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SPECTRAL CHARACTERISTICS OF EXTERNAL LAYER OF ONION BASED ON FOURIER TRANSFORM SPECTROSCOPY

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Abstract: With the Fourier transform spectrometer, the spectral characteristics of the instrument were studied in natural light environment and dark room environment.The Fourier transform spectrometer was used to detect the spectra of different positions of onion epidermis and analyze the spectral information.The study shows that the characteristic wavelength deviations obtained in two different environments are small, with the maximum value only 0.4nm, and the maximum relative deviation is 0.38%, which is less than 5%.The deviation values of both are small, reflecting the advantages of very high wave number and wavelength accuracy and strong anti-interference ability;in the spectral analysis of the outer epidermis of onion, it is found that the spectral information in front of the detector is more differentiated compared to other locations and contains more spectral information, and the detection is more effective.
Keywords: Bio-optics; Fourier transform spectroscopy; Epidermis; Onion; Spectral analysis

1 INTRODUCTION

Onion is a perennial herb in Allium of liliaceae, which is composed of fleshy scales and scale buds[1], and its components contain natural chemicals that can produce meat flavor.According to research, only allium plants can produce meat flavor, so the current food industry will use Onions and scallions as raw materials to obtain plant-based "natural" meat seasoning[2].It can be seen that Onions have great application value in daily diet[3-4].In the process of growth, due to the spraying of pesticides, pesticide residues after maturity, harmful to human health.Secondly, there are harmful substances in the soil conditions and environment involved in the growth process of onion, resulting in the mature onion containing harmful ingredients[5] to human body, and then causing diseases[6-7] Therefore, it is very important to test the composition of onion.At present, various detection technologies have been studied.For example, toxicological analysis and composition of onion's composition and structure have been carried out with the help of physical-chemical analysis technology[8-9], fluorescence analysis technology[10-11] and other optical detection technologies, so as to determine whether onion is healthy[12].
Fourier transform spectrometer, as a high-precision and high-sensitivity spectrum acquisition technology[13], has a strong application in the field of food detection, and can be used for multi-spectral detection of onion epidermis.In this paper, Fourier transform spectrometer was used to compare and analyze the difference of the acquisition environment of the instrument, and the spectral information of onion outer skin was detected.The spectral information of onion outer skin after removing the influence of light source was analyzed to seek the best detection position[14-15].

2 PRINCIPLE OF FOURIER TRANSFORM SPECTROMETER

The detection light source of the Fourier transform spectrometer is multi-color light, and for multi-color light, its light intensity[16] is:

$$I_{R(\Delta)}=\int_0^{\infty} I_{(\Delta,\sigma)}\mathrm{d}\sigma= 2RT\left[\int_0^{\infty} E_{0(\sigma)}^2\mathrm{d}\sigma+\int_0^{\infty} E_{0(\sigma)}^2\cos(2\pi\sigma\Delta)\mathrm{d}\sigma\right] \quad (1)$$

Where $R=r^2$ is the reflectivity and $T=\mathrm{t}^2$ is the transmittance.In the formula, the first term is a fixed value, and the second term is changed with the optical path difference, which is called an interferogram, when $\Delta=0$ both $\cos(2\pi\sigma\Delta)$ are equal to 1, then the coherent light intensity $I_{R(\Delta)}$ value is the largest, that is:

$$I_{R(\Delta)}-1/2\,I_{R(0)}=2RT\int_0^{\infty} E_{0(\sigma)}^2\cos(2\pi\sigma\Delta)\mathrm{d}\sigma \quad (2)$$

The left side of the above formula is the interferogram measured by the detector, and the right side is the cosine transform expression, The $E_{0(\sigma)}^2$, which is called the spectral intensity in spectroscopy $B_{(\sigma)}$, and RT is a constant that can be omitted.In the ideal case, $I_{R(\Delta)}-1/2\,I_{R(0)}$, it is a real function, and it is an even function form. Therefore, according to the principle of Fourier transform[17-18], Fourier transform can be used to replace the cosine transform, that is, the spectral intensity obtained is:

$$B_{(\sigma)}=\int_{-\infty}^{\infty}\left[I_{R(\Delta)}-1/2\,I_{R(0)}\right]\mathrm{e}^{-\mathrm{i}2\pi\sigma}\,\mathrm{d}\Delta \quad (3)$$

