Properties of organic green spinach dye as a substitute for harmful chemical green dye

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Abstract. Preparation of an environmentally friendly organic green dye, an alternative to the harmful industrial chemical green dye which is used to optical and industrial applications. The dye is extracted from spinach plant by solvent extraction process. The optical and morphological characterizations of green spinach dye are measurements, the absorbance spectrum of green spinach accord in visible region and the dye have two peaks at wavelengths ($\lambda_1$=440 nm, $\lambda_2$=685 nm) where the band gap energy is $E_g$=2.81 eV at $\lambda_1$ and the refractive index of spinach dye (n=1.36682). The fluorescence spectrum show the maximum absorption wavelength $\Delta\lambda_1$=90 nm and $\Delta\lambda_2$=195 nm respectively, and that accentuated the absorption region are extend to the dye. Also, the average particles size of spinach measured by Atomic Force Microscopy (AFM)=59.587 nm. These characterizations obtained the green dye can used in optical and industrial applications and made it a safer alternative for the toxic chemical green dye and thus protecting the environment by replacing polluting industrial chemical and their consequences.

Keywords: Extracted Spinach Dye, Optical Properties of Spinach Dye, and Spinach plant.

1. Introduction

Given the modern orientation to renewable energies using environmentally friendly natural dyes instead of chemical dyes harmful to environmental. The natural green spinach dye has been extracted and its characteristics studied to determine the extent of its use in various optical, industrial and scientific applications. Spinach is a plant belongs to chenopodiaceous family [1]. It is cultivated throughout the word as cool season annual, green leafy vegetables with significant nutritional and beneficial properties [2]. Spinach featuring in low calories is considered as a good source of minerals like iron and calcium and multivitamins [3]. It is also native to central and south western Asia. This green dye can be used in different application like; optical application [4], chlorophyll laser [5], chlorophyll dye is suitable to replace harmful tracer dyes for laser [6], possibility to replacement of green chemical dyes that are used in industry by organic dyes [7], dye sensitized solar cell (DSSCs) [8] and other applications.

In this work, green spinach dye was extracted and preparation by used ethanol, to illustrated the spinach characteristics and how much ability of use in optical and industrial applications.
2. Materials and methods

2.1. Materials

Materials used are fresh green spinach plant, ethanol and deionized water.

2.2. Preparation the organic green spinach dye

Use the solvent extraction process to extraction the spinach dye by cleaned the spinach leaf in deionized water, dried, 200g of spinach squeezer using blander, then filtering as shown in Figure 1. Added 20 ml of ethanol and placed into stirrer for 2h.

![Figure 1](image1.png) Shows spinach leaf, spinach squeezer using blander and filtering the dye extractor respectively.

2.3. Characterization and measurements

The absorbance (A) spectrum of the dye accomplished using UV-Vis shimadzu spectrometer in the wavelength of (190-1100)(nm), is use to measure the absorption rate in visible area. The optical band gap \( E_g \) calculated by using formula in (1)[9]:

\[
E = h\nu = \frac{hc}{\lambda}
\]

Where E is the stands for photon energy, \( h \) is blank's constant \( (6.626 \times 10^{-34} \text{ J.s}) \), \( \nu \) is the frequency, c is the speed of light \( (3 \times 10^8 \text{ m/s}) \) and \( \lambda \) is the wavelength.

Measured the absorption coefficient \( \alpha \) to determine the light transmittance in material, if \( \alpha \) is spadesful, its meaning the transmittance light in material is attenuation and if \( \alpha \) is small amount the material is transparent to ray passing through it. The \( \alpha \) calculated from absorption A and thickness \( d \) of cavity of dye solution (=1 cm) using formula (2)[10]:

\[
\alpha = \frac{(2.303)A}{d}
\]

The extinction coefficient \( K_0 \) used in spectroscopy to measure the concentration of a chemical in solution and calculated by using formula in (3) [10]:

\[
K_0 = \frac{\alpha \lambda}{4\pi}
\]

The refraction index \( n \) of the spinach dye was measure by Refractometer-AR4 device from Germany. The fluorescence of spinach dye measured on the fluorescence spectrophotometer Agilent on wavelength of 200-900 nm. To determination probable chromophore groups in a given natural dye infrared (IR) spectra were recorded with Fourier transform spectroscopy FTIR spectrometer from SIDCO (FTIR-600),

The surface roughness of the spinach dye was measured by atomic force microscopy (AFM), made by (DME) model (DS95), scan range 50-200 \( \mu \)m and sample size up to 150 mm.
3. Results and discussion

Multiple measurements of the dye conducted to find out the properties and the characteristics of the dye. The optical characterizations, absorbance, band gap energy, absorption coefficient, extinction coefficient, refractive index, fluorescence and transmittance of spinach dye obtained by (AFM). The observed results are summarized in the following subsections.

