Verdet constant of various types of honey and sugar solution analyzed at different concentration

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Abstract. The optical activity effect of material on the polarization of a light beam due to the external magnetic field has observed through Faraday rotation. The use of the Verdet constant represents the behaviour characteristic of the material. This paper had reported the Verdet constant of some honey types compared with a sugar solution that was analyzed at different concentrations. Laser He-Ne had been used to observe the change of its polarization angle (Faraday rotation) when the external magnetic field applied at 50 gauss, 100 gauss, and 150 gauss. They were produced by a solenoid wrapped around the sample container, connected to the DC power supply. The Verdet constants of Kaliandra honey, Randhu honey, and Pahit honey, respectively, indicate their dependence on concentration. The profile of concentration dependence of the Verdet constant for all three types of honey is the same as that of the sugar solution. However, the highest Verdet constant is achieved by Kaliandra honey when analysed at a concentration of 30%.

1. Introduction

The rotation of plane of light polarized phenomena is well known in the concept of compound chirallity in organic material. This rotational can be used as an identification technique between enantiomers (same molecular formula but they differ in their chirality)[1]. In physics, we find the similar phenomena which is considering the rotation of plane of light polarized due to magnetic field. In 1845 Faraday discovered that because of high magnetic field exposition, the plane of polarized light passing some optically inactive materials experiences faraday rotation effect [1,2,3].

The presence of magnetic field make a plane of polarized light rotating, as it passes through the medium. The amount of rotation $\theta$ is depend on the strength of the magnetic field $B$ (gauss) which is parallel to the propagation direction of the lightwave, the length of vessel where the sample is located $L$ (cm) and a proportionality constant called the Verdet Constant. More explicitly, the Verdet constant $V$ (rad.gauss$^{-1}$.cm$^{-1}$) is well noted by Eq. (1) [4,5].

$$\theta = VBL$$  \hspace{1cm} (1)

In expanse of research, these effect could identify the different caracteristic of some materials due to their concentration [6], the light passed and also their refractive index [7]. The Faraday effect has been used to measure optical rotator power and for sensing of magnetic fields (such as fiber optic current sensors)[8].The Faraday effect is used in spintronics research to study the polarization of electron spins in semiconductors [8,9]. The Faraday effect produce Verdet constant in measurement of olive oil for
magnetic field sensor olive oil [10]. Verdet constant is also useful to study the magnetic-optic in thin amorphous magnetic films and other materials [11-14]. Therefore, optical-magnetic properties of some liquid should be well described to be investigated, specially for some honey types.

The physical properties of honey are an important indicator of the quality of honey. Some of major quality criteria of interest are moisture content, sucrose content and reducing sugars content, pH value, electrical conductivity, ash content, free acidity, diastase activity and hydroxymethyl furlural (HMF) content [15]. The magneto-optic sensing system conducted of this project should be competent of detect different type of honey and sugar solution either in various concentration with a good accuracy. Therefore, this method is prospective to be agreeable and fast in detecting characteristic of liquid.

2. Method
Some equipment prepared is HeNe laser, 1000 turns solenoide, teslameter, amperemeter, DC 12 volt maximum power supply, photometer, analytical balance, beaker glass, volumetric flask, samples of 3 types of honey (Kaliandra, Randhu and Pahit) and sugar solution, aquadest. Determination of Verdet constant of sample begins from preparing the sample, setting the equipment, measuring the data and finding the Verdet constant.

2.1. Sample Preparation and Treatment
All samples, both honey and sugar, were prepared in a solution state with a concentration of 0% (treatment control), 5%, 10%, 15%, 20%, 25% and 30%. For example, to make honey with a concentration of 5%, we add 5 grams of honey with 95 grams of aquadest, then stir well. There are 3 typed of honeys to be observed, name Kaliandra, Randhu and Pahit. The last observation, all data result will be compared to sugar solution. We used white crystal sugar to be measured as comparison to the data of honey solutions.

2.2. Experimental set up
The schematic of the setup of measuring Faraday rotational effect is shown in Figure 1. Samples of both the honey and sugar solution are placed in a separate vessel. It is a non-conducting cylinder of length 3 cm made of pvc pipe which both ends are covered by glass. This system is then placed in a uniform external magnetic field B. It is produced by a 1000-winding solenoid wrapping the vessel and connected to a DC voltage source. Unpolarized light coming out of laser He-Ne becomes polarized after passing the first polarizer. The existance of sample rotate the light, so it produces Faraday effect that could observe by rotating the second polarizer, such that it can produce maximum intensity (see on fotometer).