3 EXPERIMENTAL MATERIALS

The experimental instrument was LSPF-1 Fourier transform spectrometer with a spectral range of 400~800nm.The experimental sample was onion. After rinsing with water, the outer red skin of onion was peeled off. The skin area of different skins was 1cm×1cm, and the thickness was 0.071mm. The experimental environment was room temperature.

4 RESULTS

4.1 Spectrum of Mercury Lamp Light Source in Different Environments

When no samples were placed, the spectra of mercury lamps in dark room and natural light were measured by the two light sources respectively, as shown in Fig. 1 and Fig. 2.

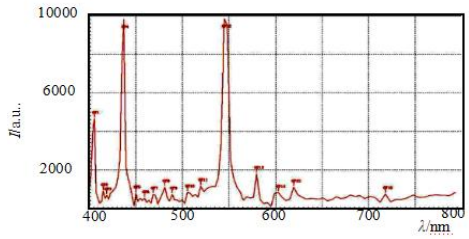

Figure 1 Spectrum of mercury lamps in natural environments

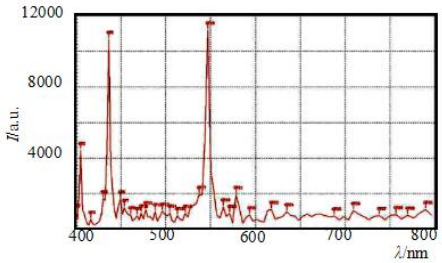

Figure 2 Spectrum of mercury lamps in a dark room environment

The characteristic spectral line wavelength of mercury lamp under natural light and dark room conditions was recorded through the self-owned peak-seeking software of the instrument, and the comparison and error analysis were made with the theoretical value[19-20]. Table 1 shows the error analysis of experimental and theoretical values of wavelength.Where, δ Nature-theory, δ darkroom-theory, and δ nature-dark room represent the relative error in the two cases, for short δ N-T, δ A-Tand δ N-A, and Dnature-anechoic room represents the characteristic wavelength deviation in the two environments, namelyDN-A.

Table 1 Error analysis of measured and theoretical characteristic wavelength of mercury lamp

Characteristic Line	theory (nm)	λmeasurement - natural light (nm)	Λmeasurement- dark chamber (nm)	δNature - Theory	δdark chamber-theory
Deep Violet	404.7	405.6	405.4	0.22%	0.17%
Violet	435.8	437.0	436.6	0.28%	0.18%
Green	546.1	544.9	547.0	0.22%	0.16%
Yellow light	577.0	579.9	578.4	0.50%	0.24%

According to the δ_{N-T} in Table 1, the relative error of wavelength of green and deep violet spectral lines is 0.22%, while that of yellow spectral lines is slightly larger (0.50%) under natural light environment. According to the δ_{D-T}, the relative error of the wavelength of green, violet and deep violet spectral lines is small (0.17%) in the dark chamber, while the relative error of the wavelength of yellow spectral lines is slightly larger (only 0.24%).These indicators fully reflect that the Fourier transform spectrometer has a very high wave number or wavelength accuracy, and the relative error of spectral line wavelength is in the range of 0.16% to 0.24%, which is an ideal index for practical applications.If ultra-precision analysis and testing are carried out, it is appropriate to choose the short-wave segment scheme under dark room conditions.

The characteristic wavelength deviation DN-D∈ [-2.1, 0.4]nm and its relative deviation δN-D∈[0.049%, 0.38%] are very small, which indicates that Fourier transform spectrometer has strong anti-interference ability to external light and can meet the requirements of fine spectral analysis.Considering the tightness of the spectral apparatus and the weak

influence of stray light on the spectrum, in order to ensure the accuracy of the experimental results, the biological sample experiment is chosen to be carried out in the dark room.

