Study the effect of changing aperture size on linear and nonlinear properties of wheat germ oil

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Abstract

The spectroscopic and nonlinear properties of wheat germ oil have been investigated. Two different sources of oil (weight 3.33gm), locally (Emad) and global (Hemani) were used in this work. The absorption and fluorescence spectra of the two types of oil were carried out to calculate the quantum efficiency of them. Nonlinear characteristics were measured by z-scan. The results showed that high quantum efficiency (91.5 for the local oil and 76.6 for the other) As for the non-linear properties, it was measured for wheat germ oil (Emad) by scanning technology (by changing the value of the closed hole (pin hole), the value of (n2) the non-linear refractive index changes with the size of the aperture (1, 1.5, 2, 2.5) mm..

Key words: wheat germ oil, nonlinear properties, z-scan, nonlinear refraction (NLR), nonlinear absorption coefficient (NLA).

Introduction

Wheat germ is the main essential element, which responsible about the whole-wheat kernel. It is considered at a richest foods through contains many minerals and vitamins like vitamin B, vitamin E, and it is naturalistsources of α-tocopherol[1], Wheat germ was also a wealthy source of carbohydrates, fatty acid, etc. [2]

Wheat germ also provides dietary fiber and healthy fats to help balance blood sugar levels, control cholesterol levels, and promote intestinal health. One kilo of natural UN refined wheat germ oil can extracted from (2000k) of wheat germ. It has been an orange color that tends to brown and is slightly sticky with a clear and sharp smell [3].
There are many techniques for measuring Non Linear Refraction (NLR) and Non Linear Absorption (NLA) in materials like nonlinear interferometry, decadent four-wave mixing, almost decadent three-wave mixing, and beam deformation measurements [4].

The first to suggest the Z-scan technique is Sheikh Bahaeet. al., which is based on the fundamentals of deformation of the beam, and it also, provides a simple measurement and high sensitivity for each of NLR and NLA [5, 9]. The researchers were interested in studying the optical properties of materials, which in turn led to looking for a technique through which to study these properties. Laser beam properties can be used and the radiation can be transformed.

In the present work, we have measured open aperture Z-scan and by used different diameter of pinhole size (1, 1.5, 2, and 2.5) mm to performed close aperture Z-scan experiment for wheat germ oil to measure NLA and NLR.

Materials and Methods:

3.33 grams of both commercial wheat germ oil (locally Emad, globally Himani) were used to measure the physical properties. Wheat germ samples were packed in glass tube and stored at room temperature during the study.

The UV-Visible device type (SP-8001) and the Spectrophotometer SL 174 were used to measure both the absorption and the fluorescence spectra respectively for wheat germ oil. The measurements were carried out at room temperature.

Z-Scan technique was used for describing nonlinear variables (refractive index and nonlinear absorption), and it based on a single beam method where the sample puts at a place in parallel with the Gaussian beam, then distortion occurs on the wave front due to Kerr effect [10]. At present study optical detector and diaphragm with different diameters (1, 1.5, 2, 2.5 mm) have been used.

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Figure (1) shows the experimental z-scan set up. It consists of Nd: YAG laser operating at 532 nm wavelength with energy of 20 mJ. Laser pulse energy was measured by the (DPSS 1830C) detector. The laser beam passes through a lens of (10 cm) focal length. Sample was moved through the beam waist of the laser beam along the z axis distance (+50, 0, -50) mm.
Results and discussion

1-Absorption and the fluorescence Spectra:

Figure (2, 3) shows the absorption and the fluorescence Spectra of local wheat germ oil and Hemani respectively. The absorption spectrum of germ oil sample showed that it has a peak at 341 nm and two small peaks at 455nm, 485nm, while one peak for the second sample appeared at 331nm. In addition, the absorption spectrum showed that the two types of oil are transparent in the visible area extending from 530-1100nm.

This difference in the absorption spectrum led to a difference in the number and values of fluorescence peaks for the two types of oil as appearance in figures (2, 3):400nm and 550nm for Emad type and 450nm for global oil. It is evident from the fluorescence spectrum of Emad oil that it can be used to produce semi white light because it has two peaks extending from 400 to 580 nm.

