deep pink color.[2] Firmness affects consumer acceptance of both raw and smoked salmon products.[3] These three quality attributes have been traditionally measured in the laboratory using titration and chromatographic techniques or, in the case of color, by visual inspection against a color card. Titration and chromatographic techniques are the “gold standard” in measuring these attributes. However, they are not amenable to in-line measurements, require destructive sample preparation, and take hours to complete a measurement. The increased demand for salmon is driving the use of novel analysis technologies that can keep pace with automated processing plants to provide a rapid and precise assessment of fish quality in-line and in real-time.

Vibrational spectroscopies such as near-infrared (NIR) spectroscopy and Raman spectroscopy are amenable to fast, non-destructive data acquisition. While NIR has been shown to be a reliable technique for measuring fat and moisture content in salmon, those attributes only report on texture. Raman spectroscopy offers the possibility of simultaneously analyzing fat, firmness, and color attributes, as well as possibly examining the interactions between these components.

Materials and methods

Raman spectra were collected from store bought samples of Atlantic salmon, wild coho, and smoked salmon. Two experiments were performed. In the first experiment, laboratory tests were performed using a Raman analyzer operating at 1000 nm equipped with a small-area (measured area~100 µm^2) contact probe. The probe was manually placed on the surface of the fish and signal collected for 10-60 seconds. In the second experiment, a Raman analyzer operating at 785 nm equipped with a large volumetric non-contact probe (measured volume ~3-6 mm^3) was used to assess compatibility with processing plant conditions. Signal was collected for 1-5 seconds. Spectra are presented without any preprocessing.

Results and discussion

Initial tests performed on store bought salmon indicate feasibility of 1000 nm excitation for laboratory measurements. The small-area probe was able to collect signal from each of these zones without significant interference from adjacent zones. Figure 1 shows representative Raman spectra from Atlantic salmon, where there are visually apparent fat-rich and muscle-rich zones. The Raman spectra are also visually different. The top spectrum contains features from mostly lipids in fat, and the bottom spectrum contains protein features. The approach of using a small-area contact probe would be applicable when more precise zonal measurements are required for quality control purposes. Notably, there were no bands observed from carotenoid pigments in spectra from Atlantic salmon. By contrast, spectra of wild

ⓘ All Raman analyzers and probes referenced in this application note are Endress+Hauser products powered by Kaiser Raman technology.

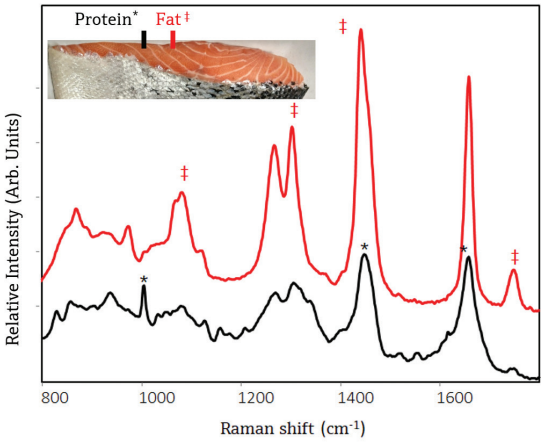

Figure 1: Raman spectra of Atlantic salmon using a small-area probe shows different chemical composition of meat and fat zones within the salmon. The top spectrum was collected from a fat zone, and spectral attributes unique to lipids are shown with a ‡. The bottom spectrum was collected from a muscle zone, and spectral attributes unique to muscle proteins are shown with a *.

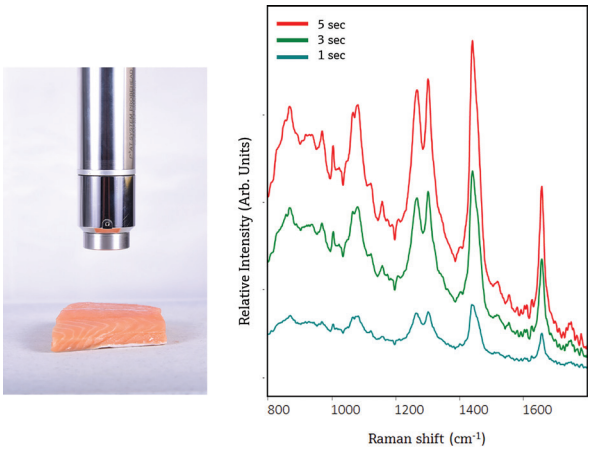

Figure 2: The large volumetric non-contact probe provides measurement of Atlantic salmon (left). The resulting Raman spectra show primarily contributions from lipids, as evidenced by the presence of narrow lipid bands at ~ 1750 cm^{-1} and 1301 cm^{-1}, a narrower Amide I envelope at ~1650 cm^{-1}, and a shifted CH^3 envelope to ~1441cm^{-1}. Spectra were not preprocessed and are offset to enable clear visualization of each spectrum.

coho salmon contained signal from carotenoid pigments, in addition to lipid and protein bands (data not shown).

Mock process measurements were performed on Atlantic salmon. The probe provides a non-contact measurement over a large volume, and the resulting spectra had contributions from the fatty and muscle portions of the tissue. Measurement times were optimized to be compatible with conveyor belt speeds. As shown in Figure 2, Raman spectra collected at 1 second, 3 seconds, and 5 seconds are suitable for input into a univariate or multivariate model with good signal-to-noise and spectral resolution. Similar to measurements collected with a contact probe, no carotenoid bands were observed in spectra from Atlantic salmon.

Conclusions

These results demonstrate the utility of Raman spectroscopy to provide a multi-attribute measurement of salmon meat quality in farmed and wild fish. The advantages of Raman spectroscopy over the standard HPLC method are manifold, including quantitation of collagen and carotenoids in addition to fat content, fast analysis on the order of a few minutes per sample, and no need for destructive or laborious sample preparation. Future studies on model development will enable rapid implementation in processing plants.

References

1. Afseth, N. K.; Wold, J. P.; Segtnan, V. H. The Potential of Raman Spectroscopy for Characterisation of the Fatty Acid Unsaturation of Salmon. *Anal. Chim. Acta* **2006**, 572 (1), 85–92.
2. Alfnes, F.; Guttormsen, A. G.; Steine, G.; Kolstad, K. Consumers' Willingness to Pay for the Color of Salmon: A Choice Experiment with Real Economic Incentives. *Am. J. Agric. Econ.* **2006**, 88 (4), 1050–1061.
3. Moreno, H. M.; Montero, M. P.; Gómez-Guillén, M. C.; Fernández-Martín, F.; Mørkøre, T.; Borderías, J. Collagen Characteristics of Farmed Atlantic Salmon with Firm and Soft Fillet Texture. *Food Chem.* **2012**, 134 (2), 678–685.