Spectroscopic Study of Green Tea (Camellia sinensis) Leaves Extraction

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Abstract. This paper reports the analysis of UV-VIS-NIR absorption spectra of different concentrations of green tea (Camellia sinensis) leaf extract in two different solvent systems (chloroform and ethyl acetate). In those solvents, two different peaks characterizing green tea are observed at different wavelengths, namely 296 nm and 329 nm (extracted in chloroform) and 391 nm and 534 nm (extracted in ethyl acetate). We then investigated the absorption spectra change as function of green tea concentration in both solvents. We found that light absorption increases linearly with the increase of green tea concentration. Different wavelengths, however, respond this change differently. However, the way it changes is wavelength dependence.

1. Introduction
Tea is one of widely consumed traditional beverages. Different countries have different way on looking at tea and thus forming a different tea culture. This unique culture includes the way tea is produced and consumed as well as the aesthetics of tea drinking. British tea culture and Chinese tea culture are two important examples not only on how tea is served but also on tea preparation. In part of China, the tea beverage is prepared by brewing with salt and butter.

In addition to being a fresh drink, tea has also been used as traditional herb which has many benefits for human health such as improved brain function, fat loss and a lower risk of cancer. For whatever reason the tea is consumed, maintaining the tea quality is very important. For a given tea drink quantity, a quality standard to meet to the general people’s flavour has to be taken. This means that density of a chemical substance characterizing the tea flavour for a given quantity has to be relatively constant.

Up to now, laboratory based analysis is still considered as the most accurate and reliable methods used to determine the quality as well as the variety of green tea. This outstanding method, however, are time consuming and expensive. To overcome this problem, many efforts have been devoted in order to develop both method and an instrument for analysing green tea simply, cheaply and accurately. Among them are methods and instrument used to determine the content of green tea [1-5] as well as to identify the green tea varieties [6].

In the last few decades, fibre sensors have received increasing attention due to their unique physical properties such as small size, flexible, and immunity to electromagnetic interference. Nowadays, fibre sensor haven been used in almost all areas where conventional sensors have long been regarded as the prime sensors [7 – 9]. Optical fibre liquid and gas sensors have also been researched over years [10-11] and many of them are already available in the market. This paper presents an early study aims at determining the absorption peak characterizing green tea as function of its concentration using fibre sensor works based on evanescence wave absorption.
2. Principle of operation and Experiment

Evanescent field based Fibre sensor reported in this paper works in the same principle as UV-VIS-NIR spectrophotometer. As polychromatic light passes through a transparent material, light at a wavelength \( \lambda \) corresponding to energy difference between ground state and excited state of a substance composing the material will be absorbed. The amount of light absorbed is determined by the absorbing substance concentration.

Whereas absorption process by a substance in UV-VIS_NIR spectrophotometer occurs along the transmission line, the process in evanescence fibre sensor occurs at certain area at which electromagnetic field of the light transmitting through optical fibre penetrates out of the fibre area and interacts with the surrounding substances. In this type of fibre sensor, the absorbed light depends not only on the concentration of the absorbing substance but also on the electromagnetic field depth penetration \( (d_p) \) as expressed by:

\[
d_p = \frac{\lambda}{\sqrt{n \sin^2 \theta - n^2}}
\]

(1)

Where \( \lambda \), \( \theta \), and \( n \) are light wavelength, incident angle at core-peeled cladding interface, and core refractive index respectively.

Evanesence fibre sensor used in this experiment was made by removing part of the POF. This was done by polishing POF which was mounted on the surface of the resin bar. Polishing this surface gently using 5000 grit of abrasive polishing paper will unclad part of the POF.

Figure 1 is the experimental setup used to measure the absorption spectra of samples using evanescence fibre sensor. One end of the POF was coupled to a white (polychromatic) light source and the other end to a spectrophotometer. The sensing element of the sensor was placed in liquid cell. As the white light was launched from one end of the fibre, light will propagate in the fibre core with multiple total internal reflections (TIR). Light is propagating through fibre optic by mean of multiple internal reflections. Since the clad of the sensing element was removed, the evanescence wave within this area leaks into the material surrounding the unclad fibre. If the material contains a substance with electronic energy different between ground state and an exited state correspond to any wavelength within the range of the launched light, part of the leakage light (evanescence wave) is absorbed. Therefore, the intensity of light at a particular wavelength coming out at the end of the fibre sensor decreases. In this experiment, the absorption strength will then be detected by spectrometer and displayed by personal computer (PC).

