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THE IMPACT OF AROMATIC ADDITIVES ON KERR EFFECT IN RAPESEED OIL

The Kerr constant and quadratic electro-optic effect were determined for a few different rapeseed oils. The aim of the study was to investigate if aromatic additives in the oil influence its optical properties. Moreover, the effect of ageing of the oils on Kerr phenomena was observed.

Keywords: Kerr effect, rapeseed oil, quadratic electro-optic coefficient.

1. INTRODUCTION

Vegetable oils are widely used in food and industrial production, what drives the search for a number of authentication techniques and evaluation of ageing processes. Among the various proposals, there are also attempts to use optical constants, e.g. detection of adulteration or contamination of castor oil based on its natural optical activity [1], authentication technique for olive oil that uses measurement of Verdet constant (describing the effect of optical activity induced by an applied magnetic field) [2], or estimation of the ageing processes in medicinal castor oil based on Kerr constant [3].

During this study, Kerr constants for different rapeseed oils were determined. Having that data it was possible to describe the influence of aromatic additives as well as ageing process on Kerr constant and quadratic electro-optic coefficient.

The rapeseed oil is produced from oilseed rape from Brassica genus. Rapeseed oil is mainly a mixture of triglycerides of fatty acids of vegetable origin. For the most part it contains triglycerides of olein acid. Its molecules have mono-unsaturated structure with double bonds with a cis configuration [4, 5].

During the experiments, several different rapeseed oils were used. Firstly it was pharmacy oil produced by Pharma Cosmetic K.M. Adamowicz Sp. z o.o.; 26 Pasternik Street 31-354 Kraków [6]. Secondly it was pharmacy oil but after expiry date. The third oil came from Wielkopolska and were produced by "SENCO" Krystyna Just; Śmiłowo 75 Spacerowa Street; 65-500 Szamotuły. Finally there were three different oils produced by ZT "Kruszwica" S.A. 42 Niepodległości Street; 88-150 Kruszwica. Each of them had different aromatic additives: 1) lemon and basil, 2) basil, and 3) tomato, garlic and basil. The last of them, similarly like the pharmacy oil, was measured before and after expiry date. It was composed in 96.3% of rapeseed oil, 1.3% of tomato, 1.5% of garlic, 1.1% of basil and contained salt, oregano and aromatic additives of tomato, garlic and basil. Oil with basil was composed in 98.8% of rapeseed oil, 0.3% of basil and contained aromatic additives of basil.

2. THE MEASUREMENT

2.1. Kerr constant

The Kerr effect is the phenomenon of appearing of birefringence in medium under influence of electric field. The effect is connected with the difference between refractive indices of the ordinary and extraordinary waves (Δn) which is proportional to square of intensity of electric field inducing the effect [7].

The optical part of the measurement system was composed of light source i.e. He-Ne laser, the first quarter-wave plate, polarizer, Kerr cell, the second quarter-wave plate, analyzer and photodiode which gave a voltage proportional to the intensity of light beam. The constant component of this voltage was measured with a digital multimeter and the voltage of second harmonic of modulating field was determined with a lock-in amplifier. Moreover, a computer was applied to control and register the measurements. The intensity of light passing through the analyzer can be express by the formula

$$I = I_0\left\{\cos^2(\alpha) - \sin(2\beta)\sin[2(\beta-\alpha)]\sin^2\left(\mathit{\Delta\Gamma}/2\right)\right\}, \tag{1}$$

where: I_0 is the intensity of incident light, α is the angle between planes of polarization of the polarizes, β is the angle between the plane of polarization and the direction of the applied electric field and

$$\mathit{\Delta\Gamma} = \mathit{\Delta\Gamma}_E + \mathit{\Delta\Gamma}_O, \tag{2}$$

where: $\Delta\mathit{\Gamma}_E$ is the phase difference between the slower and faster waves in the oil and $\Delta\mathit{\Gamma}_O = \pi/2$ is the phase shift introduced by the quarter wave plate.

In this experiment, the polarizes are crossed, $\alpha = \pi/2$, and the polarizer and the Kerr cell are oriented so that $\beta = \pi/4$

$$\Delta\Gamma_E = \frac{2\pi L}{\lambda}\Delta n, \tag{3}$$

where: L is the length of optical path in the oil, $\lambda = 632{,}8$ nm is the wavelength and $\Delta n = \lambda K E^2$, where K is the Kerr constant and E is the external electric strength in the oil.