![Figure 1. Experimental set up of Faraday effect measurement.](image)

where P : polarizer, C : sample within solenoide, A : Analizer, Ameter

2.3. Data Measurement
After performing a calibration of the instrument, a scale factor which must be given to the results of the calculation of the Verdet constant is equal to a data multiplier of 0.001. Samples of the honey or sugar solution are placed in a PVC vessel whose edges are made of glass. This part becomes the window of
the vessel where the transmission of polarized light passes through the sample. When a magnetic field is applied, the sample must be kept at a temperature of 20°C. After being exposed to a magnetic field, the intensity of polarized light will decrease. By turning the analyzer in such a way as to produce maximum light intensity, we get the Faraday rotation angle of the sample when given a certain magnetic field. Having collected all the data of rotation angle, we can analyze how the concentration of liquid affects the Verdet constant. Some comparison should be observed between Verdet constant of some honey types and sugar solution.

3. Result and Discussion

3.1. Faraday rotation of some honey types and sugar solution
The first step conducted was measuring the rotation angle of some honey types and sugar solutions. As the magnitude of magnetic field changed due to the change of voltage source, the final intensity of polarized laser also changed. Therefore, the second polarizer (analyzer) need to be rotated to find the maximum intensity showed from the photometer. It is called rotational Faraday due to magneto-optical effect. All data performed the change of plane of laser polarization within the mediums described on the Table 1.

| Table 1. Rotational Faraday of Kaliandra Honey in various concentration. |
|---------------------------------------------------------------|
| C                      | θ ± Δθ (rad) 50 gauss | θ ± Δθ (rad) 100 gauss | θ ± Δθ (rad) 150 gauss |
|-----------------------|-----------------------|-----------------------|-----------------------|
| 0%                    | 0.195 ± 0.015         | 0.390 ± 0.020         | 0.586 ± 0.020         |
| 5%                    | 0.213 ± 0.023         | 0.433 ± 0.026         | 0.642 ± 0.034         |
| 10%                   | 0.261 ± 0.012         | 0.516 ± 0.023         | 0.757 ± 0.042         |
| 15%                   | 0.304 ± 0.020         | 0.589 ± 0.026         | 0.879 ± 0.032         |
| 20%                   | 0.342 ± 0.020         | 0.673 ± 0.020         | 1.008 ± 0.034         |
| 25%                   | 0.345 ± 0.015         | 0.684 ± 0.026         | 1.019 ± 0.038         |
| 30%                   | 0.380 ± 0.026         | 0.718 ± 0.031         | 1.067 ± 0.034         |

| Table 2. Rotational Faraday of Randhu Honey in various concentration. |
|---------------------------------------------------------------|
| C                      | θ ± Δθ (rad) 50 gauss | θ ± Δθ (rad) 100 gauss | θ ± Δθ (rad) 150 gauss |
|-----------------------|-----------------------|-----------------------|-----------------------|
| 0%                    | 0.195 ± 0.023         | 0.387 ± 0.023         | 0.579 ± 0.031         |
| 5%                    | 0.213 ± 0.026         | 0.415 ± 0.019         | 0.618 ± 0.046         |
| 10%                   | 0.227 ± 0.012         | 0.447 ± 0.010         | 0.659 ± 0.029         |
| 15%                   | 0.272 ± 0.010         | 0.534 ± 0.042         | 0.792 ± 0.023         |
| 20%                   | 0.331 ± 0.028         | 0.642 ± 0.023         | 0.904 ± 0.045         |
| 25%                   | 0.370 ± 0.026         | 0.722 ± 0.026         | 0.942 ± 0.017         |
| 30%                   | 0.426 ± 0.034         | 0.788 ± 0.023         | 0.959 ± 0.017         |

| Table 3 Rotational Faraday of Pahit Honey in various concentration. |
|---------------------------------------------------------------|
| C                      | θ ± Δθ (rad) 50 gauss | θ ± Δθ (rad) 100 gauss | θ ± Δθ (rad) 150 gauss |
|-----------------------|-----------------------|-----------------------|-----------------------|
| 0%                    | 0.192 ± 0.021         | 0.387 ± 0.023         | 0.586 ± 0.057         |
| 5%                    | 0.206 ± 0.015         | 0.426 ± 0.026         | 0.628 ± 0.025         |
| 10%                   | 0.255 ± 0.020         | 0.499 ± 0.020         | 0.645 ± 0.017         |
| 15%                   | 0.259 ± 0.026         | 0.509 ± 0.015         | 0.768 ± 0.021         |
| 20%                   | 0.304 ± 0.023         | 0.586 ± 0.020         | 0.806 ± 0.026         |
| 25%                   | 0.356 ± 0.026         | 0.621 ± 0.034         | 0.925 ± 0.021         |
| 30%                   | 0.384 ± 0.021         | 0.652 ± 0.026         | 0.973 ± 0.019         |
Table 4. Rotational Faraday of Sugar Solution in various concentration.