4.2 Spectrum of External Layer of Onion Under Different Placement

A mercury lamp light source was used in the Fourier transform spectrometer to measure the transmission spectra of the light source placed in front of the detector, in front of the moving mirror, and behind the light source in order of the light propagation direction, as shown in Fig 3, Fig 4, and Fig 5, where the horizontal axis represents the wavelength and the vertical axis represents the relative intensity of the spectrum.

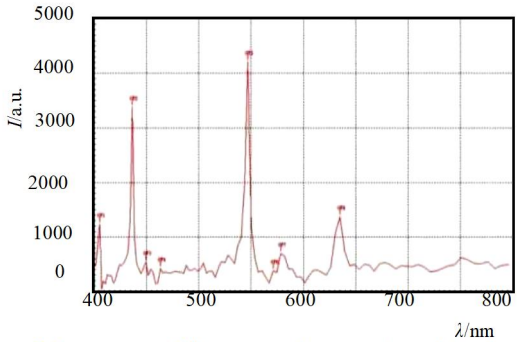

Figure 3 Spectrum of "mercury lamp-onion skin-detector front"

4.2.1 The external layer of onion is placed in front of the detector

It can be seen from Fig 2 and Fig 3 that the spectrum of the external layer of onion placed in front of the detector is somewhat similar to that of the sample not placed in the dark room of the mercury lamp.The changes of 5 characteristic wavelengths of the dark room of the mercury lamp light source and the external layer of onion in front of the detector are shown in Table 2.

Table 2 Changes in the wavelengths of the first five features of the detector

Wavelength (nm)	405.4	436.6	547.0	578.4	635.0
Mercury lamp	4429.0	10664.8	11199.1	1950.8	978.3
Onion	1236.3	3377.1	4206.8	692.2	1370.0
Δrelative light intensity	3192.7	7287.7	6992.3	1258.6	-391.7
relative light intensity	0.279	0.317	0.376	0.355	1.400

It can be seen from Table 2 that after placing the sample, characteristic spectral lines appear at the wavelength of 635.1nm, and the relative light intensity decreases at the wavelength of 405.4nm, 436.6nm, 547.0nm and 578.4nm, and increases at the wavelength of 635.0nm (red-orange light), indicating that the light transmittance of onion outer skin at 635.0nm is weak.The change of relative strength is large, (-391.7~7287.7), and the change rate of relative strength is (0.279~1.400).

4.2.2 The external layer of onion is placed in front of the moving mirror

As can be seen from Fig 2 and Fig 4, relative light intensity of the spectra of onion outer epidermis when placed in front of the moving mirror and without the sample (under the condition of mercury lamp darkroom) is reduced, because when the onion outer epidermis is placed in front of the moving mirror, light propagates through the sample twice, resulting in a certain weakening.The changes of 5 characteristic wavelengths of mercury lamp light source darkroom and onion outer skin before moving mirror are shown in Table 3.

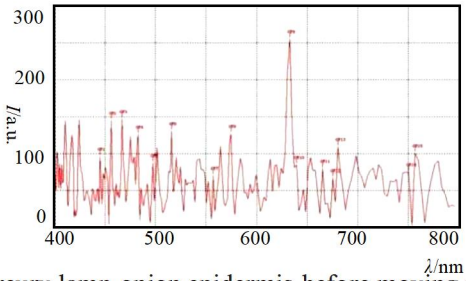

Figure 4 Mercury lamp-onion epidermis-before moving microscope spectra

Table 3 Changes in the wavelengths of the first five eigenlengths of the moving mirror

Wavelength (nm)	405.4	436.6	547.0	578.4	635.0
Mercury lamp	4429.0	10664.8	11199.1	1950.8	978.3
Onion	142.7	144.7	128.2	128.5	253.9
Δ relative light intensity	4286.3	10520.1	11070.9	1822.3	724.1
The rate of change of relative strength	0.032	0.014	0.011	0.066	0.259

As can be seen from Table 3, when the outer skin of onion was placed in front of the moving mirror, the relative light intensity decreased at 405.4nm, 436.6nm, 547.1nm, 578.5nm and 635.1nm.Compared with no samples placed (under the condition of mercury lamp darkroom), the decrease of light intensity at 635.1nm was much smaller than that at other wavelengths.The change of relative strength is large, (724.1~11070.9), and the change rate of relative strength ∈(0.011~0.259).

