Ibn Al Haitham Journal for Pure and Applied Sciences

Journal homepage: http://jih.uobaghdad.edu.iq/index.php/j/index

Optical Properties of Organic Beetroot dye and its Different Applications

Suma H.Al-Shaikh Hussin
Department of Physics, College of Science for Women, University of Baghdad, Baghdad, Iraq.
sumaha_phys@csw.uobaghdad.edu.iq

Article history: Received,11 , November, 2021, Accepted, 25, January,2022, Published in April 2022.

Doi: 10.30526/35.2.2722

Abstract

Extraction and preparation of red organic dye from beetroot plant in different concentrations by using the solvent extraction process. Ethanol was the solvent used to prepare five different concentrations at the ratio of (Dye: Ethanol) abbreviated (D: E) 5:0,4:1, 3:2, 2:3,1:4. The optical, structural, and morphological properties are studied for the samples. The results appeared using the UV-Vis spectroscope the maximum peak of absorption (A) spectrum at wavelength $A_{\lambda max}$=480 nm when the transmittance (T) at the same wavelength 25% and the reflectivity 0.8%. Florescent (F) spectrum of beetroot dye is measured at wavelength $F_{\lambda max}$=535nm achieved to redshift about $\Delta\lambda$=55 nm. Also, measured the energy band gap E_g=2.36 eV and the refractive index n=1.36 of beetroot dye. Finally, the atomic force microscopy (AFM) found the average particle size of dye is 85.9 nm. The results illustrated the organic beetroot dye has a good homogeneity and stability at room temperature so that it can be used in painting, optical, and industrial applications. Also, the dye can be applied in color optics and color optical contact lenses, LASER, and sensitive dye solar cells, which means in different applications because it was harmless, environmentally friendly, and fall under green energy.

Keywords: Beetroot plant; Extracted Beetroot Dye; Optical Properties of Beetroot Dye; Organic dye; Red dye.

1. Introduction

Dyes are organic chemical compounds that depend on light absorption properties to produce colors[1]. Dyes are classified into two types; synthetic dyes derived from chemical materials and natural dyes derived from natural sources like plants, animals, and minerals[2]. Pigments are colored materials that absorb selective wavelengths. Some of these pigments fade in washed or sunlight or are exposed to air. While, others do not adsorb onto fibers, or cannot be dissolved in water[3]. However, the range of colors in plants varies from yellow to black [4]. The type of root plants ranging in color from purple to red contains a high proportion of the compound betaines is the material that earns the color red[5]. Beetroot dyes were derived from the beetroot plant in different methods such as the use of continuous diffusion devices. The dye of beet can be from powder by drying or freeze-drying. Usually, the beet dye is obtained from the hydraulic age and then compressed and squeezed to obtain the dye after filtration and the resulting quantity is about 50% of the quantity of beetroot [6]. In 2012 A.Thankappan et al. They studied the effect of betanin natural dye extracted from red beetroot on nonlinear optical properties of ZnO Nanoplates embedded in polymeric matrices. The natural pigment from a plant has been extensively investigated as a sensitizer for the DSSC, in which red beetroot pigments maximum conversion efficiency of 0.67%[7]. M.Abdelrahmanet.al in 2013 they researched the possibility of using the beet dye as a laser gain medium. They concluded that the beet dyes solution has a high fluorescence quantum yield to act as a laser gain medium [8]. A.K.Shoo 2015extracted a natural color from amaranth and beetroot dyes. Used two techniques to draw the dyes from amaranth and beetroot ultra-sonication assisted extraction techniques, microwave-assisted extraction techniques. They found these two methods increase the rate of extraction of natural color as compared to other cultural techniques. Natural color is safe to use, nutritious, and less polluting [9]. Lorain et al. in 2018investigated the thither acidity on the stability of beetroot by drying spray and freeze drying[10]. R.Arthikha and K.Madhanasundareswari 2019 found that beetroot was an avenue as a major source of natural pigments with high content of betacyanins. The study shows that the beetroot sample yields the highest extraction with 5gram in 10ml of distilled at 100^0C in 10min with a pH range of 4. This work takes a step toward the replacement of synthetic dyes with natural dye which is eco-friendly and safe [11].