| C   | θ ± Δθ (rad) 50 gauss | θ ± Δθ (rad) 100 gauss | θ ± Δθ (rad) 150 gauss |
|-----|----------------------|------------------------|------------------------|
| 0%  | 0.192 ± 0.017        | 0.380 ± 0.015          | 0.583 ± 0.016          |
| 5%  | 0.234 ± 0.010        | 0.457 ± 0.015          | 0.659 ± 0.023          |
| 10% | 0.248 ± 0.015        | 0.499 ± 0.020          | 0.708 ± 0.020          |
| 15% | 0.286 ± 0.010        | 0.530 ± 0.023          | 0.757 ± 0.016          |
| 20% | 0.304 ± 0.010        | 0.576 ± 0.017          | 0.827 ± 0.016          |
| 25% | 0.331 ± 0.030        | 0.631 ± 0.015          | 0.904 ± 0.023          |
| 30% | 0.342 ± 0.020        | 0.659 ± 0.015          | 0.956 ± 0.015          |

3.2. Concentration dependent faraday rotation of honey and sugar solution

Verdet constants of various honey and sugar solutions are obtained through fitting data between the faraday rotation parameters and the external magnetic field. The gradient magnitude of the linear regression is then used to calculate the Verdet constant using equation (1). All data are performed the different magnitude of Verdet constant among the sample (Table 5).

Table 5. Verdet constant of various honey types and sugar solution at different concentration.

| Concentration | Verdet constant (× 10⁻⁵ rad gauss⁻¹ cm⁻¹) | Honey of Kaliandra | Honey of Randhu | Honey of Pahit | Sugar |
|---------------|-------------------------------------------|-------------------|----------------|---------------|-------|
| 0%            |                                           | 1.30 ± 0.00       | 1.29 ± 0.01    | 1.30 ± 0.02   | 1.29 ± 0.04   |
| 5%            |                                           | 1.43 ± 0.03       | 1.37 ± 0.04    | 1.40 ± 0.05   | 1.47 ± 0.10   |
| 10%           |                                           | 1.68 ± 0.07       | 1.47 ± 0.04    | 1.45 ± 0.36   | 1.58 ± 0.14   |
| 15%           |                                           | 1.95 ± 0.05       | 1.76 ± 0.04    | 1.70 ± 0.02   | 1.68 ± 0.19   |
| 20%           |                                           | 2.24 ± 0.03       | 2.01 ± 0.22    | 1.80 ± 0.27   | 1.84 ± 0.17   |
| 25%           |                                           | 2.26 ± 0.03       | 2.12 ± 0.50    | 2.03 ± 0.25   | 2.01 ± 0.19   |
| 30%           |                                           | 2.36 ± 0.00       | 2.16 ± 0.83    | 2.13 ± 0.31   | 2.12 ± 0.14   |

Figure 2. Concentration dependent Verdet constant of various types of honey and sugar solution.
As control data, samples of honey and sugar solution at a concentration of 0% have a good agreement with the results of Sayyan's research (1997) [16]. Therefore, the results of Verdet constant measurements are quite accurate. At temperature of 20°C, Sayyan (1997) presented it at of 1.3 x 10⁻⁵ rad.gauss⁻¹cm⁻¹. The data shows that increasing the concentration of material gives a fairly linear increase in the Verdet constant. This is reflected in the curve generated on the graph containing the data plots of the two parameters giving a linear tendency to increase (Figure 2). The higher the concentration of honey, the more fructose and glucose levels in honey, known as substances that are optically active [17]. Here, we can describe how the types of honey are quite differ with sugar solution through Verdet constant.

At various concentrations, all samples performed different magnitudes of Verdet constant. However, honey of Kaliandra has the largest Verdet constant, at a concentration of (10-30)%. It defines that the material has a strong Faraday effect [4]. It is very sensitive to external magnetic fields, so that the plane of polarized light is easily changed. The effect of this phenomena is that the gradient of Verdet constant as a function of its concentration is relatively high. This is probably caused by the high water content of Kaliandra honey, which reaches 26.52%, compared to Randhu honey (20.77%) [18]. The amount of water content in honey indicates the hygroscopic nature of honey. In this situation, the chemical bonds in honey tend to be more stable. This instability causes water molecules to be electrically polarized, producing a magneto-optical response that is strong enough, when subjected to an external magnetic field.

The profile of concentration dependence of the Verdet constant for all three types of honey is the same as that of the sugar solution. This indicates that all three honey samples have the same active optical content as sugar, which is sensitive to external magnetic field exposure. Furthermore, Pahit honey appears to have the dependent characteristics of the Verdet constant which is almost similar to the sugar solution. We can see that the two linear regression lines are relatively coincide with each other.

4. Conclusion

As the result of discussion above, we can conclude that Faraday's rotation is affected by the concentration of honey and sugar solution. The greater the concentration given, the greater the rotation of Faraday obtained. These characteristics cause the Verdet constant of Kaliandra honey, Randhu honey, Pahit honey and sugar solutions to be linearly increased as a function of concentration. The highest Verdet constant is achieved by Kaliandra honey when analyzed at a concentration of 30%.

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