![Figure 1. The experimental setup used to measure absorption spectra of green tea. (1) light source, (2) Polymer optical fibre, (3) unclad fibre sensor, (4) liquid cell, (5) spectrometer (6) PC](image)

3. Results and Discussion

Figure 2 shows absorption spectra of green tea recorded at room temperature using UV-VIS spectrophotometer both for those extracted in (a) chloroform and (b) ethyl acetate. It can be seen from figure 2 that absorption peaks characterizing green tea extraction in both solutions are different. Green tea extract in chloroform is characterized by two main absorption peaks located at 296 nm and 329 nm, while for that in ethyl acetate their unique absorption peaks are 391 nm and 666 nm. It is also clearly seen that the intensity of light within measured wavelength range depends on the tea concentrations. In all wavelengths, the absorbance increases with increasing green tea concentration. In fact, we have used this finding to presume that green tea concentration in a single green tea solution can be determined by looking at light absorbance at any particular wavelength using equation:
\[ A = -\log T = \varepsilon c l \]  

With \( A, T, \varepsilon, c \) and \( l \) are absorbance, transmittance, extinction coefficient, speed of light, and sample path length, respectively.

Evanescent wave fibre sensor reported in this paper was developed based on the above finding. Absorption process in UV-VIS-NIR Spectrophotometer is different from that in evanescent fibre sensor. The measured material in UV-VIS-NIR spectrophotometer absorbs relatively intense light passing through it, whereas in evanescent fibre sensor the measured substance absorbs relatively weak light penetrating out of the fibre core within the unclad fibre area with depth penetration \( d \) following equation 1.

![Absorption spectra recorded at room temperature using UV-VIS Spectrophotometer for different concentrations of green tea extracted in (a) Chloroform and (b) ethyl acetate](image)

**Figure 2.** Absorption spectra recorded at room temperature using UV-VIS Spectrophotometer for different concentrations of green tea extracted in (a) Chloroform and (b) ethyl acetate.

Figure 3 shows the absorbance recorded using evanescent fiber sensor of green tea extracted in two different solutions: (a) chloroform and (b) ethyl acetate. These results are in a good agreement with those recorded using UV-VIS-NIR Spectrophotometer in that light absorbance increase with the increase of green tea concentration (equation 2). Following equation 1, increasing green tea concentration also means the index of refraction increases. This results in increasing depth penetration. As absorption is a process of material-light interaction treating a beam of light as a stream of particles, deeper light penetration into the sensed material means that more light particles will be absorbed by the electrons composing the sensed materials.

![Concentration dependence of evanescent wave absorbed by green tea extracted in (a) chloroform and (b) ethyl acetate.](image)

**Figure 3.** Concentration dependence of evanescent wave absorbed by green tea extracted in (a) chloroform and (b) ethyl acetate.

Further from figure 3, it can be seen that light absorbed by the material increases with the increase of wavelength (\( \lambda \)). This finding is in a good agreement to that expressed in equation (1) at
which depth penetration (d) is linearly related to wavelength. Increasing the sloop as the wavelength increases is attributed by both increasing wavelength and concentration simultaneously.

4. Conclusions
Spectroscopic properties of green tea extracted both in chloroform and ethyl acetate have been studied. Their absorption spectra within the wavelength ranging from 200 – to 700 nm have been measured as function of green tea concentration using UV-VIS-NIR spectrophotometer. We have found that the absorbance increases with the increase of green tea concentration. Based on this result, we have used it to examine an evanescence fiber sensor designed for measuring single component solution of green tea. We have shown that light absorbed by mechanism of evanescence increase linearly with the increase of green tea concentration. This result suggests that the evanescent fiber sensor developed in this research might be potentially used to monitor the quality of green tea drinks.

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