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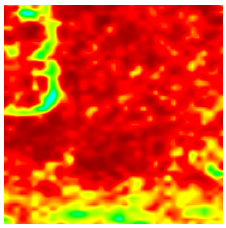
Raman Spectroscopy

Fat acids characterization for food quality using Raman Spectroscopy



Application Note

Food Beverage RA51

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Abstract

Raman Spectroscopy was used as a probe for the analysis of fatty acids. The presented examples show that this technique can be used for characterisation of fats of both animal and vegetal origins.Two experimental configurations were used: backscattering and transmission, involving different analysis methods: point measurement, XY mapping and multivariate analysis.

Key words

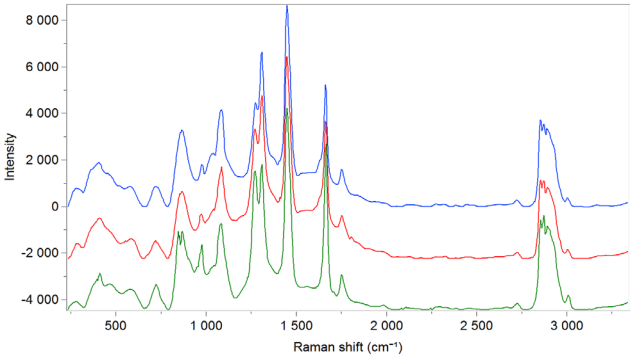
fatty acid composition, adulteration of vegetable oils, adipose tissue, transmission Raman, Raman mapping, food quality

Introduction

The fatty acid composition of foods dictates a diversity of aspects regarding food quality, ranging from product shelf life and sensory properties such as taste and texture through to nutrition and the impact on health aspects. It also reflects factors like feeding regimes, animal metabolism and even genetic origin. Consumer awareness on human health and food products has increased in recent years, not least related to fat consumption. Efficient and reliable methods for characterisation and documentation of the fatty acid profiles of food products are thus of great importance in industrial applications, as well as for research purposes. Raman spectroscopy is known to be a sensitive probe for qualitative and quantitative characterisation of fatty acid composition, ranging from gross fatty acid features to single fatty acids. Raman spectroscopy also provides multiple sampling possibilities for analysis of lipid containing samples at the macro and micro scale. Being rapid, non-destructive and highly chemical sensitive, it brings an alternative to traditional methods, for addressing problems such as adulteration, quality control, or advanced research about fats and oils.

Characterisation of vegetable oil blends

The adulteration of vegetable oils is a huge challenge in the food industry, as lower quality or cheaper oils may substitute the more expensive ones. Figure 1 illustrates Raman spectra of vegetable oils and oil blends. The top figure shows the clear spectral signature differences between olive oil (a highly mono-unsaturated oil), sunflower oil (a highly polyunsaturated oil), and a blend of the two. The bottom figure shows the Principal Component Analysis score plot of duplicate Raman spectra of olive oil (O), sunflower oil (S), fish oil (F), and 60- 40 blends of all oils (capital letters denote the most abundant oil). This illustrates the ability of Raman to characterize oils, making it a useful tool for determining the composition and the real quality of a given oil blend.



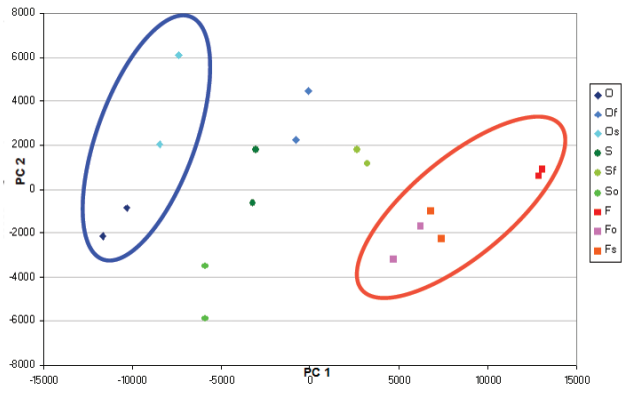


Figure 1: Upper: Raman spectral signatures of olive oil (blue), sunflower oil (green), and a blend of the two oils (red). Lower: Principal Component Analysis score plot of duplicate Raman spectra of pure oils and oil blends. Along the first PC, a clear separation according to carbon-carbon unsaturation is visible (increasing from olive oil to fish oil).

Characterisation of the lipid composition of bovine tissue at the microscale

Utilising the high spatial resolution of Raman microscopic systems gives the possibility of studying and document specific lipid features within cell populations as well as biological tissues and food products.
In figure 2, bovine adipose tissue is analysed by focusing on the lipid-rich parts of intact bovine tissue. What is especially interesting in the Raman spectra of adipose tissue is the different aspects related to the configuration of the carbon-carbon double bonds. In this respect, the C=C stretching vibration around 1660 cm^{-1} is particularly sensitive. For instance, in the spectra of figure 2 a clear shoulder on the right side of this band is seen, which is related to the trans-configuration of the double bonds. Varying influences from the protein-matrices could also be revealed in the spectra.