The aims of the work are preparation red organic natural dye by extraction from the beetroot plant and investigated the optical, structural and morphological properties, and determined how the ability to use organic dye is friendly with the environment used for painting, optical, industrial applications.

1.2 Optical Properties of Beetroot dye.

Optical properties and optical constants are important in determining the range of ability to use the beetroot dye in the optical application. When a light wave propagates in a medium, its intensity will be reduced exponentially. The reduced intensity occurs due to the absorption in the medium. The Lambert-Beer law describes how light intensity changes when light passes through a medium [12].

$$I_{(x)} = I_0 e^{-\alpha x} \qquad (1)$$

where I_0= Initial intensity of the incident radiation, $I_{(x)}$= Light intensity of the light passes through a distance x,α=Absorption coefficient.

The absorption coefficient $\alpha$is the ratio of the decrease in the emission of the radiation to the unit of distance towards the propagation of the wave within the center depends on the energy of the falling photon and the characteristics of the semiconductor and the length of the absorbed center path. Also αrefers to a fraction of light absorbed in the medium at an optical thickness (d)can be calculated from use equation (2) [12].

$$\alpha = 2.303\ A/d \qquad (2)$$

Reflection (R) related between absorbance (A) and transmittance (T) are [12]:

$$R = 1 - A - T \qquad (3)$$

The extinction coefficient (K_0) represented the inertia of the electromagnetic wave within the material and represents the imaginary part of the coefficient of refraction related to the absorption coefficient in the following equation (4)[13].

$K_0=\alpha\lambda/4\pi$ (4)

Bandgap energy *E(eV)*could be obtained by equation (5) [14]:

$\lambda_{cut\ off=\frac{1240}{E}}$ (5)

Where $\lambda_{cut\ \mathrm{off}}$ =cut off wavelength in (nm).

2. Materials and Method

The materials used to prepare organic red beetroot dye are : one kilo of fresh beetroot pant as shown in **Figure 1**.

Figure 1. Fresh beetroot pants.

Used ethanol solvent to prepare beetroot dye as shown in **Figure 2.** The properties of ethanol as shown in **Table 1.**

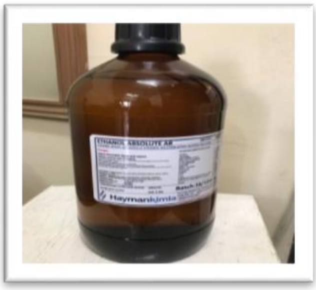

Figure 2. Ethanol solvent.

Table 1. The properties of ethanol solvent.

1	The chemical formula for ethanol	C_2H_5OH
2	Made in	UK
3	Color	transparent
4	Status of the material	Liquid
5	Density	0.789gm/cm^3
6	boiling temperature	78 ^{0}c
7	Solubility in water	Good mixing
8	Purity	99.95%

2.1 Method of preparing beetroot dye

Used 1 kg of beetroot plant and cleaned from the soil and contaminants by washing in distilled water then left it dry at room temperature .The clean beetroot was crushed using mortar into small pieces as shown in **Figure 3**.

Figure 3. Beetroot crushing using mortar into small pieces.

Filtrated the crushing beetroot by using multilayers to obtain the pure red squeezer as shown in **Figure 4**.

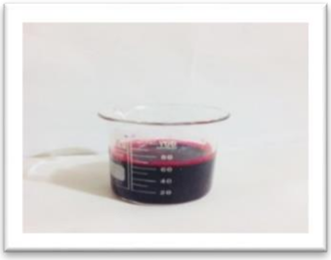

Figure 4. Beetroot squeezer.

To convert the pure red squeezer to the red dye we added ethanol solvent in different concentrations as shown in **Table 2**.

Table 2. Different concentrations of dye.

Number of samples	Concentrations dye: Ethanol
1	Pure dye 5:0
2	4:1
3	3:2
4	2:3
5	1:4

Figure 5 refers to a samples image of the red dye in different concentrations.

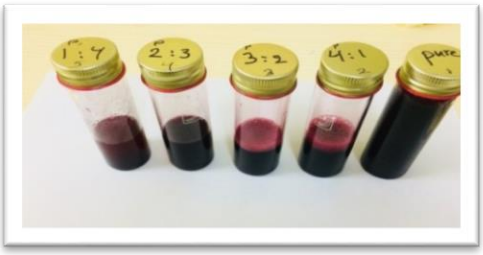

Figure 5. The samples of red dye in different concentrations.

