Method of fluorescence polarization for a new alternative tool for investigation of cooking oil and lard

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Abstract. Testing the quality of cooking oil is very important, especially to ensure the quality and identification of other unexpected mixture of cooking oil. In this paper, the fluorescence polarization method will be used to test the presence of lard contamination on cooking oil. Fluorescence polarization is similar to fluorescence intensity, in that it is based on the emission of light by an excited fluorophore. However, samples are excited by polarized light which is selected by specific polarizing filters. The angle of linearly polarized incoming light was adjusted by using a polarizer. The change of fluorescent polarization angle was measured by using a second polarizer (analyzer) to obtain a relation between $\theta$-value and $\varphi$-value for all samples. The samples were various edible oils, i.e., chicken oil, lard, and canola oil. The test is carried out by measuring the change in the average polarization angle of the fluorescent light to the polarizing angle of each incoming light over the sample directly. The results of the critical angle showed that all three samples were characteristic. Chicken oil has $\varphi_c = 20^\circ$ with $\theta_{av} = 11.28^\circ$ to $13.63^\circ$, lard has $\varphi_c = 40^\circ$ with $\theta_{av} = 7.13^\circ$ to $9.51^\circ$, whereas canola oil has $\varphi_c = 30^\circ$ with $\theta_{av} = 2.59^\circ$. These results show that the fluorescence polarization method has a good prospect for oil contamination test on cooking oil.

1. Introduction
Polarization as a parameter of oil quality has been introduced using electro-optical methods for light transmission, and subsequent research results can significantly distinguish the quality of various cooking oils[1]. It is alleged that the polarization by the electro-optic has the prospect of being the only quality parameter for cooking oil, replacing other parameters [2]. But with fluorescence polarization, we get more significant test results than natural polarization, and the test is used in olive oil and palm oil, related to the expiration date [3,4].

The main source of fatty acids is vegetable oil. In vegetable oils, there are triglycerides (95% - 98%), and (5% - 2%) consist of complex mixtures of minor compounds in various chemical classes [5]. Comparison of saturated and unsaturated fatty acids has an important role in the character of vegetable oils. Oxidation of unsaturated fatty acids is a complex phenomenon that produces mainly hydroperoxides but also volatile compounds through three-phase processing: initiation, propagation, and termination. Oxidation causes degradation of the quality of vegetable oils [6].

The distribution and composition of saturated and unsaturated fatty acids in cooking oil is a major cause of fluorescence polarization related to the quality of various animal oils [3, 7, 8]. In our previous study, polarization changes can be specified [8] as $\theta = \theta_{nat} + \theta_{elec}$, where $\theta_{nat}$ is the natural
polarization angle because the asymmetric TG molecule, or what is called the optical active TG molecule, and ecelec are the electro polarization angles -optic caused by electro-optical effects due to the addition of an external electric field. The $\theta$ ecelec value is contributed by all TG molecules (all asymmetric and symmetrical TG molecules) which become electric dipoles. In this situation, the dominant unsaturated and saturated fatty acids in cooking oil contribute to the $\theta$ ecelec value. Without an external electric field, we get $\theta$ ecelec = 0, etc. $\theta = \theta_{nat}$.

The advantage of fluorescence polarization rather than electrooptic polarization is that there is no need for additional induction electric fields in the sample, making it more practical and simple. The advantage over other methods is that fluorescence polarization is simpler, practical, and inexpensive. Direct measurement of fluorescence polarization has never been carried out by other researchers. This principle uses the difference in polarization of light scattered with incoming light, where the wavelength of scattered light is greater than that of incoming light. But until now there has not been fundamentally answered what physical variables are most responsible for significant changes in polarization by scattering or fluorescence. It is assumed that the increase in polarization in scattering light is related to the accumulation of the formation of a longer fatty acid chain. Likewise, the wavelength of the light used still needs further research so that the most optimal work area is obtained for determining the quality and level of halal due to contamination of lard.

In this research, we measure the change of polarization angle of fluorescence light $\theta$ as a function of the change of the polarizing angle $\varphi$ of the incoming light to obtain the fluorescence polarization profile on various vegetable oils. The relation between $\theta$-value and the saturated and unsaturated fatty acids composition is also being studied assuming that the $\theta$-value is a linear combination of a number of fatty acids according to the reference [8]. We also discuss the prospects of the method as a new alternative method for investigation cooking oil.

2. Research Methods

Data retrieval is done by observing changes in the polarization angle in two types of cooking oil and lard. The oil sample used is placed in a cuvette and observes the change in polarization angle in the analyzer. Polarization angle change test is done using a green laser.

The next step is to observe changes in the polarization angle by fluorescence on cooking oils. The oil sample used is placed in a cuvette and observes the change in the polarization angle in the analyzer. Scattering and fluorescence observations are carried out using a set of polarimeter consisting of a green laser, a polarisator, and an analyzer placed parallel to the polarisator, camera, sample cuvette.