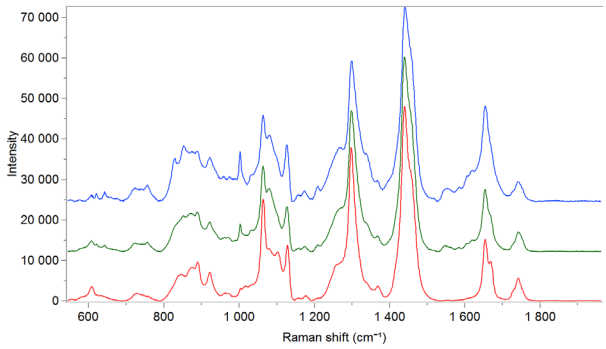


Figure 2: Microscopic Raman analysis of bovine adipose tissue. All spectra are obtained with a Raman microscope (785 nm).

These local differences can be viewed on larger scale by performing mappings of an area of a sample. A bovine adipose tissue is analyzed under the Raman microscope over an area of 1.2 x 1.2 mm. Figure 3 shows the distribution of the trans-configuration of the double bond of the fatty acids over the mapped area.

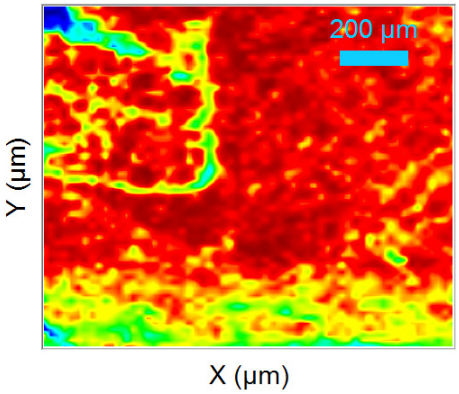


Figure 3: Raman image of the trans-configuration distribution of a 1200 x 1200 µm bovine adipose tissue sample, using a 785 nm excitation.

Reproducible characterisation of adipose tissue employing transmission Raman spectroscopy

The previous example demonstrates the local differences observed in adipose tissues. Variation of composition in fatty acids was also established between the different fat layers (outer and inner) of adipose tissues. In that respect, being able to get an averaged spectrum of a bulk sample is necessary, if global information is required.
Transmission Raman spectroscopy provides such averaged information: by collecting the Raman transmitted light over a large area, the resulting spectra will be representative of the whole sample, independent of local variations.
Adipose tissues of lamb, veal and pork chops were measured in transmission: samples of various sizes and thicknesses were analyzed without any preparation by transmission Raman spectroscopy.

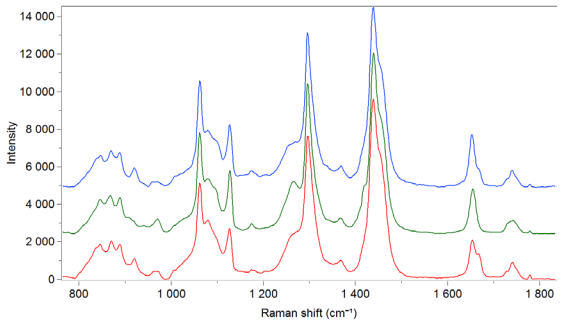


Figure 4: Transmission Raman spectra of adipose tissues from different species (lamb, pork, veal) using the transmission accessory operating at 785 nm.

Raman spectra give multiple indications about the sample composition. For example, trans fatty acids are readily observable from the spectra: the peak at 1668 cm^{-1} is directly linked to the trans configuration of the C=C double bond of fatty acids. The consumption of trans fats increases the risk of health problems and is therefore submitted to regulations in many countries.
In a similar way, Raman spectra could be used to derive quantitative information about the fatty acid profiles.

Classification of species according to the Raman signature of their adipose tissues is also possible, as shown by the score plot in Fig. 5.

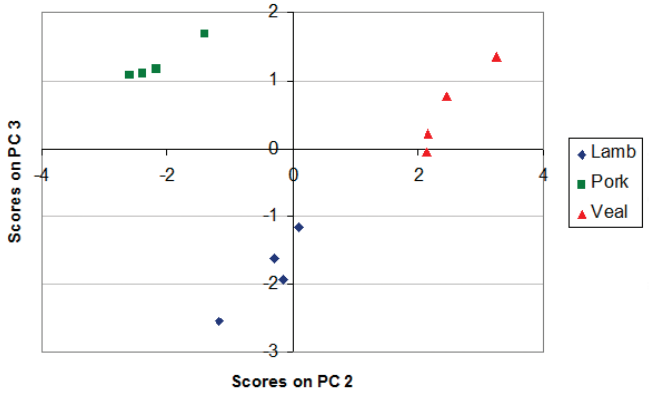


Figure 5: Principal component analysis score plot of samples of lamb, pork, and veal adipose tissues.

Conclusions and perspectives

This opens the door to a rapid and non-destructive characterization technique, an alternative to wet chemical methods which may be costly, time consuming, and require sample preparation. This would also allow more systematic control of foodstuffs on a wide range of analysis, giving rapid indications about food quality, origin and potential adulteration of products. The use of a single instrument provides information on bulk scale (including the transmission option) as well as on microscale.

References

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