All the five samples of the red dye in different concentrations putting into a magnetic stirrer for 2h respectively then aging all the samples for three days before use. **Figure 6** shows five samples of preparation red dye in different concentrations after aging for three days.

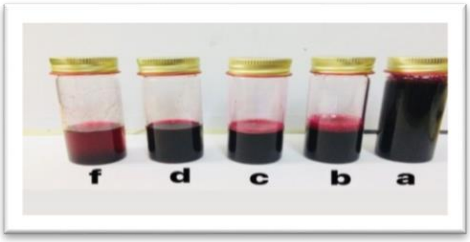

Figure 6. Five different concentrations of red dye after aging for three days.

2.2 Preparation of thin films of beetroot dye.

Prepared five thin films in different concentrations by depositing 0.2 ml of different concentrations of the dye in glass slid and dried for seven days at room temperature as shown in **Figure7**.

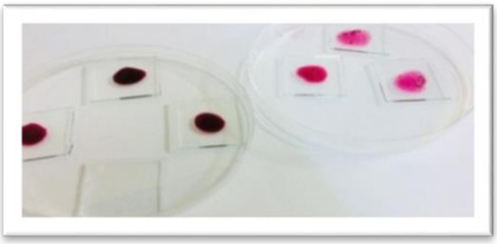

Figure 7. Thin films in different concentrations of beetroot dye

3. Result and Discussion

Study the characterizations of the organic beetroot dye, by measuring the optical properties and optical constants that include absorption(A), transmission(T), reflectivity(R), energy bandgap (E_g), absorption coefficient (α), extinction coefficient(K_0) and refractive index (n). Also, structural property such as Fourier transform (FTIR), and morphological property is measured by atomic force microscopy (AFM).

3.1 Optical Properties and optical constant of beetroot dye.

The optical properties of the beetroot dye were obtained by obtaining the absorbance spectrum for all concentrations from wavelengths (200-1100)nm. **Figure 8** shows the maximum peak of absorption spectra of the different concentrations of beetroot dyes at the wavelength λ_{max}=480 nm and that agrees with research [15], [16].

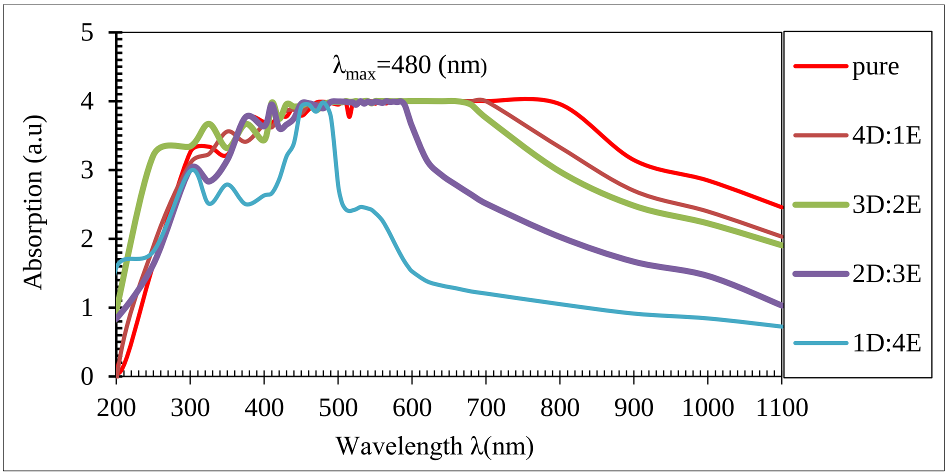

Figure 8. Absorption spectra for all different concentrations of organic beetroot dye.

The optimum concentration of beetroot dye is3:2 which gives the lowest transmittance with the highest absorption as shown in **Figure 9**. The maximum absorption wavelength at λ_{max}=480 (nm) confronts the minimum transmittance of about T= 25% and that results agree with the researcher[17].

