Effect of ozone addition on virgin coconut oil using changes in light transmission polarization

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Abstract. Today, the investigation of ozonized cooking oil becomes a very interesting research development topic, in addition to the study of ozone interactions in liquids and its application to the treatment of skin cancer. This research was conducted to determine the change in the transmission polarization angle in Virgin Coconut Oil (VCO) that was interacted with ozone. Laser pointers with a wavelength of 650 nm were used as light sources. The polarization changes are proportional to the duration of ozonation, and the longer duration is accompanied by more accumulative numbers of free fatty acids. The interaction is considered to be quite effective, with supposedly one ozone molecule interacting with one symmetric triglyceride molecule to become a new asymmetric triglyceride molecule in the interaction. This interaction increases the active optical properties of VCO samples. In contrast to the latest sophisticated spectroscopic methods, the polarization method seems simpler by simply measuring the change in polarization of light. With the ability of the polarization method that can distinguish the characteristics of cooking oil before and after experiencing treatment, this method has a large chance to be developed in subsequent studies relating to polarization as an indicator of the interaction of light with the material in the field of biophysics and other related fields.

1. Introduction
Recently study on adding ozone to Virgin Coconut Oil (VCO) is very interesting because of its two different sides of effects. The first effect is possibilities to increase the active oxygen content in VCO as skincare or external treatment, which in turn will increase its health benefits. The second effect is a disadvantageous side, that with the addition of ozone it will reduce the quality of VCO as consumed edible oil [1-2]. Further investigation of ozonation on triglyceride molecules results in the new development of information for study on aged fingerprint residues [3].

In this paper, we study the interaction between VCO and ozone using light transmission polarization. The polarization method is proven to be used as an alternative test of cooking oil quality and is quite reliable compared to conventional methods [4-13]. It is considered that the significant difference of various cooking oil quality using polarization method provides as a new single parameter quality, or at least this method is able to complement the latest sophisticated methods.

As similarly occurring in sugar molecules, the light polarization change in cooking oil, including VCO, is generally caused by asymmetric triglyceride (TG) molecules with very little optical activity compared to the optical activity of sugar. If the oil is open in the air, the interaction of air molecules with TG molecules will be more intense than if the oil is tightly closed which results in increasing the asymmetric TG molecules resulting in a greater change in the polarization of light. In this study, we
proposed that an identical condition can also occur if the oil is ozonized so that greater polarization is obtained. During the interaction between ozone and TG molecules of VCO some fatty acids and hydrogen peroxides are supposedly released from TGs, therefore, it leads to more asymmetric TGs resulting in greater polarization of light. We discussed only the possible asymmetric triglyceride and or diglyceride production from former symmetric TGs in relation to the light polarization change due to free fatty acids.

2. Methods
The sample used in the study was ozonized VCO oil shown in table 1. The ozone flow rate was 0.6 liters/minute with a treatment duration of 30 minutes, 60 minutes and 90 minutes using the Dielectric Barrier Discharge Plasma reactor. The light sources were red laser pointers with $\lambda = 650$ nm with the maximum power of 5 mW and 100 mW. In the case of transmission light polarization, the measurement procedures of polarization change referred to as the Afiefah et al [9]. Samples validation examination was performed using the free fatty acid test.

| Sample | Duration of ozonation (minute) |
|--------|-------------------------------|
| $S_0$  | 0                             |
| $S_{30}$ | 30                           |
| $S_{60}$ | 60                           |
| $S_{90}$ | 90                           |

3. Results and discussions
Figure 1 shows the changes in the transmission polarization angle on the VCO for sample $S_0$ using pointer laser with a maximum power of 5 mW and 100 mW in the polarizer angle range from $0^\circ$ until $90^\circ$.

Figure 1. Change of polarization angle on sample $S_0$ without ozonation as a function of polarizer angle.

In our previous study, the transmission polarization change ($\Delta \theta$) was supposedly constants against polarizer angle due to the assumption that the TG molecules of oils are very tiny and homogeneous so it is independent on the orientation of molecules, i.e. polarizer angle. The uncertainty of polarization change measurement is mostly dependent on parallax error due to the observation. Therefore more repetition of measurement will reduce parallax error of value $\Delta \theta$. In this experiment (figure 1),
repetition measurement more than 100 times of value $\Delta \theta$ provides a reduced error of measurement accuracy less than 2%. From fig 1 it is shown that actually the value $\Delta \theta$ is dependent on the orientation of molecules or polarizer angle. The fluctuation of value $\Delta \theta$ could be due to the relaxation time of TG molecules of VCO. The higher intensity of the laser will be an indication that more electric fields of light will interact with molecules and results in higher value $\Delta \theta$. It means that more photons interact with the oil so that more TG molecules are polarized and in turn increases the chances of polarization angle. Therefore, the difference of power laser in this case considerable does not change the characteristics of VCO. Similar results are also obtained for sample S1, S2 and S3 that the polarization change is dependent on the polarizer angle in the range of 0° until 90°. Figure 2 and figure 3 show the results of polarization change vs. polarizer angle for S0, S1, S2 and S3 at maximum power laser of 100 mW and 5 mW, respectively.

