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Study of the most responsible parameters on polarization for powerful preliminary test of oil quality

K. Sofjan Firdausi[1)]*, Suryono[1)], Priyono[1)], and Zaenul Muhlisin[1)]

[1)] Department of Physics, Faculty of Sciences and Mathematics, Diponegoro University
Jl. Prof. Soedarto SH., Semarang 50275 Indonesia

Email: *firdausi@fisika.undip.ac.id*; *k.sofjanfirdausi@yahoo.co.id*

Abstract

In this study, the most responsible parameters on polarization in total natural vegetable oils and fats have been investigated by determination of the relation between the polarization change and fatty acids (FA) composition. The change of light polarization was simply measured by using a pair of polarizer-analyser to indicate oil quality level, and the FA composition was obtained by using Gas Chromatography and Mass Spectrometer (GCMS) method. Various vegetable oils and fats were examined without any preliminary treatments. The experimental condition of the samples during measurement was assumed to be constant. It has been shown that various oils and fats have different angle of change of polarization, which indicates various oil quality level relative to each other, in agreement to the previous works. Especially for vegetable oils, high change of polarization has been considered as low quality of oil. The long chain of saturated fatty acids (SFA) and unsaturated fatty acids (UFA), which are distributed at third position (R_3) and first position (R_1) of triglycerides (TG) molecules, are responsible for the change of polarization and presented as a linear combination of the number of SFA or UFA. The result shows that the polarization could be used as powerful method for preliminary detection of oil quality level. The highest number of coefficient of C19:0 in lard indicates that this method has provided good prospect to evaluate the halal level of oil due to lard contamination.

Keywords—polarization, triglyceride (TG), saturated fatty acid (SFA), unsaturated fatty acids (UFA)

Abstrak

Pada penelitian ini, hendak dicari parameter-parameter yang paling bertanggung jawab pada perubahan polarisasi untuk sampel minyak nabati dan minyak hewani dengan menentukan hubungan antara perubahan polarisasi dan komposisi asam lemak. Perubahan sudut polarisasi cahaya secara sederhana ditentukan menggunakan sepasang polarisator – analisator untuk menunjukkan tingkat kualitas relatif dari sampel, sedangkan komposisi asam lemak ditentukan dengan Gas Chromatography and Mass Spectrometer (GCMS). Sampel yang digunakan adalah minyak sawit, minyak ayam, dan minyak babi yang diuji tanpa perlakuan awal. Kondisi pengukuran dari sampel-sampel tersebut dianggap tetap. Diperoleh bahwa perubahan sudut polarisasi yang berbeda-beda mengindikasikan berbagai tingkat kualitas minyak yang satu dengan yang lain, dan sesuai dengan hasil penelitian terdahulu. Terutama untuk minyak nabati, perubahan polarisasi yang tinggi menunjukkan kualitas yang relatif rendah. Pada kondisi ini, perubahan polarisasi minyak babi paling besar. Rantai panjang dari asam lemak jenuh C19:0 dan tak jenuh ganda C19:2 yang terdistribusi pada posisi R_1 dan R_3 pada molekul trigliserida paling bertanggung jawab pada perubahan polarisasi. Perubahan ini direpresentasikan sebagai kombinasi linier dari empat asam lemak utama yakni C17:0, C19:0, C19:1, dan C19:2. Hasil-hasil ini menunjukkan bahwa polarisasi dapat digunakan sebagai indikator awal yang handal pada mutu minyak. Nilai koefisien yang tinggi pada C19:0 untuk minyak babi memberikan prospek, metode ini dapat digunakan lebih lanjut untuk penyelidikan tingkat kehalalan minyak akibat cemaran minyak babi.

Kata Kunci—*polarisasi, trigliserida, asam lemak jenuh, asam lemak tak jenuh*

Introduction

The light polarization in vegetable oils exists due to asymmetric triglyceride (TG) molecules. The reason of asymmetric TG molecules, that causes optically active, has been believed as the difference between the first and the third fatty acids (FA) in a TG molecule. Not only differing in composition, but also differing greatly in chain length of fatty acids in TG has been considered to cause optical activity of TG. The most important result has shown that a saturated TG was observed to be optically active if the chain length of third FA greater than first FA [1].

