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Characteristics of Palm Oil and Animal Oil Based on Relative Dissociation Energy Using Electrooptic Polarization

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Abstract— The interaction between triglyceride molecules in cooking oil can be described by Van der Waals interaction which the potential energy between molecules is fulfilled by the potential energy of Lenard-Jones. This study aims to obtain relative dissociation energy in palm oil and animal oil using electro-optics polarization. In the experiment, we measured the change of light polarization as the sample was induced by potential difference or so-called electro-optics. The relative potential of Lenard-Jones as a function of the relative molecular distance was assumed proportional to the average change of electro-optics polarization as a function of potential difference. The results show that in this experimental condition, palm oil has relative dissociation energy greater by a factor of 100 than animal oils, and it decreases after the sample is heated. The observation of Van der Waals interaction through the electrooptic polarization is a new perception and it relatively can be achieved by using a simpler polarization experiment.

Keywords— Electro-optic, Polarization, Palm Oil, Animal Oil, Dissociation Energy

I. INTRODUCTION

There are several methods to test the quality of cooking oil, such as dielectric sensor [1,2], NMR spectroscopy [3], VIS-NIRS [4], Differential Scanning Calorimetric (DSC) [5], FTIR-ATR [6], Gas Chromatography -Flame Ionization [7] and others. Each of these methods has its test parameters to determine the feasibility of a cooking oil product. With so many test parameters from some of the previously mentioned methods, the cooking oil quality test is very complex. So we need an alternative method with simple equipment but still reliable and reliable results. In 2020, Sampson conducted a study using the AOCS method to evaluate the quality properties of three commonly consumed oils in Ghana, namely vegetable oil, palm oil, and coconut oil [8]. Negas et al. [9] tested the quality of imported and local vegetable oils using a cross-sectional study design to collect 60 random samples.

Oil degradation and the presence of primary and secondary oxidation products have been evaluated by thermogravimetric analysis (TGA) and Fourier transform infrared spectroscopy (FTIR [10]. Oil quality is determined by changes in water content, acid value (AV), and free fatty acids (FFA). , iodine number (IV), peroxide number (PV), and total polar compound (TPC). Several quality parameters such as saponification value, acid value, peroxidase value, and iodine value will help in estimating the quality of edible vegetable oil [11]. Dudi et al [11] evaluated the difference in quality between cooked and crude oil. The materials used utilized various samples of vegetable oils from major Indian brands such as sunflower oil, soybean oil, canola oil, almond oil, coconut oil, and olive oil using this method AOCS. The results showed that in comparison to crude oil, cooking oil had a significantly higher saponification value. The acid value also increased in the cooking oil compared to the uncooked oil. The widely used sunflower oil has a twofold significant increase in saponification value and a fivefold significant increase in acid value after cooking. The impedimetric sensing method was proposed by Yi Kung [12] to assess the condition of cooking oil used repeatedly.

Azam et al have conducted a study using the fluorescence polarization method for the investigation of cooking oil and lard [13]. Sucipto et al [14] conducted a study to distinguish lard from tallow and palm oil based on their electrical properties, namely conductance, impedance, and capacitance. Multivariate statistics consisting of principal component analysis (PCA) and cluster analysis (CA) were used to evaluate the data. The results showed that lard can be distinguished using all parameters of the electrical properties of the material.

Through the electrooptic effect, it has been known that nonlinear optics in cooking oils can also be observed by measuring the change of light polarization, and this opens up new horizons and potential possibilities in the development of cooking oil quality evaluation along with the study of the interaction of light with matter [15-22]. Since the oil quality parameters accompanied by their methods or instruments are usually too many and complex, then there needs to be such a new idea that it is possible to obtain a single quality parameter [16, 17]. The term electrooptic gradient has been first used [18] to describe the quality characteristics after undergoing heating and its relation to the composition of the fatty acid content, which describes the average polarization value per applied potential difference on a sample. Still based on the hypothesis in the study of [16, 17], the study of electro-optical polarization shows that the parameters of the electro-optic gradient are closely related to the molecular interactions in cooking oil. The interaction between triglyceride molecules in oil obeys Van der Waals interaction, in which the potential energy E_{LJ} of Lenard-Jones as the distance between adjacent molecules R is given by

