In situ meat quality control applying Raman diode laser spectroscopy at 671 nm

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Abstract

In situ meat quality control was performed on pork (musculus longissimus dorsi) applying Raman spectroscopy with a microsystem diode laser at 671 nm. With a Raman optode as handheld-sensor systematic laser measurements in parallel, with laboratory analytical methods for reference analyses were carried out. The Raman method can distinguish between ripened products and spoilage and allows even non-invasive measurements through the package.

Introduction

Meat quality control along the production chain from the slaughterhouse to the consumer is of increasing importance. Up to now, the determination of food quality is often based on empirical knowledge of experts or on time consuming and expensive laboratory analytical methods. A demand for more efficient methods is obviously, i.e. in-situ techniques which can measure fast, non-invasive and through a packaging. Optical methods, especially Raman spectroscopy, can address this.

Raman set-up and measurements

Raman spectroscopy is based on the inelastic scattering of light and the excitation of vibrational and rotational modes of molecules. This causes a red shift of scattered photons, the so-called Stokes shift. These spectra, which deliver information on type and composition of the sample, were often called “fingerprint” spectra. Another advantage of this method is that no interferences from water (80 % in the meat) occur. The method is used for the investigation of the condition of biomolecular components during the aging process of meat.

Particularly suitable for Raman spectroscopic field applications are diode laser because of their small unit sizes and low power consumption. We introduce a specifically designed Raman sensor with a micro-system based external cavity laser (ECL) with reflection Bragg grating diode laser emitting at 671 nm. This wavelength is the minimum in the absorption band of the heme molecule, i.e. with this minimal absorption we reach a sufficient penetration of the laser light in the depth in meat. In Figure 1 the scheme of the diode laser is shown. The spectral line width of the diode laser is below $\Delta\tilde{\nu} = 10\ cm^{-1}$, i.e. $\Delta\lambda = 0.1$ nm and the optical power should be larger 200 mW. Up to now compact diode lasers with these specifications, especially with internal gratings to achieve the necessary small spectral line-width, are not available – diode laser with typical spectral widths of about 1 nm are not suitable for Raman spectroscopy.

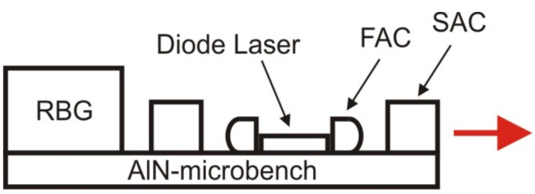

Figure 1. Scheme of the 671 nm diode on a AIN micro-optical bench with a length of 13 mm and a width of 4 mm – FAC: fast axis collimator, SAC: slow axis collimator, RBG: reflection Bragg grating.

The micro system diode laser was integrated on an optical bench containing lenses and filters for collecting and filtering of the Raman signal. The Raman optode is shown in Figure 2. The sensor exploits the fingerprinting characteristics of Raman spectra for substance identification and is able to follow the physicochemical and biochemical changes upon aging of meat. Time dependant spectroscopic measurements are performed with *musculus longissimus dorsi* (pork) as test sample stored under well defined conditions, i.e. aged for up to 4 weeks at 5°C. In parallel, laboratory analytical methods are applied for reference analyses.

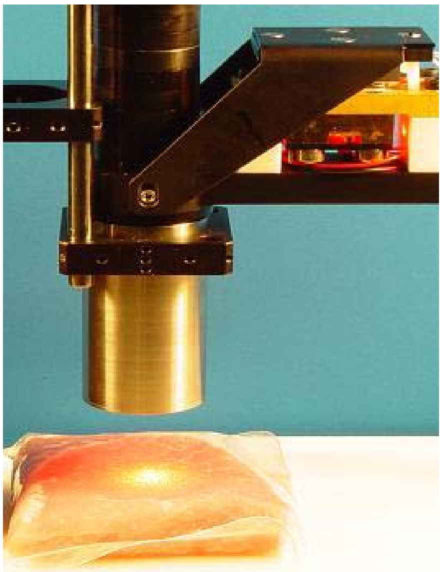

Figure 2. Raman optode working in 180° backscatter geometry (length: 200 mm, diameter 30 mm) – measurement of meat through the package.

Results

A distinction between fat, meat and bone is possible as well as the measurements through the package. The latter measurement is shown in Figure 3. In the top trace the measured spectrum of meat in the package is shown, in the middle the spectrum of the meat itself. The differences are obvious. The spectra of the pure meat can be determined simply by calculating the difference spectra. Meat can be identified by the typical peaks of a protein spectrum, e.g. the amid I band at 1650 cm^{-1}. This proves that the method is well-suited for a measurement through the package.