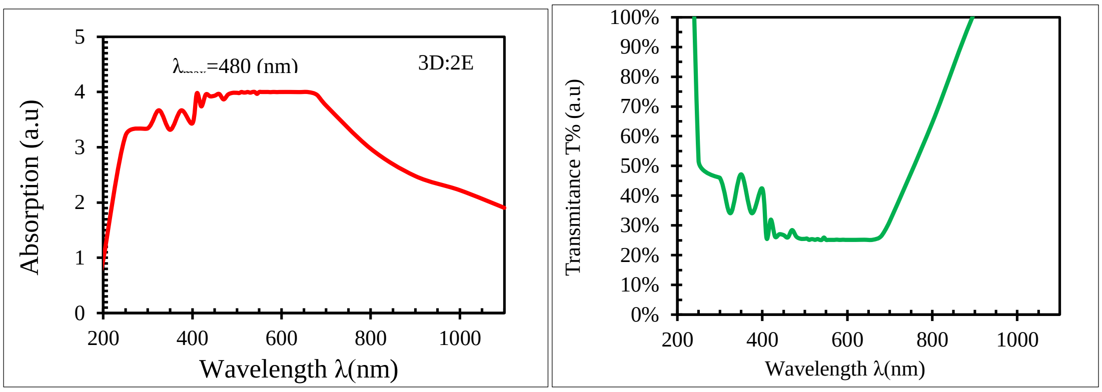

Figure 9. The absorption (A) and transmittance (T) of beetroot dye in concentration 3:2.

Figure 10 refers to the best reflectivity spectrum at concentration 3:2was found to be the lowest value of 0.8% and consistent with the results of the absorbance spectrum, when the reflectivity is the lowest the absorbance will be the highest value.

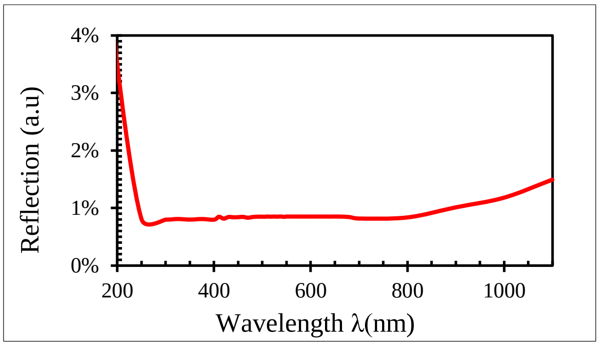

Figure 10. The spectrum of reflectivity of beetroot dye concentration is 3:2.

Figure11 represents to fluorescence spectrums of the beetroot dye and the maximum shift obtained from concentration3:2. Thus, the shift difference ($\Delta\lambda$) between the peak of the fluorescence wavelength at 535 nm and the peak of the absorption wavelength at 480 nm. The shift difference ($\Delta\lambda = F_{\lambda max} - A_{\lambda max} = 55$ nm) means the redshift leads to expansion of the absorption spectrum of the dye, and that agrees with the researcher [18]. These optical properties of the dye can be utilized in panting, color optics, color optics contact lenses, laser, and industrial applications.

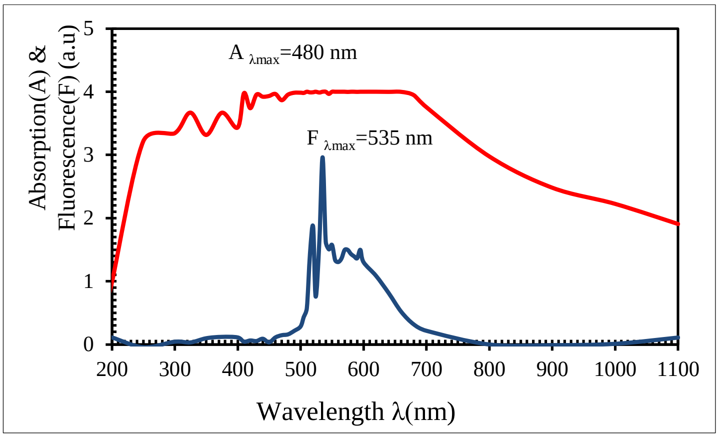

Figure11. Fluorescence spectrums Fand the shift difference Δλof the beetroot dye at concentration 3:2.

The energy band gap was calculated to the optimum concentration 3:2which give the highest absorbance by equation 5 is(E_g=2.58 eV)and that agrees withresearcher[19].

