International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 13; Issue: 5; May 2026
Website: www.ijrrjournal.com
Research Paper *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Evaluation of Thermal Degradation in Palm Oil Using Light Polarization Analysis

Heri Sugito

Department of Physics, Diponegoro University, Semarang, Indonesia.

Corresponding Author: Heri Sugito

DOI: https://doi.org/10.52403/ijrr.20260568

ABSTRACT

This study investigates the thermal degradation behavior of palm oil using a light polarization method. Palm oil samples were subjected to different heating durations of 0, 2, 4, 6, and 8 hours at an average temperature of 100°C. The degradation process was analyzed by observing changes in natural and electro-optic polarization angles under an applied voltage of 0–9 kV using a 532 nm laser source. The results showed that the polarization angle increased proportionally with heating duration, indicating progressive oil degradation. Palm oil heated for 8 hours exhibited the highest increase in polarization angle, corresponding to a significant reduction in oil quality. The findings demonstrate that light polarization analysis can be utilized as a non-destructive optical method for evaluating thermal degradation in edible oils.

Keywords: palm oil, thermal degradation, light polarization, edible oil quality

INTRODUCTION

Cooking oil is one of the most widely used food-processing materials in daily life. Continuous heating during frying processes can cause physical and chemical degradation of edible oils, including oxidation, hydrolysis, polymerization, and free radical formation. These degradation processes reduce nutritional quality and may produce harmful compounds that negatively affect human health. Palm oil is one of the most widely consumed vegetable oils in the world due to its affordability, high oxidative stability, and extensive applications in food processing industries. Palm oil Repeated heating of palm oil during frying processes, however, can induce thermal degradation that alters its physicochemical properties and decreases its quality and safety. Thermal degradation causes oxidation, hydrolysis, and polymerization reactions that produce free radicals, aldehydes, ketones, and other harmful compounds. These changes not only affect the sensory characteristics of food products but may also contribute to adverse health effects such as cardiovascular diseases and carcinogenic risks. Therefore, monitoring the degradation level of palm oil is essential for food safety, quality control, and industrial process optimization (Tsai, 2023).

Several conventional methods have been developed to evaluate cooking oil degradation, such as peroxide value analysis, viscosity measurement, refractive index analysis, Fourier Transform Infrared Spectroscopy (FTIR), and Gas Chromatography-Mass Spectrometry (GC-MS). However, many of these methods require complex sample preparation, expensive instrumentation, or destructive testing procedures.

Optical techniques based on light polarization have recently attracted attention as non-destructive alternatives for

evaluating edible oil quality. Firdausi et al. (2013) reported that changes in natural polarization angles could be used as indicators of the initial quality of cooking oils. Their study showed that degraded oils exhibited larger polarization angle shifts due to structural changes in fatty acid molecules. Susan (2011) investigated the electro-optic properties of vegetable oils under external electric fields and found that the polarization angle changed quadratically with increasing applied voltage. Similar results were also reported by Sugito et al. (2014), who demonstrated that oils with poorer quality exhibited greater electro-optic polarization responses compared to fresh oils.

Murni et al. (2013) studied the effect of heating duration on several vegetable oils and observed that polarization angle changes increased linearly with heating time in the range of 0–10 hours at approximately 180°C. Their findings indicated that extra virgin olive oil experienced the largest polarization change (39%), followed by olive oil (31%), palm oil (21%), and corn oil (16%). The increase was associated with the accumulation of free radicals formed during prolonged heating.

Rahmawati et al. (2020) conducted a light polarization study for soybean oil quality testing. The results showed that natural polarization and electro-optical polarization provide different physical meanings in relation to the oil's fatty acid composition. Natural polarization indicates that the increase in polarization is caused by an increase in polyunsaturated and saturated acids in asymmetric triglyceride molecules. This is accompanied by a decrease in polarization due to an increase in monounsaturated acids in symmetric triglyceride molecules. Meanwhile, electro-optical polarization explains that all fatty acids contribute to the increase in polarization due to an increase in the induced dipoles of all acids.

Compared with previous studies, the present research focuses specifically on evaluating thermal degradation in palm oil using both natural and electro-optic polarization measurements under controlled heating treatment. Unlike earlier works that mainly compared multiple oil types or only analyzed natural polarization effects, this study emphasizes the relationship between heating duration, electro-optic polarization behavior, and fatty acid composition in palm oil. In addition, the use of a 532 nm laser source and high-voltage electro-optic configuration provides a more sensitive optical characterization of degradation phenomena.