The samples were various edible oils, i.e., chicken oil, lard, and canola oil listed in table 1. These were obtained from the market and assumed to be fulfilled by the Indonesian National Standardization (SNI).

| Edible oil  | remark |
|-------------|--------|
| lard        | B1, B2, B3, B4, B5, B6 |
| Chicken Oil | A1, A2, A3, A4, A5, A6 |
| Canola Oil  | C      |

The angle of linearly polarized incoming light was adjusted by using a polarizer from $\varphi = 0^\circ$ to $180^\circ$ with an increment of the angle of $10^\circ$. The change of fluorescence polarization angle $\theta$ was measured by using a second polarizer (analyzer) to obtain a relation between $\theta$-value and $\varphi$-value for all samples. To calibrate the relation between $\theta$ and $\varphi$, we measured a change of polarization angle of light scattering using aqueous solution at a range of polarizer angle $0^\circ \leq \varphi \leq 180^\circ$ using the experimental procedure from Firdausi et al. [10]. The incoming light was pointer laser of a 532 nm-wavelength, which was perpendicular to the direction of fluorescence light. The simple design of the measurement of polarization angle can be described as figure 1.
3. Results and Discussions

Figure 2 shows the fluorescence polarization angle profile in the range \(0 \leq \varphi \leq 180^\circ\) of each sample. The profile of the fluorescence polarization angle for chicken oil (Figure 2), lard (Figure 3) and canola (Figure 4). All samples have a pattern similar. All cooking oil fluorescence polarization profiles show symmetrical characteristics in the range \(0 \leq \varphi \leq 180^\circ\), which is the polarization in the range \(0 \leq \varphi \leq 90^\circ\) reflected with identical values in the range of \(90^\circ \leq \varphi \leq 180^\circ\).

Although the pattern is the same, there are several different characteristics of polarization changes \(\theta\). From the profile shown in Figure 2, we find the following results:

1. First, each type of cooking oil has a certain critical value of \(\varphi\),
2. seconds, at a critical polarization angle \(\varphi_c\), each type of oil has a different \(\Delta \theta\) minimum value.

According to the profile of fluorescence polarization angle, we obtained some characteristics values for the various sample condition, i.e., the \(\theta\) values at \(\varphi = 0^\circ\), \(\theta_{\text{min}}\) at critical polarization value \(\varphi = \varphi_c\), and average value \(\theta_{\text{avg}}\) listed in table 2.
Figure 4 Characterization of change of polarization angle as a function of polarization angle for canola oil

![Graph](image)

**Table 2** $\theta$-value of light of fluorescence at critical polarization angle $\varphi_c$ of incoming light

| Edible oil | $\varphi_c$ ($^\circ$) | $\theta_{Av}$ ($^\circ$) |
|------------|------------------------|------------------------|
| B1         | 40                     | 9.51                   |
| B2         | 40                     | 9.51                   |
| B3         | 40                     | 7.49                   |
| B4         | 40                     | 9.19                   |
| B5         | 40                     | 8.67                   |
| B6         | 40                     | 7.13                   |
| A1         | 20                     | 12.87                  |
| A2         | 20                     | 11.58                  |
| A3         | 20                     | 13.63                  |
| A4         | 20                     | 12.50                  |
| A5         | 20                     | 11.28                  |
| A6         | 20                     | 12.92                  |
| C          | 30                     | 2.59                   |

Based on the results above, the critical value $\varphi_c$ and the mean value $\theta_{Av}$ seem to play a very important role for the fluorescence polarization of each sample. The critical value $\varphi_c$ shows the reversal phase of the electric field at that point: the transformation phase $\theta$ of the left circular rotation when $\varphi$ changes from $0^\circ$ to $\varphi_c$, and the right circular rotation when $\varphi$ increases gradually from $\varphi_c$ to $90^\circ$. In this case, the minimum fluorescence polarization was varied from $\varphi = 0^\circ$ to the critical angle $\varphi_c$, which shows at least the different orientations of the TG molecules during exposure to light.

![Graph](image)

**Figure 5** Graphic of $\Delta \theta_{Av}$ as a function of $\varphi_c$. 

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In the following section, we discuss the possibility of fluorescence polarization as a new alternative method for evaluating the quality of cooking oil. From table 2 we find that each type of cooking oil has characteristics so that it can be used to distinguish the type and quality of cooking oil. There are several possibilities to distinguish different types of cooking oil based on the value of the critical angle and the average value of changes in the angle of polarization. In figure 5, look chicken oil has $\phi_c = 20^\circ$ with $\theta_{Av} = 11.28^\circ$ to $13.63^\circ$, lard has $\phi_c = 40^\circ$ with $\theta_{Av} = 7.13^\circ$ to $9.51^\circ$, whereas canola oil has $\phi_c = 30^\circ$ with $\theta_{Av} = 2.59^\circ$. These results show that the fluorescence polarization method has a good prospect for oil contamination test on cooking oil.

4. Conclusion
The profile of fluorescence polarization as a function of polarizer angle of the incoming light of each sample provides two important variables, i.e., the average fluorescence polarization angle $\theta_{Av}$ and critical value of polarizer angle $\phi_c$ of the incoming light. Chicken oil has $\phi_c = 20^\circ$ with $\theta_{Av} = 11.28^\circ$ to $13.63^\circ$, lard has $\phi_c = 40^\circ$ with $\theta_{Av} = 7.13^\circ$ to $9.51^\circ$, whereas canola oil has $\phi_c = 30^\circ$ with $\theta_{Av} = 2.59^\circ$. These results show that the fluorescence polarization method has a good prospect for oil contamination test on cooking oil.

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