Figure 12 shows the linear absorption coefficient(α) at optimum concentration 3:2 calculated by equation2., which is a function of wavelength and depends on absorbance(A) and thickness (d) of the cavity of dye solution (=1 cm).

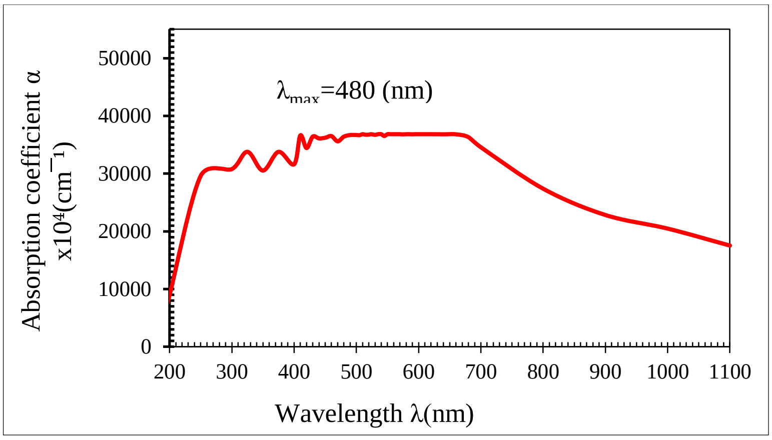

Figure 12. Absorption coefficient(α) of beetroot dye.

Figure 13 shows the extinction coefficient (K_0), which represents the extinction of the electromagnetic wave within the material, which is absorbed by the matter electrons from the falling photon energy [20]. The extinction coefficient is calculated by the value of the absorption factor at the wavelength (480nm) according to equation 4. The extinction coefficient depends on absorbance and wavelength and increases with wavelength and absorption coefficient.

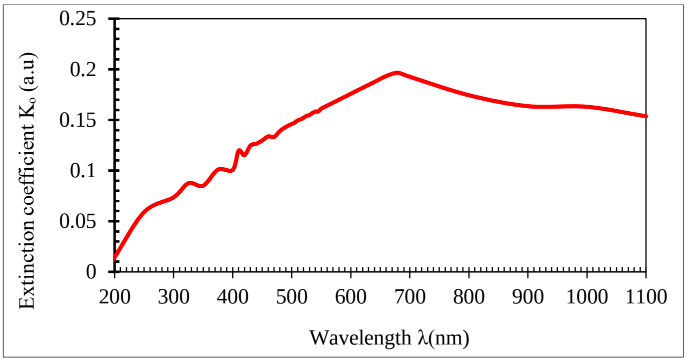

Figure 13. The extinction coefficient (K_0) variation as a function of wavelength of beetroot dye at concentration 3:2.

The refractive index (n) of solution beetroot dye in optimum concentration3:2 measured by refractometer AR4 device from Germany and the refractive index value was equal to n=1.3668.The benefit of finding the refractive index of a dye is analyzing the sample's purity and determining the amount or concentration of dissolved substances within the sample.

3.2 structural properties of beetroot dye.

The structural property of Fourier transforms infrared spectroscopy FTIR is tested to optimum sample.

3.2.1 FTIR to beetroot dye.

FTIR is used to determine the chemical elements and identifies the chemical bonds in the compounds[21]. The FTIR spectra of optimum concentration of beetroot dye 3:2 are analyzed and given in **Figure 14**. The transmittance bond to the organic groups like OH occurred between (3800-3000)($cm^{=1}$) stretching hydroxyl (O-H), which denoting water as moisture was observed as the broad bank. Peaks at (293,2889)(cm^{-1}) indicated stretching modes. The peak (2360cm^{-1}) refers to the existence of ferredoxin Fe-s. Stretching of carboxylate is typical of an amino acid (C=O) occurred at(1639 cm^{-1}) the peak (1385 cm^{-1}) is a weak band of ammonium ion (NH_4^+) and the weak bond of sulfate occurred at peak (1054 cm^{-1})stretching vibration of ester modes C-O and these results are useful in determining the degradation of the dye during storage, therefore its use in optical and industrial applications and that agreement with researches[22-23].