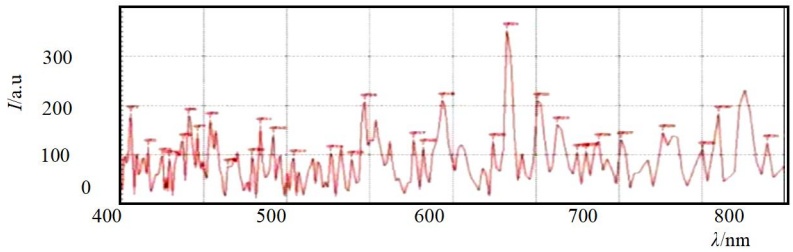

Figure 5 Mercury lamp-onion skin-before spectrum after light source

As can be seen from Fig 2 and Fig 5, the relative light intensity of the spectra of the onion outer skin after the light source is decreased compared with that without the sample(under the condition of mercury lamp darkroom), because when the onion outer skin is placed under the light source, some light rays are blocked through the onion skin and the light intensity is weakened.The light beam after passing through the sample is divided into two beams of interference light after passing through the beam splitters, and its intensity is further weakened.Therefore, the spectral patterns obtained are very different and the relative light intensity is significantly reduced.As can be seen from Fig 4 and Fig 5, the spectral line peak value of onion outer skin placed behind the light source and in front of the moving mirror is dense, and the spectral line similarity is high.There are characteristic spectral lines at the wavelength of 632.7nm, and the relative light intensity decreases significantly.The changes of 5 characteristic wavelengths in the dark room of mercury lamp light source and onion outer skin after light source are shown in Table 4.

Table 4 Changes in the wavelengths of the first five eigenlengths of the moving mirror

Wavelength (nm)	405.4	436.6	547.0	578.4	635.0
Mercury lamp	4429.0	10664.8	11199.1	1950.8	978.3
Onion	184.4	127.7	208.8	131.1	352.9
Δ relative light intensity	4244.6	10537.1	10990.3	1819.7	625.4
The rate of change of relative strength	0.042	0.012	0.019	0.067	0.361

As can be seen from Table 4, after the outer skin of onion was placed in the light source, the relative light intensity decreased at the wavelengths of 405.4nm, 436.6nm, 547.0nm, 578.4nm and 635.0nm.The change of relative strength is large, (625.4~10990.3), and the change rate of relative strength is (0.012~0.361).

Through comparison at different positions, when placed in front of the detector, because the two beams of light have interfered, the light absorption is less after passing through the onion skin, so the spectrum is similar to the spectral line compared with the sample without being placed, but the relative intensity is weakened.The sample was placed in front of the moving mirror, and the light beam passed through the onion skin twice, and the light absorption was more, and the relative light intensity decreased more.After the light source is placed, part of the light is absorbed through the onion skin, and the light intensity is also weakened, so the obtained spectral map has a large difference and the relative light intensity is significantly reduced.Therefore, spectral acquisition can be performed before the detector is selected in order to obtain more spectral information.

5 CONCLUSION

Through the study of spectrum acquisition environment, Fourier transform spectrometer has strong anti-interference ability and is suitable for weak signal detection.By comparing the interferogram of different positions, the three positions all showed that the characteristic spectral line appeared at the wavelength of 635.1nm on the external layer of onion, and the spectrogram placed in front of the detector was still obvious, indicating that the interference effect was relatively good, and it could be used as the best position for the detection of onion spectral information.

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COMPETING INTERESTS

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