3.1. Absorption of spinach dye

Figure 2 refers to the UV-Vis absorbance spectrum of spinach extracted with ethanol spectrum of spinach extracted with ethanol in the visible light spectrum. The dye have two peaks ($\lambda_1=440$ nm, $\lambda_2=685$ nm) in cyclohexane indicated the existence of either anthocyanin, chlorophyll, carotene or mixture of them which have absorption peak at wavelength 420 nm and 665 nm [11].

![Figure 2](image)

**Figure 2.** The absorption spectra of spinach extracted with ethanol have two peaks ($\lambda_1=440$ nm, $\lambda_2=685$ nm).

Spinach is fertile in chlorophyll due to all green plants consisted of chlorophyll, which qualified for photosynthesis operation having glucose from simple organic molecules (carbon dioxide and water) under the action of visible radiation [12]. The band gap energy of spinach dye is ($E_g=2.81$ eV at maximum wavelength $\lambda_{max}=440$ nm) was calculated by formula 1. Figure 3 refer to absorption coefficient $\alpha$ which is a function of wavelength and depends on absorbance and thickness of the film according to the formula 2.
Figure 3. Absorption coefficient ($\alpha$) of spinach dye.

Figure 4. Extinction coefficient of spinach dye which increases by increasing the absorption coefficient and wavelength calculated by formula 3.

3.2. Refractive index of spinach dye.
The refractive index $n$ of spinach dye ($n=1.36682$) is measured by Refractometer device in liquid phase.

3.3. Fluorescence of spinach dye.
Figure 5 demonstrated fluorescent spectrum, after excitation with two peaks in wavelengths (440, 685) (nm) as functions of emitted radiations wavelengths at ($\lambda_{f1}=530$, $\lambda_{f2}=880$)(nm). Fluorescents maxima with respect to absorptions maxima shifted as ($\Delta\lambda_1=\lambda_{f1}-\lambda_{1\text{max}}=90$ nm) with apply the same equation to the second peak at ($\Delta\lambda_2=\lambda_{f2}-\lambda_{2\text{max}}=195$ nm), the fluorescence spectra shifted towards red region and thus agreement with searcher [13].

Figure 5. Fluorescent spectrum of spinach dye and the maxima shifts ($\Delta\lambda_1=90$ nm and $\Delta\lambda_2=195$ nm), the fluorescence spectra shifted towards red region.
3.4. **Infrared-IR spectroscopy of spinach dye.**

The FTER spectra of spinach as shown in Figure 6. In IR spectrum, the absorption band of iron sulphides is not clear at lower wavenumber. While, the presence of sulfate is indicated by the appearance of asymmetric stretching of carboxylate C=O and a band at 1056 cm\(^{-1}\). Whereas, the existence of a band at 2356 cm\(^{-1}\) is attributed to the presence of ferredoxin (Fe-S). In addition, (\(-\text{OH}\)) vibration cause the occurring of a band at 3431 cm\(^{-1}\), while the band occurring around 2923 cm\(^{-1}\) attributed to the stretching mode of (C-H) in the spinach.

![Figure 6. FTER spectra of spinach dye.](image)

3.5. **Atomic force microscopy (AFM) of spinach dye.**

The AFM analysis the surface morphology and roughness of spinach dye. The roughness average 31.152 nm, and the average particle size 59.587 nm, determine using 2D, 3D images as shown in Figure 7. These results agreed with searcher [15].

![Figure 7. AFM image of spinach dye in (a) 2D image, (b) 3D image.](image)

\[\text{Figure 7. AFM image of spinach dye in (a) 2D image, (b) 3D image.}\]
4. Conclusion
Synthesis an organic green dye extracted from spinach plant used as alternative to green chemical dyes which are toxic and harmful to environment. The spinach dye have two peaks in visible region at wavelength $\lambda_1=440$ nm, $\lambda_2=685$ nm and the fluorescence shifted $\Delta \lambda_1=90$ nm and $\Delta \lambda_2=195$ nm respectively, these shifts contributed to extend the absorption spectrum to the dye, also found the band gap energy $E_g=2.81$ eV at $\lambda_1$, the refractive index of spinach dye $n=1.36682$ and the average particle size 59.587 nm. These characterizations elucidate the green spinach dye can used in optical and industrial applications because it was friendly to environment, safe and have multiple uses. Spinach dye is a good alternative to green chemical dyes. In the future, is possible to extracted natural dyes from origin with different colors to be used in optical and industrial applications instead of harmful chemical dyes.

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