Therefore, this study aims to investigate the thermal degradation characteristics of palm oil through light polarization analysis and to evaluate the feasibility of polarization methods as rapid and non-destructive techniques for edible oil quality assessment. The novelty of this research lies in the application of light polarization analysis as a practical and non-destructive approach for assessing thermal degradation in palm oil. Unlike conventional chemical methods, the proposed approach emphasizes optical interaction mechanisms that are sensitive to structural and compositional changes within the oil. This study is expected to contribute to the development of rapid optical sensing techniques for edible oil quality monitoring and provide additional scientific understanding regarding the relationship between thermal degradation and polarization properties of palm oil.

MATERIALS & METHODS

The sample used in this study was commercial palm oil. The oil samples were heated at an average temperature of 100°C with different heating durations of 0, 2, 4, 6, and 8 hours. The equipment used in this research consisted of main equipment and supporting equipment. The main equipment was composed of 1) light source using a green laser with a wavelength of 532 nm, 2) polarizer that functions to select the direction of the electric field from the light source passed on the sample, 3) analyzer that serves to measure the change in angle polarization of light after passing the

sample, 4) A cuvette that functions as a container for the sample to be tested, 5) The source of a high DC power supply that functions as a static electric field generator with a voltage of 0-9 kV, 6) The camera functions to observe changes in polarization angle after passing through the analyzer, 7) Two metal plates parallel which function to induce samples, 8) PC which connected to camera to observe changes in polarization angle. All equipment was designed as shown in figure 1.

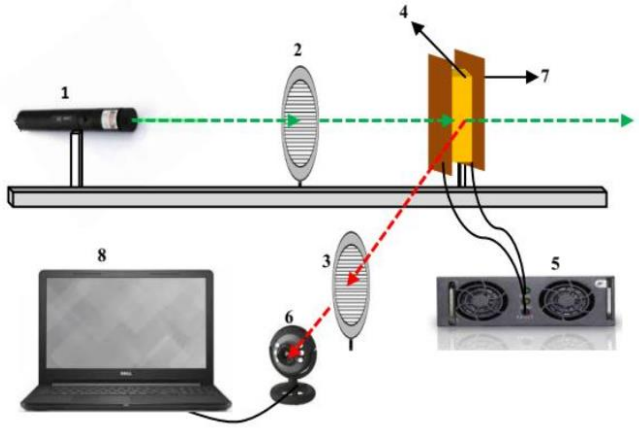

Figure 1 Integrated polarizer

The polarization angle of each sample was measured using an electro-optic transmission polarization method. Changes in natural polarization and electro-optic polarization were recorded for each heating duration.

RESULT AND DISCUSSION

Heated cooking oil will experience an increase in polarization angle, both natural polarization and electro-optical polarization. The degradation of cooking oil quality is indicated by an increasing change in polarization angle. The largest change in polarization angle indicates low quality cooking oil. The results of the study obtained a change in the polarization angle of palm oil with heating for 0 hours of 0.16. After heating for 8 hours, the polarization angle changed by 0.27, an increase of 62.7%.

Based on the results of Gas Chromatography-Mass Spectrometry (GC-MS) tests, there are three types of fatty acids dominant in cooking oil: saturated fatty acids (C19:0), monounsaturated fatty acids (C19:1), and polyunsaturated fatty acids (C19:2). Of these three fatty acids, the one with the greatest effect on increasing the polarization angle is saturated fatty acid, or stearic acid (C19:0). This is because stearic acid has the longest carbon chain bonds, which tend to be unstable, causing the oil molecules to become looser and increasing the number of free radicals in olive oil.

Furthermore, monounsaturated fatty acids, or oleic acid, also influence changes in the polarization angle. This is because oleic acid has a relatively long carbon chain bond; when heated, the molecular bonds stretch, resulting in an increase in the polarization angle. Polyunsaturated fatty acids, on the other hand, have less effect on changes in the polarization angle because they have shorter carbon chain bonds (Nurhasanah, 2019).

Figure 2 shows the relationship between fatty acid composition and heating time in palm oil, which shows that the most dominant fatty acid composition in palm oil is monounsaturated fatty acids (46%), then the composition of saturated fatty acids is around 44% and the least is polyunsaturated fatty acids around 10%. Palm oil has the highest composition of saturated fatty acids among other oils, thus causing a fairly large change in the polarization angle after being heated for 8 hours.