Before computing the value of Kerr constant one has to determine the relation between modulation index $m^{2\omega}$ and square of the rms value of modulating voltage U_m applied to the Kerr cell

$$m^{2\omega} = aU_m{}^2 + b\,. \tag{4}$$

What more, the modulation index can be defined as the ratio of the rms voltage $U^{2\omega}$ measured at the second harmonic and the constant voltage U^0 on the photodiode

$$m^{2\omega} = U^{2\omega}/U^0\,. \tag{5}$$

The slope a of the function (2) can be expressed as

$$a = \frac{\sqrt{2}\pi L K}{d^2}\,, \tag{6}$$

where: d is a distance between electrodes and L is the length of optical path. Having this slope, the Kerr constant can be calculated from the formula

$$K = \frac{ad^2}{\sqrt{2}\pi L}\,. \tag{7}$$

2.2. Quadratic electro-optic coefficient

Before calculating the quadratic electro-optic coefficient, the refractive indices n of the examined oils must be determined. All the refractive indices were measured by Abbe refractometer. Having these results, the values of quadratic electro-optic effect were calculated using the formula

$$g_{ef} = \frac{2\lambda K}{n^3}\,, \tag{8}$$

where: $\lambda = 632.8$ nm is the wavelength of the light emitted by the He-Ne laser and n is the refractive index of the oil under the investigation.

3. RESULTS

The first measurement of the Kerr constant was performed on the pharmacy rapeseed oils. The Kerr constants for both oils have similar value. The average value for oil before the expiry date is $(3.27 \pm 0.03) \cdot 10^{-15}$ m/V^2 and after the expiry date $(3.25 \pm 0.02) \cdot 10^{-15}$ m/V^2.

The second measurement was performed for oil from Wielkopolska. The value of Kerr constant for this oil is $(3.3 \pm 0.2) \cdot 10^{-15}$ m/V^2.

Then, the oil with tomato, garlic and basil were measured both before and after the expiry date. The Kerr constant for the oil after expiry date has slightly lower values. However the uncertainty of the constant is relatively big. The average value of Kerr constant for the oil before the expiry date is $(3.28 \pm 0.01) \cdot 10^{-15}$ m/V^2 and for the oil after the expiry date is $(3.20 \pm 0.01) \cdot 10^{-15}$ m/V^2.

Another oil was flavored with basil. The average value of Kerr constant for this oil is $(3.31 \pm 0.01)\cdot 10^{-15}$ m/V^2.

Then the rapeseed oil with lemon and basil was measured. The measurements were performed for four days every five hours. The changes of Kerr constant value during this time could be observed. However, the character of that change cannot be described. The average value of Kerr constant for this oil is equal to $(3.12 \pm 0.10) \cdot 10^{-15}$ m/V^2.

Table 1 shows the average values of Kerr constant for all the tested oils. The results are similar for most of them. However, one can see that the Kerr constant are smaller for oils after their expiry date.

Table 1

The average values of Kerr constant and quadratic electro-optic coefficients for measured oils

Type of oil	K [10^{-15} m/V^2]	g_{ef} [10^{-21} m^2/V^2]
pharmacy oil (at room temperature)	3.27 ± 0.03	1.29 ± 0.01
pharmacy oil – after expiry date	3.25 ± 0.02	1.27 ± 0.01
oil Wielkopolska	3.30 ± 0.02	1.29 ± 0.01
oil with tomato, garlic, basil – after expiry date	3.19 ± 0.01	1.26 ± 0.01
oil with tomato, garlic, basil	3.28 ± 0.01	1.29 ± 0.01
oil with basil	3.31 ± 0.01	1.31 ± 0.01
oil with lemon and basil	3.12 ± 0.10	1.23 ± 0.01

The quadratic electro-optic coefficient was calculated using formula (8). The refractive index for all the oils was measured. It was near the same and equal to 1.474±0,001 at the temperature of 293 K. The average values of the coefficient were calculated for each oil. The results are presented in Table 1. The poor accuracy for oil from Wielkopolska is a result of small number of repetition of measurement for this oil. Similarly like in the case of Kerr constant for oils measured after expiry date, the value of quadratic electro-optic coefficient is slightly smaller.

4. CONCLUSIONS

The method of measurement proved to yield repeatable results. However the measurement of Kerr constant is not enough sensitive neither to detect aromatic additives in rapeseed oil nor to observe the ageing process of that oil. Even though some differences in magnitude of Kerr constant were observed, most of them where in the range of the measurement error.

Considering the ageing process the biggest difference in magnitude of Kerr constant was observed for the oil with lemon and basil, although one cannot describe character of that change. The small change of electro-optic properties as an effect of ageing was observed also for oil with tomato, garlic and basil. In that case, the oil measured after the expiry date has slightly smaller Kerr constant value than the oil measured before the expiry date.

Values of the Kerr constant of the measured oils were compared with previous experiments performed on different organic oils. In both cases, the value of Kerr constant has comparable magnitude.

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WPŁYW DODATKÓW AROMATYCZNYCH W OLEJACH RZEPAKOWYCH NA EFEKT KERRA

Streszczenie

Zmierzono stałe Kerra i współczynniki kwadratowego efektu elektrooptycznego dla różnych olejów rzepakowych. Celem tego eksperymentu było zbadanie czy dodatki aromatyczne w olejach mają wpływ na wartość stałej Kerra. Uzyskane rezultaty wskazują, że analizowane dodatki nie mają wpływu na wartość stałej Kerra w granicach niepewności pomiarowej. Zastosowanie tej metody do wskazanych celów wymaga znacznie większej dokładności metody pomiarowej.