![Absorption and Fluorescence Spectra](image1)

Figure: (2) Absorption and fluorescence spectra of Emad wheat germ oil

![Absorption and Fluorescence Spectra](image2)

Figure (3): Absorption and fluorescence spectra of global (Hemani) Wheat germ oil.
The results shown in Table 1 indicate that the quantitative efficiency of Emad oil is higher than the quantitative efficiency of the global oil whereas, the quantitative efficiency values were calculated according to the following equation[11]:

\[ q_{fm} = \frac{\text{NumberOfQuantaEmitted}}{\text{NumberOfQuantaAbsorbed}} \]  

Table (1) shows the wavelengths of absorbance and fluorescence spectra and the quantitative efficiency of the two types of wheat germ.

| Type     | \( \lambda_{\text{abs.}} \) (nm) | \( \lambda_{\text{fluor.}} \) (nm) | Quantum Efficiency | \( q_{fm} \) |
|----------|-------------|-------------|-------------------|------------------|
| Emad     | 341         | 401.531     | 91.5%             |                  |
| Hemani   | 333         | 453         | 76.6%             |                  |

2- The non-liner properties.

The nonlinear region was extended from -50mm to 50mm; the nonlinear absorption coefficient (\( \beta \)) was calculated from Figure (4). Maximum value of transmittance 0.009 and small transmission was 0.0018 at pinhole size 2.5, 1mm respectively. The sign of the refraction nonlinearity is positive, i.e. self-focusing observed as shown in figure (5), and figure (6) shows the direct proportional between pinhole size and the nonlinear refractive index.

The values of the nonlinear absorption coefficient were calculated using the following equation [12] and as its value is shown in Table (2) in addition to the values of linear absorption and refractive index (\( \alpha, n_0 \)):

\[ q_o(Z) = \frac{I_0 L_{eff} \beta}{1 + \frac{Z^2}{Z_o^2}} \]  

Where: \( Z \): the position of sample, \( L_{eff} \): effective thickness of sample, \( I_0 \): Intensity of the laser beam at focus \( z = 0 \).

"Nonlinear refractive index (n2)" of wheat germ oil with different pinhole diameter (1, 1.5, 2, 2.5mm) was calculated from the equation [13]:

\[ n_2 = \frac{\Delta \Phi_o}{I_0 L_{eff} K} \]  

\[ \Delta T_{p-o} = 0.406|\Delta \Phi_o| \]
\[ \Delta T_{P-V}: \text{the difference between the normalized peak and valley transmittances, } \Delta \Phi: \text{nonlinear phase shift.} \]

\[ L_{\text{eff}}: \text{the effective thickness of the sample which calculated by using following relationship:} \]

\[ L_{\text{eff}} = \frac{(1 - e^{-\alpha_{\text{L}}})}{\alpha_{\text{G}}} \]

Where: \( \Delta \Phi_{\text{G}}: \text{nonlinear phase shift, } k: \text{is the wave number.} \)

![Figure (4): Open aperture Z-scan](image-url)
Figure (5): Close aperture Z-scan, (pinhole=1, 1.5, 2, 2.5mm).

Figure (6): Relationship between pinhole diameter and nonlinear refractive index.
Table (2): The linear and nonlinear parameters of wheat germ oil.

| pinhole diameter | ΔTpV  | ΔΦ0*10^-6 | n2 (cm^2/W)*10^-10 |
|------------------|-------|------------|-------------------|
| 1 mm             | 0.001452222 | 0.007609   | 0.0908731         |
| 1.5 mm           | 0.002546667 | 1.36098    | 0.171562          |
| 2 mm             | 0.00377 | 2.01475    | 0.243356          |
| 2.5 mm           | 0.004697778 | 2.51056    | 0.303245          |

Conclusion:

It has been shown a different in fluorescence between the two types of oil investigated in our study and this leads us to consider Emad oil as a suitable material to generate semi-white light. It was concluded that wheat germ oil has nonlinear properties through the values of nonlinear refractive index that changed directly with the size of the aperture, this makes us suggest that this oil maybe use as a nonlinear liquid lens.

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