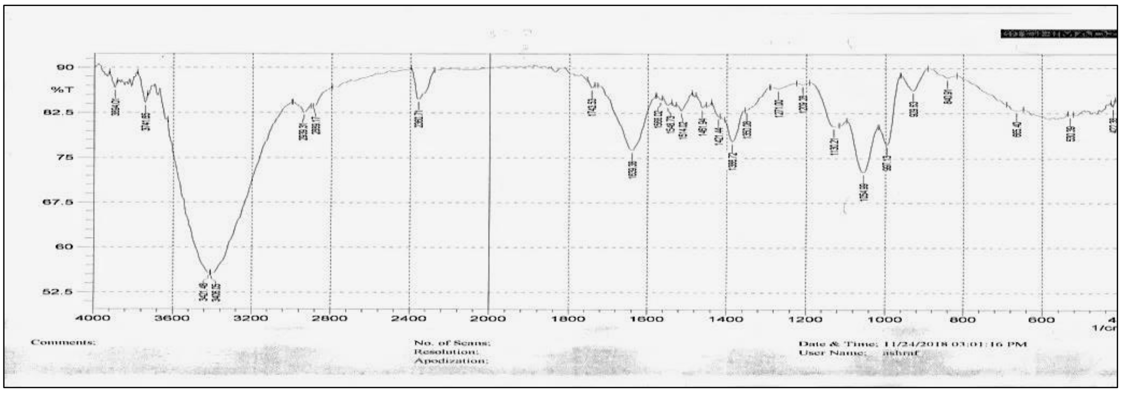

Figure 14. FTIR of beetroot dye at concentration 3:2.

3.3 The morphological characterizations of beetroot dye.

The morphology of beetroot dye investigates by atomic force microscopy (AFM).

3.3.1 (AFM) analysis.

Surface morphology and roughness optimized sample at concentration 3:2 investigated using AFM. The roughness average (12.775nm), root mean square(23.359nm) and the average particle size (85.9nm), determine using 2D,3D images as shown in **Figure 15**. These results show a good homogeneity and stability of the dye also, It can be used in optical and industrial applications, and that agreement with research [24-25].

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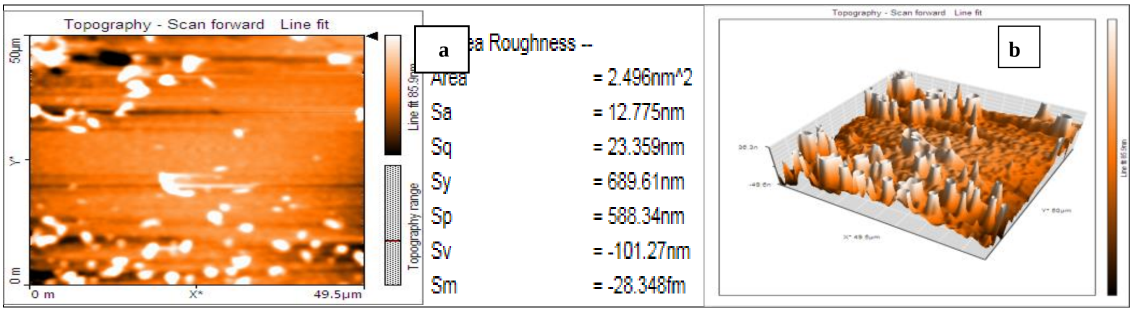

Figure 15. AFM images for beetroot dye in concentration 3:2 a) 2D images, b) 3D image.

4. Conclusion

From the results obtained, it can extract organic red dye from beetroot plants and used to in optical applied applications instead of harmful chemical red dyes. Prepares five different concentrations of beetroot dye and the optimized concentration at 3:2.The maximum absorption wavelength of the dye ($A_{\lambda max}$=480nm). Also, bandgap energy (E_g=2.58eV) and the refractive index (n=1.36). The maximum fluoresces wavelength of the dye at ($F_{\lambda max}$=535nm) and shifts differently ($\Delta\lambda$=55nm), which means redshift. The average particle size of the dye is (85.9nm). From these results, obtained the organic red dye can be used in different applications such as (optical, industrial, and scientific research). Used natural beetroot dye example to develop toolkits for creating structural colors that could offer a more sustainable alternative to conventional pigments, the production of which can have baleful impacts on the environment.

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