Meanwhile, our previous work has shown that TG in complex mixture of vegetable oils shows very small optical rotation using ordinary light. Average change of polarization in standard edible oils has value of rotation less than 1° without any preliminary treatments [2-5]. Although it is very low optically active, various types of oil show different small polarization depending on oil condition. It certifies that polarization could be used for powerful preliminary test of oil quality [2]. Our work has also shown that small value of rotation in oil can be increased significantly by adding an external electric field to the sample, or so called electro-optics [3-5]. This leads to a new single parameter of oil quality, which is simpler than recent standard parameters according to Indonesia National Standardization [6-7]. In electro-optics consideration, we have obtained important results that electro-optics gradient of the polarization change from various degradation of oil quality is influenced by the predominant FA and is a linear combination of the main FA composition in the palm oil [8]. Another interesting application of electro-optics technique has been used to indicate waste cooking oil treatment using ZnO thin film for Photo-catalytic [9].

In this paper, most responsible parameters of TG in total complex oils that due to the change of polarization, have been studied. It has been proposed that only SFA and UFA in TG have been considered to be most active in contribution to the light polarization, and the other parameters have been ignored. It has been also assumed that the third fatty acids (R_3), in any saturated or unsaturated form, should be always much greater in chain length than the first (R_1) according to the reference [1]. The change of polarization due to asymmetric TG is supposedly a linear combination of the number of SFA and UFA of TG molecules according to the reference [8]. Figure 1 describes a model of an asymmetric TG, where the R_1 and R_3 represent fatty acids in different length and quantities.

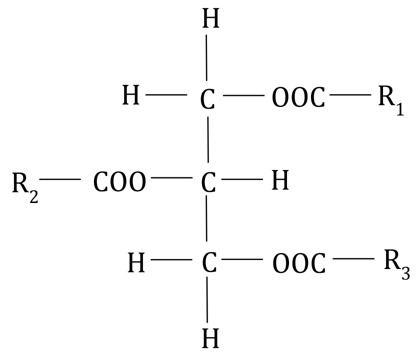

Figure 1 a model of TG. R_1 and R_3 could be replaced by SFA or UFA where R_3 has much longer chain than R_1 in order to be optically active.

Method

Various vegetable oils were used as samples in the experiment. The sample was obtained from the market, assumed to be fulfilled by SNI. The fats were chicken oil and lard oil obtained from the traditional market and as well as were expected from a standard extraction.

The change of polarization was determined by using a pair of polarizer-analyser and measured in degree (°). The experiment was carried out from May until August 2015. All samples were measured in the same condition at room temperature without any previous treatment. Any change of sample temperature not more than 1°C was considered to be not significant in contributing to light polarization. The samples were examined by using GCMS for determination and identification of SFA and UFA fraction.

Results and Discussion

Figure 2 shows the polarization change in vegetable oils and animal oils or fats. The palm1 (expired in 2014) is expired oil and palm2 (expired in 2017) is edible oil. The fats, i.e. chicken oil and lard (pig oil), were used to evaluate halal level for future information. The "halal level" means in this case that a possibility an edible oil is contaminated by lard.

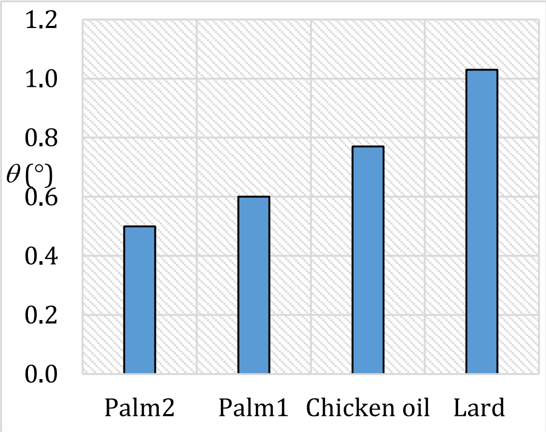

Figure 2 the change of polarization in vegetable oils and animal oils. The animal oils or fats were represented by chicken oil and lard (pig oil), which were obtained in the market in May and June 2015. Palm2 is still edible oil (expired: 2017) and palm1 is already expired (expired: 2014)

It is shown that expired oil (palm 1) has higher change of polarization than the edible one (palm 2). In agreement to our previous work [2], in many cases, an expired oil has always higher polarization than the edible or fresh one. It should be mentioned that recent standard methods could not obtained simply and simultaneously due to various parameters. In our case, the difference between expired and edible oil is easily obtained by using polarization. Therefore our method is much more powerful for preliminary test of oil quality than the standard methods.