$$E_{LJ} = E_D\left[\left(\frac{R_m}{R}\right)^{12} - 2\left(\frac{R_m}{R}\right)^{6}\right] \qquad (1)$$

where E_D is dissociation energy and R_m is the distance as the potential energy has a minimum value. The condition of the sample after undergoing treatment in the form of heating or the addition of an external electric field is to place molecules in the θ state, or what is known as the change in the polarization θ when interacting with light. Therefore, according to the hypothesis that the average polarization per potential difference θ/V is most likely proportional to potential energy E_{LJ}

$$\frac{\theta}{V} \sim E_{LJ} \qquad (2)$$

The characteristics of cooking oil are therefore determined by the E_D and R_m values reflecting the quality conditions of the sample. In this paper, the characteristics of these values are to be obtained, and discussed how they relate to the sample after heating. This research is very interesting in that the characteristics are expected to represent in the future as a single oil quality parameter.

II. METHODS

The basic hypothesis used refers to the preliminary study [17], so here we still consider that the average polarization per potential difference θ/V is proportional to the potential energy E_{LJ}. The increase in potential difference V is proportional to the increase in the distance between adjacent molecules R. Thus, a new relative potential energy equation is obtained here from the modification of equation (1) which can be written in the following equation

$$\frac{\theta}{V} \sim D\left[\left(\frac{s_m}{s}\right)^{12} - 2\left(\frac{s_m}{s}\right)^{6}\right] \qquad (3)$$

with D is now the relative dissociation energy, s_m is the relative distance when the potential reaches a minimum value, and s being the scale factor which is represented as the relative distance between molecules. The graph θ/V of the function s in equation (2) is now representative of the relative potential Lenard-Jones, where the relative dissociation energy of D is desired in this study. Since applying the voltage V to the sample results in a change in the distance between molecules R, the scale s is assumed proportional to V, and it can be written as follows.

$$s = \frac{V+a}{b} \qquad (4)$$

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where *a* and *b* are the parameters of a scale whose values are determined in such a way that the experimental data corresponds to a relative potential graph. In equation (3), the left part will be equal to the right part if it is multiplied by a proportional coefficient. By assuming the proportional coefficient is unity and entering equation (4) into equation (3), the relative potential energy equation is obtained as follows:

$$\frac{\theta}{V} = Y_0 + D\left[\left(\frac{s_m b}{V+a}\right)^{12} - 2\left(\frac{s_m b}{V+a}\right)^{6}\right] \quad (5)$$

The value of Y_0 is the intersecting point with the θ/V axis and it usually does not have to be zero. By varying potential difference V we obtain a similar pattern as in equation (1),

$$\frac{\theta}{V} - Y_0 = D\left[\left(\frac{s_m b}{V+a}\right)^{12} - 2\left(\frac{s_m b}{V+a}\right)^{6}\right] \quad (6)$$

The experimental data θ/V as a function of V will be plotted and the parameters D, and s_o, that are found from the fitting curve are the desired parameters of the quality characteristics of the oil.

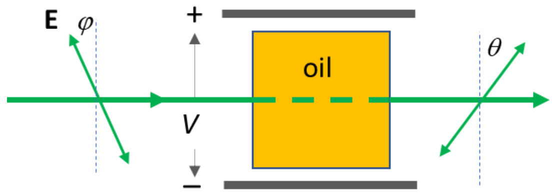
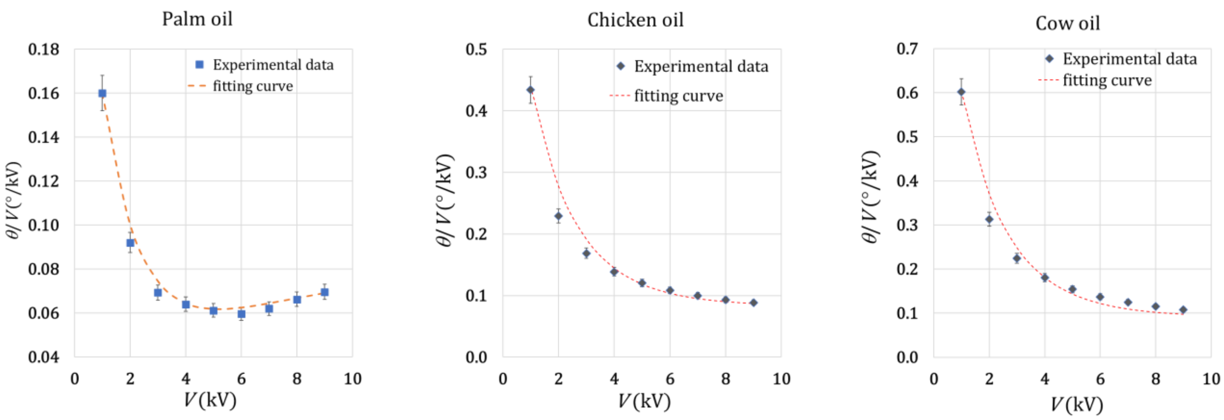