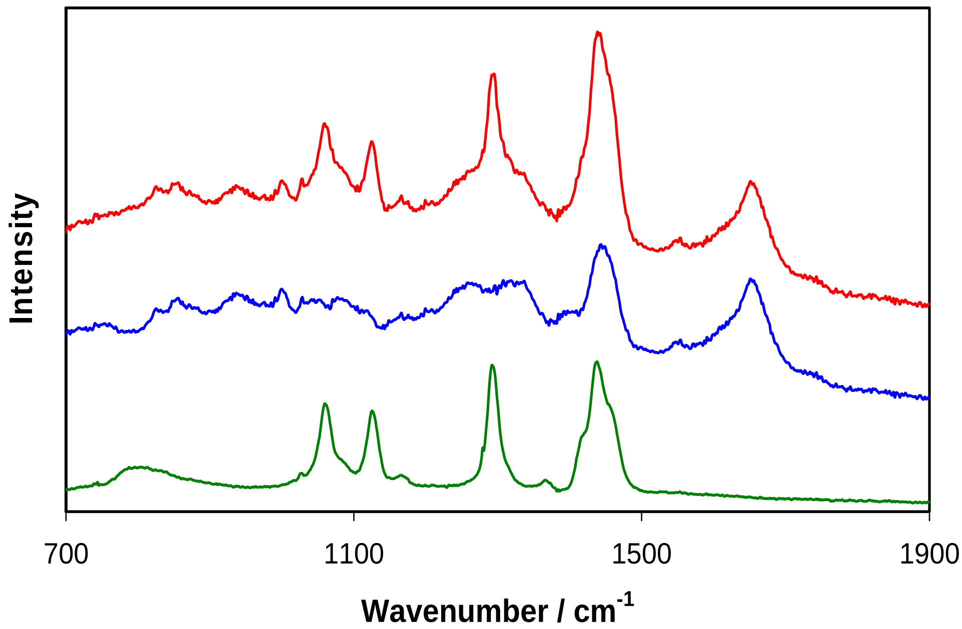

Figure 3. Raman spectra of meat through the package (upper curve), package (lower curve) – meat (middle).

Data are evaluated by chemometrical methods. Principal components analysis (PCA) of the Raman data can identify changes of structure and composition of the protein matrix. This allows to distinguish ripened meat and incipient spoilage for the storage at 5°C. For the meat investigated spoilage starts at day 9 – see Figure 4. This result correlates to measurements performed in parallel in the microbiogical laboratory.

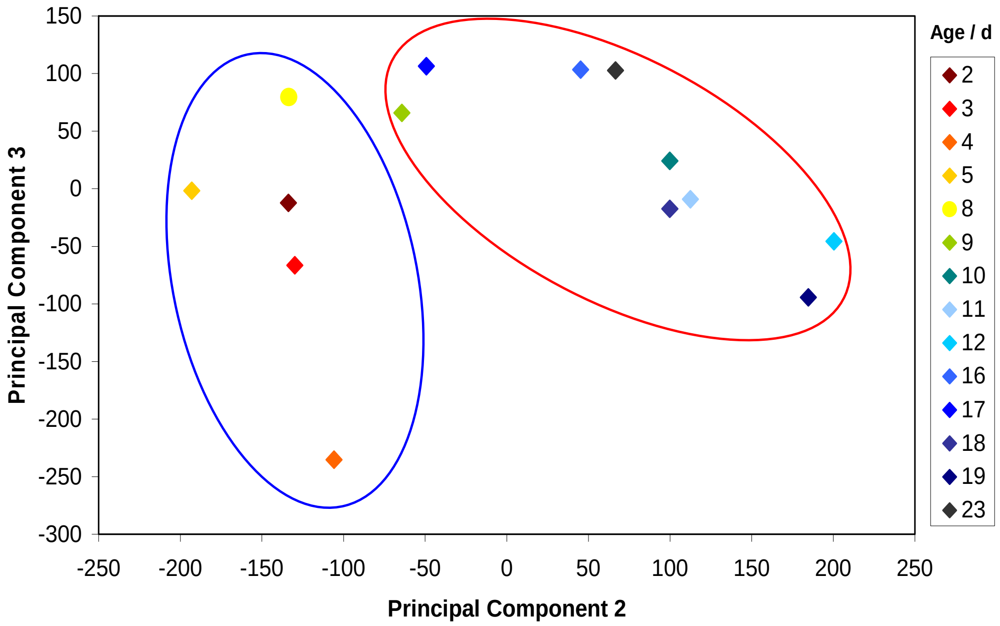

Figure 4. Statistical analysis (PCA) of the Raman spectra. Distinction of Raman spectra evaluated by principal components (scores of PCA) between day 8 and 9 of storage at 5 °C.

Outlook

These initial result shows that Raman spectroscopy is well suited as tool for food quality control. The method can distinguish between ripened products and spoilage and allows measurements through the package. The combination of Raman spectroscopy and micro-system diode laser technology to design a compact Raman optode is promising. A further miniaturisation will deliver a compact handheld laser scanner for the *in situ* food control.

Although the applicability of the method was particularly demonstrated for meat, the concept can be implemented to other foodstuffs by adapting the excitation source and the optical elements.

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