**Figure 2.** Change of polarization angle on sample S0, S1, S2, and S3 as a function of polarizer angle for maximum laser power of 100 mW.

**Figure 3.** Change of polarization angle on sample S0, S1, S2, and S3 as a function of polarizer angle for maximum laser power of 5 mW.
Table 2 shows the average value of polarization change or all samples at a power laser of 5 mW and 100 mW. All ozonation on samples can be considered as significantly influenced to samples indicated by increasing the average polarization change.

| Sample | Average polarization change (°) |
|--------|----------------------------------|
|        | 5 mW | 100 mW |
| S_0    | 0.38  | 0.49   |
| S_1    | 0.58  | 0.74   |
| S_2    | 0.73  | 0.90   |
| S_3    | 0.96  | 1.22   |

The effective treatment of ozone on VCO also can be described by increasing polarization change linearly with the duration of ozonation as shown in figure 4 at a special case of polarizer angle of 0°. The linear correlation $R^2$ more than 0.99 is reflected that at the flow rate of ozone the interaction with VCO is taken place effectively.

Figure 4. The effect of ozonation duration on the changes in the transmission polarization angle on VCO with the polarizer angle of 0°.

The linear correlation between polarization change and duration of ozonation, indicates obviously that the polarization change is proportional to the volume of ozone. The similar results were also obtained using fluorescence polarization by Azzahroh et al [13]. Using the fact that the change polarization is dependent on a number of asymmetric TGs, the number of ozone interacted with VCO can be considered proportional to the increasing number of asymmetric TGs. The basic explanation at least can be clarified by the development of new asymmetric TGs and asymmetric diglycerides from previous symmetric TGs. As already explained in the previous study [3], the production of new asymmetric TGs during interaction with ozone can be explained by development of TG mono-ozonide as the new asymmetric TGs where one of the unsaturated fatty acids in symmetric TGs is attacked by a single ozone and then it is captured by double bond carbon to become a reactive TG mono-ozonide. In addition, the new asymmetric diglycerides can be produced by oxidation of symmetric TGs triggered by ozone – air combination accompanied by releasing fatty acids or so-called free fatty acids.
Therefore the development of new asymmetric TGs and diglycerides due to the ozonation should effectively contribute to the polarization change, as already described by the linear curve in fig. 4. It can also be said that the active optical properties of VCO increase with increasing ozonation on VCO.

For validation, at least, several examinations such as GCMS test for fatty acids or TGs composition, peroxide number, and free acids number test should be done. Due to the limitations of the experimental condition, we only used a test for free fatty acids number. Figure 5 and figure 6 show the number of free fatty acids against the duration of ozonation and the polarization change against the number of free fatty acids, respectively.

![Figure 5](image5.png)

**Figure 5.** The number of free fatty acids vs. duration of ozonation.

![Figure 6](image6.png)

**Figure 6.** The polarization change vs. the number of free fatty acids

Figure 5 shows the production of free fatty acids during ozonation. The acid number is one of the standard quality parameters of cooking oil according to Indonesia National Standardization (SNI) and indeed by the ozonation, this number is still below the maximum value permitted by SNI. These free fatty acids themselves have no effect on changes in polarization. And according to the discussion
above these products are accompanied by new asymmetric diglycerides due to the oxidation of TGs that is triggered by ozone. As indicated in figure 6, the increasing number of free fatty acids is accompanied by increasing asymmetric diglycerides which is indicated by increasing polarization change. With the lack of other validation of examination such as GCMS test, we still consider the explanation of the formation of asymmetric TGs mono-ozonide and asymmetric diglycerides is a reasonable explanation without having to test the composition of fatty acids or TG using the GCMS method.

4. Conclusions
The changes of polarization angle are larger for maximum power laser 100 mW than for 5 mW indicating more photons that interacted with TGs. Increased polarization changes with increasing ozonation time, and accompanied by accumulative numbers of free fatty acids indicate at least a new formation of asymmetric TG (known as TG mono-ozonide) and asymmetric diglycerides. In contrast to the latest sophisticated spectroscopic methods, the polarization method looks simpler by simply measuring the change in polarization of light. With the ability of the polarization method that can distinguish the characteristics of cooking oil before and after experiencing treatment, this method has a large chance to be developed in subsequent studies relating to polarization as an indicator of the interaction of light with the material in the field of biophysics and biosciences.

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