Fig. 1 The setup of electrooptic polarization: sample was induced by DC high voltage *V*. A linear polarized incoming light with **E**-field after through the polarizer with an angle φ is changed after through the sample with angle of polarization θ.

The samples used in the study were palm oil, chicken oil, and cow oil, and had been heated for 2 hours, 4 hours, 6 hours, and 8 hours. The procedure of the experiment referred to the previous study [17] with a light source using a 532 nm pointer laser. Because of a huge amount of data experiment, in this study, it was chosen a linear polarized light only at a polarizer angle $\varphi = 0°$. The setup of measurements can be seen in Fig. 1.

III.RESULTS AND DISCUSSION

After plotting curves of θ/V against V we obtain the following results. Figure 2 is the relative potential curves with fitting experimental data for palm oil, chicken oil, and cow oil before heating. Other samples after heating were also carried out by matching experimental data with a relative potential energy curve similar to the results in Fig. 2.



(a) (b) (c)

Fig. 2 Fitting curve of relative Lenard-jones potential energy using experimental data for sample before heating: (a) palm oil; (b) chicken oil; and (c) cow oil

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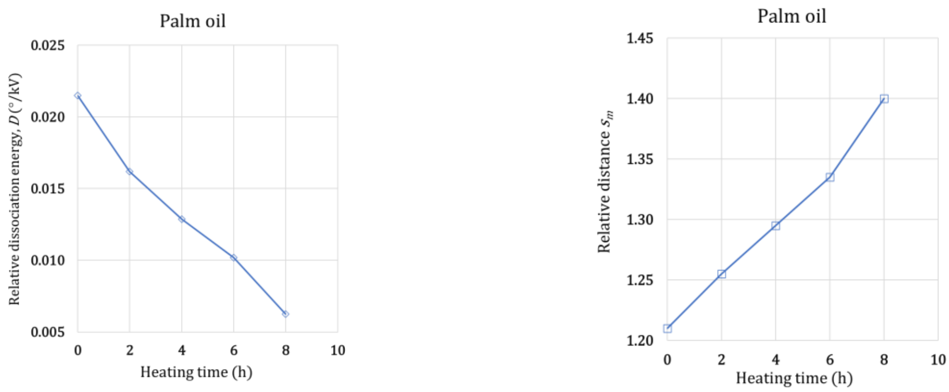
Table 1 shows the values of relative dissociation energy *D*, the intercept point Y_0, and relative distance s_m only for samples before heating according to the fitted curves of equation (5) with chosen scale parameters *a* = 20 and *b* = 19. It can be seen that the value *D* of palm oil is higher by a factor of 100 times than chicken and cow oil before heating.