As shown in figure 2, the lard has the highest polarization compared to the others. This has provided a good prospect for evaluation of halal level due to lard for future. However, it still remains questions, why it has highest polarization angle. It was still suspected that SFA and UFA play an important role to the change of polarization. For the reasons, it was then examined using GCMS to obtain further information of the SFA and UFA number.

Table 1 shows the total fraction of SFA and UFA of the total samples obtained using GCMS instrument, and these are chosen only for the highest possibility that causes optical rotation in high number of carbon atoms. The SFA labelled with C17:0 and C19:0 represents methyl palmitate ($C_{17}H_{34}O_2$) and methyl stearate ($C_{19}H_{38}O_2$), respectively. The double bond UFA assigned with C19:2 and single bond assigned with C19:1 represent respectively methyl linoleate ($C_{19}H_{34}O_2$) and methyl oleate ($C_{19}H_{36}O_2$).

Table 1 List of oils, its expiration date, and the highest fraction of SFA and UFA.

Sample	expiration date	Fraction of Fatty acids				Change of polarization (°)
		C17:0	C19:2	C19:1	C19:0	
Palm 2	16/02/2017	0.3523	0.1061	0.4112	0.0336	0.50
Palm 1	25/10/2014	0.3602	0.099	0.4273	0.0329	0.60
Chicken oil	NA*	0.1927	0.1798	0.3979	0.0458	0.77
Lard (pig oil)	NA*	0.2009	0.1389	0.3456	0.0815	1.03

* Both chicken oil and lard were bought in 24 May 2015 and 4 June 2015, respectively. The expiration date was not available.

The increasing change of polarization in table 3 was also accompanied by increasing fraction of C19:0, except for palm oil, which is almost equal change of polarization. It is some possibility that both of C17:0 and C19:0 were very predominant to the optically activity of the whole oils or fats. If the long chain of R_1 must differ from R_3, these positions should be replaced by short chain of FA and long chain FA such as C17:0 and C19:0 respectively. The longer chain of R_3 the higher optical activity of the TG. In this case, with high fraction distributed among C17:0, C19:2, C19:1, and C19:0, the highest possibility that the optical rotation could be observed in asymmetric TG, the combination R_1 = short chain of FA and R_3 = C19:0 would be the best pair of fatty acids in TG in accordance to contributing highest change of polarization. The R_2 position that plays a role of centre of symmetry could be replaced by any of SFA or UFA among in TG. The rotation angle of polarization here was supposedly considered to be linear combination of fraction of SFA or and UFA distributed in the whole palm oil according to equation (1),

$$\Delta\theta = a\, f_{17:0} + b\, f_{19:2} + c\, f_{19:1} + d\, f_{19:0}, \quad (1)$$

where, $\Delta\theta$ is change of polarization, f represents fraction of the FA, a, b, c, and d represent linear coefficients in °, which should be considered how dependent these SFA or UFA on change of polarization are. Solving the linear eq. 1 by using fraction in Table 1, the coefficient values of a, b, c, and d are approximately listed in Table 2.

Table 2 values of linear coefficient of fraction of SFA and UFA

Fatty acids	Coefficient	Value (°)
C17:0	*a*	-4.5
C19:2	*b*	-6.5
C19:1	*c*	5.9
C19:0	*d*	9.6

From table 2, the SFA of C19 seems to play most important role in increasing the change of polarization. Our results seem in agreement with the previous results [8], in which the change of polarization is a linear combination of most FA, such as C20:2, C20:1, and C20:0 with fair correlation for C20:0 and strong correlation for C20:1. The dominated FA such as C20:1, and C20:0 in contributing to the polarization change is the understandable due to the long chain and most abundant molecule.

Conclusions

The polarization has shown oil quality level. In case of showing the difference between edible and expired oil, this method shows powerful compared to other standard methods. The change of polarization, so far, is related to the formation of SFA and UFA. The change of polarization is a linear combination of the number of the main FA. The most dominant polarization in lard from chicken oil should take in to account of additional SFA, which it has highest coefficient of C19:0 from all samples and provides a good prospect for evaluation of halal level of oil.

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