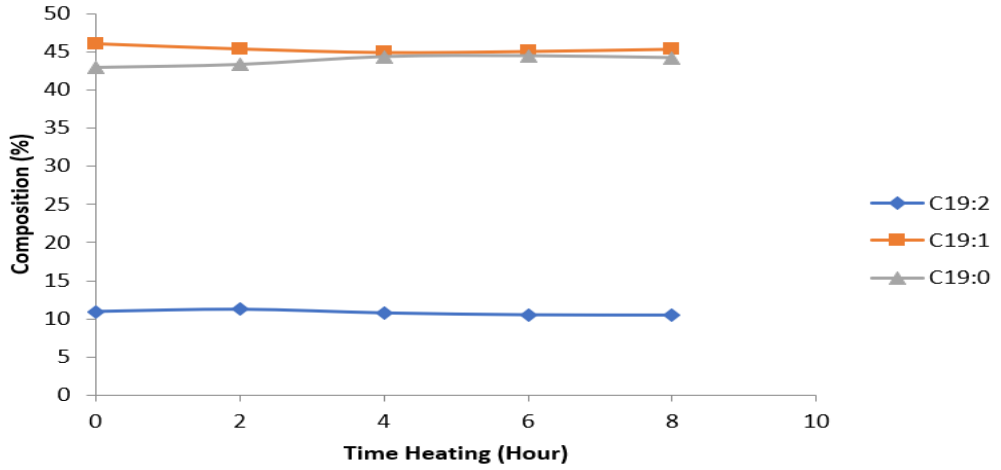

Figure 2 Relationship between fatty acid composition and heating time in palm oil with λ = 532 nm

CONCLUSION

This study demonstrates that the polarization angle of palm oil increases with heating duration. Palm oil heated for 8 hours exhibited the greatest degradation, indicated by a significant increase in polarization angle. The increase in both natural and electro-optic polarization angles was directly proportional to heating duration. Therefore, light polarization analysis can serve as a promising non-destructive optical technique for evaluating thermal degradation in edible oils.

Declaration by Authors
Acknowledgement: None
Source of Funding: None
Conflict of Interest: No conflicts of interest declared.

REFERENCES

1. Firdausi, K.S., Sugito, H., Suryono, Priyono, Amitasari, R., dan Murni, S., 2013. *Evaluasi Degradasi Mutu Minyak Goreng Kemasan Berdasarkan Polarisasi Cahaya dengan Variasi Suhu Sampel.* Prosiding Seminar Nasional Fisika, ISBN: 978-979-028-528-6, UNESA Surabaya, 26 Januari, pp. 56-59.
2. Firdausi, K.S., Sugito, H., Amitasari, R., dan Murni, S., 2013. *Metode Elektrooptis sebagai Pendeteksi Radikal Bebas dan Prospek untuk Evaluasi Total Mutu Minyak Goreng*. Indonesian Journal of Applied Physics, 3(1), pp.72–78.
3. Murni, S., Bawono, A., Hidayanto, E., dan Fidausi, K. S.,2013. *Evaluasi Kualitas Beberapa Jenis Minyak Goreng Kemasan Setelah Dipanaskan Menggunakan Sifat Elektrooptis.* Berkala Fisika, ISSN: 1410-9662, Vol.16, No.3, 63-66.
4. Nurhasanah, Sugito, H., Richardina, Azam, Firdausi, K.S., 2019. *Korelasi Polarisasi Elektro-Optis Dengan Komposisi Asam Lemak Pada Minyak Zaitun Sebagai Metode Uji Alternatif Mutu Minyak Goreng.* Berkala Fisika,22 (1), pp. 24-31.
5. Rahmawati, A., Firdausi, K. S., Sugito, H., Azzam, Richardina and Susanto, Q. M. B., 2020, *The contribution of fatty acids composition of soybean oil on natural and electro-optics polarization*, Journal of Physics: Conference Series, doi:10.1088/1742-6596/1524/1/012007
6. Sugito, H. dan Firdausi, K. S., 2014. *Natural Polarization and Electrooptics Comparison for Evaluation of Cooking Oil Total Quality*. Jurnal Sains dan Matematika, 22(4), pp.102–106.
7. Susan, A. I., Firdausi, K. S., Setiabudi, W., 2011. *Studi Uji Alternatif Kualitas Minyak Goreng Berdasarkan Perubahan Polarisasi Terimbas.* Berkala Fisika, ISSN: 1410-9662, Vol. 14, No.4, 135-138.
8. Tsai, Y. H., et al. 2023. Thermal degradation of vegetable oils. *Foods*, 12(9), 1839.

How to cite this article: Heri Sugito. Evaluation of thermal degradation in palm oil using light polarization analysis. *International Journal of Research and Review*. 2026; 13(5): 699-702. DOI: *10.52403/ijrr.20260568*

******