TABLE I
RELATIVE PARAMETERS FROM FITTING

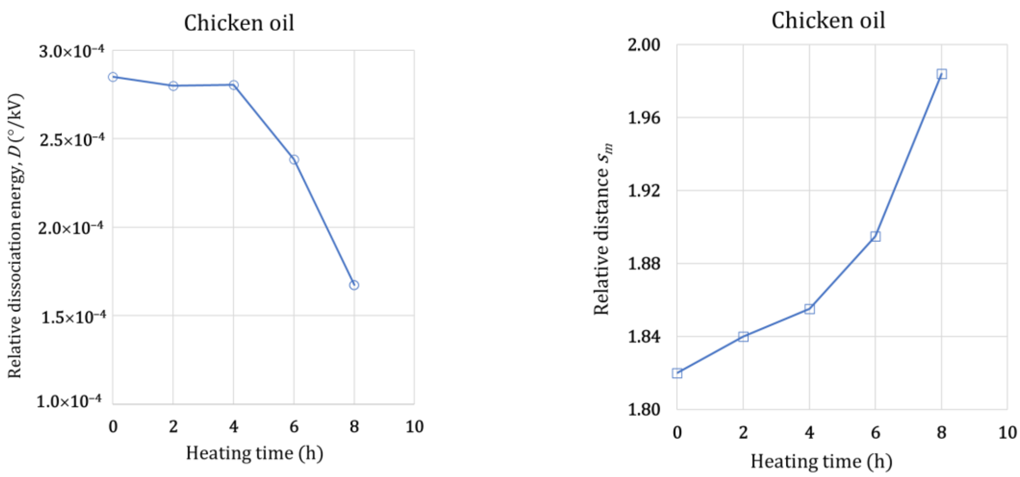
Sample	**Intercept** Y_0	**Relative dissociation energy** D	**Relative distance** s_m
Palm oil	8.32×10^{-2}	2.15×10^{-2}	1.21
Chicken oil	7.96×10^{-2}	2.85×10^{-4}	1.82
Cow oil	9.10×10^{-2}	2.06×10^{-4}	1.93

From the fitting experimental data, the important value *D* and s_m as a function of heating time are summarized as follows. Fig. 3-5 depict the characteristics value *D* and s_m against heating time for palm oil, chicken oil, and cow oil, respectively.



(a) (b)

Fig. 3 (a) The relative dissociation energy *D*, and (b) the relative minimum distance s_m of palm oil from fitting curve



(a) (b)

Fig. 4 (a) The relative dissociation energy *D*, and (b) the relative minimum distance s_m of chicken oil

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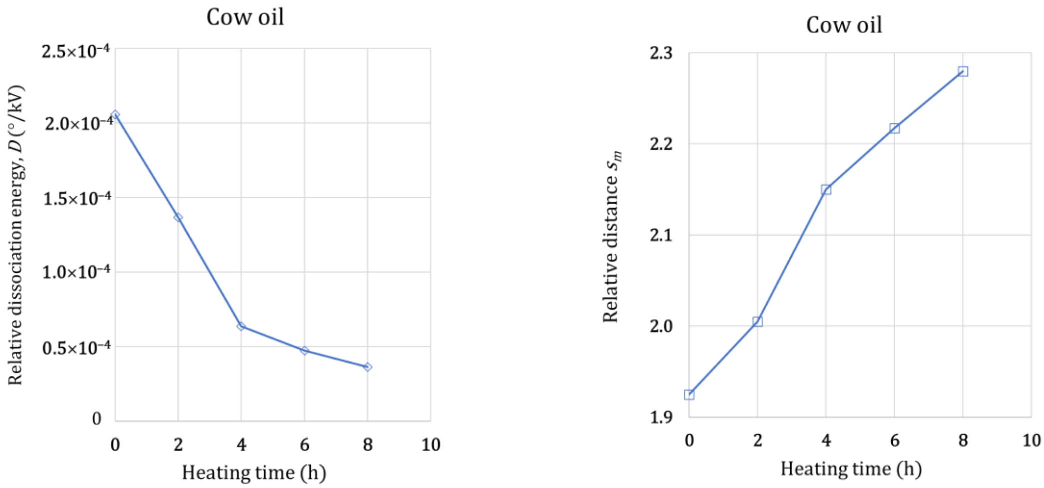
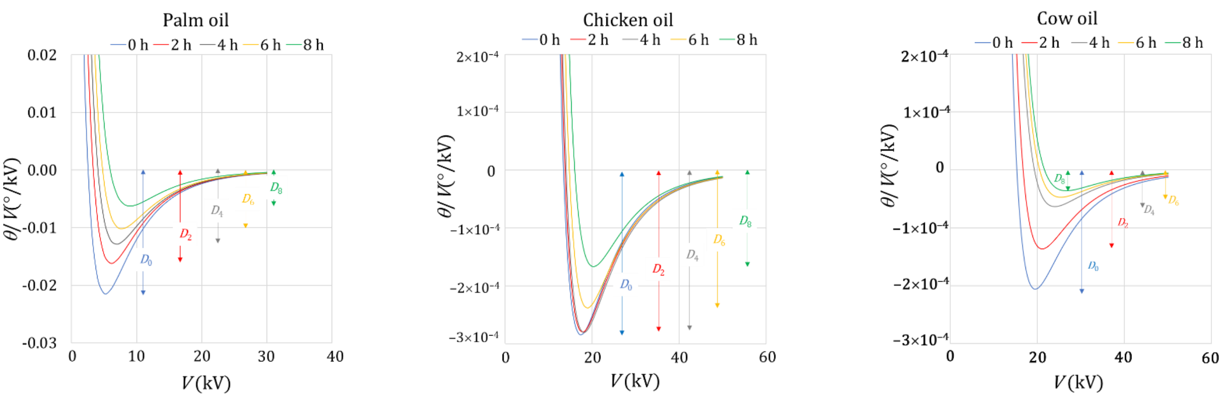


