A Portable Spectrum Measurement System Based on Laser-Raman and Fluorescent Spectrum for Cooking Oil Analysis

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Abstract: A system based on spectrum analysis for cooking oil testing which combining laser-induced-fluorescence and laser-Raman technology is established. Several oil samples are testing by this system. The measurement results show that, there are rich information for fluorescence and Raman spectrum for the oil samples and there are obvious difference between the fluoresce spectrums for these samples, which can be used as a reference for oil pollution classification and recognition. This technology can be used for in-situ monitoring equipments.

Introduction

The occurrence of large food safety issues over these years has resulted in a decline in public trust in China. Representative examples of issues that have emerged in the last decade include melamine, clenbuterol, abandoned edible oils, etc. There is a need for early identification of emerging food safety issues in order to prevent them from developing into health risks⁵. Abandoned edible oil is a very serious problem for the food safety of China. It comes back to dinning table again and again⁶. At present, we have much difficulty in how to situate rapid detection and prevention.

Cooking oil testing has traditionally relied upon chemical methods, such as GC, HPLC, MS, GC-MS, etc. These classical approaches are delicacy, accurate and nearly complete. However, most of them need large instruments, professionals, expensive testing costs, and complicated pretreatment⁴. Due to these drawbacks, traditional devices are limited in sampling tests in lab and have difficult in online real-time monitoring. There is a compelling case to be made for advances in situ detection and analysis⁵.

Raman spectrum analysis technology has been developed in these years. It has been proved to be fast, real-time, less reagent, and remotely operated. Moreover, since the band intensities caused by OH stretching vibrations are weak in Raman spectra, a water-rich sample can be directly analysed⁶. Besides, the development of laser has impelled the spectrum analysis technology to mature. Surface-enhanced Raman spectrum (SERS) and laser-induced fluorescence spectrum (LIF) have made great progress in high sensitivity test⁷. As one of the most sensitive detection technique, LIF detection technology has been applied to many fields such as biology, chemistry, environment, medicine, etc⁸. The development of LIF technology is extremely fast. And the recent advance in LIF detection system, fluorescence probes, fluorescence analysis technology and application has been introduced⁹. Additionally, sensor design and electronics are becoming increasingly sophisticated and much less expensive¹⁰. All of them make the popularity of portable detection become possibility.

The main ingredients of abandoned edible oil are the mixture of vegetable oil and animal fat. After high-temperature processing, the oxidation and hotpolymerization of various fatty acid of abandoned edible oil leads to the increase of saturated fatty acid. During the process, the pyrolytic polymer, such as fenalamide, benzene-2-roasted, etc, has been released. Because of these
special material released in the secondary operation, the LIF spectrum and Raman spectrum performances of recycled oils is different from common cooking oils. These spectrums, like people’s fingerprint, can be used as the basis identification of cooking oil.

In this paper, we describe the design and performance of a portable measurement system based on Laser-Raman and fluorescence spectrum in fast testing of cooking oil.

**Description and Instrument**

Fig. 1 shows a detailed schematic diagram of the portable spectrum measurement system. The excitation wavelength of fluorescence detection system is 405 nm. After passing the Precision Fiber Optical Couple, emitted light enters into Y optical fiber. Y optical fiber is an integration of a few optical fibers. Fig. 2 shows its profile. The six peripheral fibers (named A in Fig. 2) communicate emitted light, and on the other side they are linked together with Precision Optical Fiber Coupler by SMA905. The middle fiber (named B in Fig. 2) is used to collect light. After going through an optical filter, fiber B is interfaced with Fluorescence spectrometer by SMA905. The detection range of fluorescence spectrum is 200-1100 nm. Similar structure is adopted in Raman spectrometer. However, there is one differentia. Due to high requirements of light source, pigtail laser with 785 nm wavelength is adopted as the excitation source in Raman spectrometer. The effective detection range of Raman spectrum is 150-3900 cm\(^{-1}\).

**Experiment**

![Fig. 1 The spectrums detection system for oil analysis](image1)

![Fig. 2 The profile for optical fiber probe](image2)

![Fig. 3 The fluoresce spectrums comparison of several peanut oil and waste oil](image3)

![Fig. 4 The Raman spectrum comparison of peanut oil and waste oil](image4)

![Fig. 5 The Raman spectrum comparison of the different bonds of cooking oil](image5)

**The spectrum comparison of cooking oil and recycled oil.** Fig. 3 shows the LIF emission spectrum of lampblack oil, abandoned edible oil, pure squeezing peanut oil, one brand peanut oil in the wavelength region of 200-1100 nm. From the measuring results, all oils are characteristic of strong fluorescence emission. And all the four types of samples have a strong emission peak at the wavelength around 560 nm (marked as the first characteristic peak in Fig. 3, C lampblack oil, D abandoned edible oil, E pure squeezing peanut oil, F one brand peanut oil).
The second characteristic peak of pure squeezing peanut oil is around 660 nm, while some brand peanut oil’s are around 670 nm. In the emission of pure squeezing peanut oil, the second characteristic peak is higher than the first one. While the second characteristic peak of the brand peanut oil is quite as strong as the first one. The main reason is that the double bonds of nature fatty acids are generally cis conformation. And raw oils have high degree of unsaturation and bad stability[8]. After heating, the cis conformation of cooking oils would be damaged. This leads to the above situation. Fig. 4 shows the Raman spectrum of peanut oil and waste oil. The Raman spectrum of peanut oil is clearer and less miscellaneous peaks. Around the wave number of 3000, peanut oil has strong emission, while waste oil has almost no emission.

Comparison of the different bonds of cooking oil. Fig. 5 shows the Raman spectrum of the different brands of cooking oil. All of them have two characteristic peaks, at around 800 cm⁻¹ and 1020 cm⁻¹. Furthermore, the other small peaks look like in the same location. Therefore, the main ingredients of the oil are alike. However, they are different in relative intensity. The Raman spectra relative intensity is only related to the component content of the oil, and these differences are resulted from their production process.

Conclusion

This paper introduces a kind of fast detection system of cooking oil based on spectrum analysis. Several typical oil samples were measured and analyzed by the system. The results showed that fluorescence spectrum and Raman spectrum of recycled oil were different from those of vegetable oil. In the fluorescence spectrum, recycled oil has less characteristic peaks compared with vegetable oil. And cooking oil made from different processing technology has different peak height ratio. In the Raman spectrum, the peaks of recycled oil are excessive and dense. Moreover, it has few peaks around 3000 cm⁻¹, while vegetable oil has characteristic peaks in this region. These remarkable differences provide new ideas in the fast detection of cooking oil security.

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