(a) (b)

Fig. 5 The relative dissociation energy D, and (b) the relative minimum distance s_m of chicken oil



(a) (b) (c)

Fig. 6 Relative potential energy using equation (6) for (a) palm oil; (b) chicken oil; and (c) cow oil

From Fig. 3 to Fig. 5, it is very exciting results to be noticed that as the length of heating of the sample increases, the value D decreases and fortunately is accompanied by an increase in the minimum relative distance between molecules s_m, which is in agreement with our previous study [16,17]. Firstly, the decrease in value D as the increase in heating time can be explained by the development of various asymmetric molecules during the heating sample. Because the longer heating time results in the growth of more asymmetric molecules which leads to an increase in polarization changes. Since a symmetric molecule has a relatively greater contact area than an asymmetric molecule, the attraction of forces between symmetric molecules is stronger than asymmetric molecules. It needs much energy to separate away between two adjacent symmetric molecules, and therefore the dissociation energy in palm oil with rich symmetric should be high. Secondly, the shift in relative distance s_m to greater value as the increase in the duration of heating time is most likely due to the consequence of the increase in the various size of the asymmetric molecules. Because an asymmetric molecule is less compact than a symmetric one, it leads most probably to increase the relative distance intermolecular as the molecules reach the lowest potential energy. The curves of the relative potential energy of Lenard-Jones with all their relative D and s_m for various heating times from equation (6) for palm oil, chicken oil, and cow oil are demonstrated in Fig. 6.

The value θ vs. V is polynomial in 2[nd] order as has been obtained also in our previous study [18-22] as nonlinear optics characteristics. The value θ/V, which is supposedly proportional to the potential energy of Lenard-Jones, is very surprising. Coincidentally, the plot θ/V against V is closely corresponding to the graph of E_{LJ} as function R from equation (1). It indicates that the applying voltage V to the sample leads to the change of molecular distance *R*. The Lenard-Jones potential that can be demonstrated via electrooptic polarization will new insights into how to describe Lenard-Jone's potential using a simpler electrooptic experiment. This method can be used also for other transparent substances as long as it is neutral molecules that are appropriate to potential E_{LJ}. However, comprehensive derivation from θ/V to E_{LJ} will be an interesting task in the future. The study about Van der Waals interaction with its relative potential of Lenard-Jones through electro-optic polarization seems to be developed for other types of oils to obtain a more comprehensive interpretation, mapping various characteristics and other applications.

IV. CONCLUSIONS

Through the electrooptic polarization, the relative dissociation energy of palm oil is 100 times the energy of animal oil, and the value was reduced after all sample was heated. The reduced energy could be caused by developing more various asymmetric molecules, in which the attractive force among asymmetric molecules is relatively smaller than symmetric molecules. And as the increase of heating time, it was accompanied by increasing relative molecular distance s_m that could be caused by less compactness of various asymmetric molecules resulting in relative distance molecular as it reaches minimum potential energy. The electro-optic polarization seems operative to be applied also for other transparent materials to study various Van der Waals interactions and the relative potential energy of Lenard-Jones. The condition of polarization θ can be regarded as θ*the* condition after heating, applying an external field, or other treating on samples. The value average polarization per potential difference θ/V seems proportional to the potential energy of Lenard-Jones, and the applied field *V* to the samples is most likely changing the molecular distance and results in relative potential energy against relative molecular distance as if it occurs in Van der Waals interaction. This method is an advantage to observing Van der Waals interaction for other molecules by using relatively simpler equipment.

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