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EFFECT OF AGEING ON THE MAGNITUDE AND TEMPERATURE DEPENDENCE OF THE KERR CONSTANT IN THE CASTOR OIL USED IN PHARMACY

This work presnts measurements of the Kerr constant and its temperature dependence in the fresh and aged castor oil used in pharmacy. It is shown that the effect of aging noticeably affects electrooptic properties of the oil.

Keywords: quadratic electooptic effect, castor oil, ageing proces.

1. INTRODUCTION

It was Kerr who first observed the quadratic electrooptic effect in glass, later he found this effect in fluids (in the rosin and castor oil) [1]. This is why the changes in the refractive index quadratic with the field, observed in liquids, gases and other isotropic media are usually called the Kerr effect. The birefringence originating from the Kerr effect makes the liquid optically uniaxial

$$\Delta n = K\lambda E^2 , \tag{1}$$

where K is the Kerr constant and λ is the light wavelength. According to the frequency of the involved modulating fields one can consider the electrooptic and optical Kerr effect for the static or low-frequency and the optical frequency electric fields, respectively. The nature and, therefore, magnitude of nonlinear interactions responsible for the electrooptic and optical Kerr effect is different. In this work the electrooptic Kerr effect in the castor oil is considered.

The castor oil is of interest from the point of view of different applications, for example in medicines and other parapharmaceutical products, in cosmetics and as a component of biodiesel. The basic physical and chemical properties of the oil are known (see, e.g. [2, 3]). The castor oil is highly biodegradable, environmentally friendly, and what is the most important, it is derivable from renewable resources. It is known, however, that properties of oils obtained from plants change with time (see, e.g. [4-6]). This process often called aging is related mainly to the oxidation and gumming of unsaturated carbon double bonds. In the aging process three main mechanisms occur: hydrolysis, oxidation and oxidative polymerization [6]. As far as we know, no investigations of changes in the castor oil properties that result from the aging processes have been investigated employing the Kerr effect. The aim of this work is to check if the aging processes can affect the magnitude of the Kerr constant of the oil.

2. EXPERIMENTAL

In our mesurements, we employed the dynamic-polarised method based on the measurement of the intesity of light passing through a Kerr cell with oil, placed between crossed polarizer and analyzer (see, e.g. [7-9]). The intensity of a light beam passing trough the cell is given by [10]

$$I = I_0\left\{\cos^2(\alpha) - \sin(2\rho)\sin[2(\rho-\alpha)]\sin^2\left(\frac{\Gamma}{2}\right)\right\}. \tag{2}$$

Here I_o is the emerging light intensity in the absence of the electric field, α is the angle between the planes of polarization in the polarizer and analyzer, ρ is the angle between the plane of polarization and the direction of the applied electric field, and Γ is the phase difference between the ordinary and extraordinary beams, namely

$$\Gamma = \Gamma_0 + kL\Delta n\ . \tag{3}$$

In this, Γ_o is that part of Γ which is independent of the electric field, $k = 2\pi/\lambda$ and L denotes the path length of the light beam in the liquid subjected to the electric field. For polarizers crossed and oriented in such a way that $\rho = \pi/4$ and when an optical bias $\Gamma_o = \pi/2\ (2n + 1)$, where n a natural number, is provided by a retardation plate, Eq. (3) may be rewritten in the form

$$I = \frac{I_0}{2}\left[1 + \sin(k\Delta nL)\right]. \tag{4}$$

For a sinusoidal modulating voltage the Kerr constant may be obtained as

$$K = \frac{ad^2}{\sqrt{2}\pi L}. \tag{5}$$

In Eq. (5), d is the distance between electrodes and the coefficient a is used in the linear fitting of the modulation index and the modulation index $m^{2\omega}$ as the function of the rms modulation voltage U_m

$$m^{2\omega} = aU_m + b. \tag{6}$$

The modulation index in Eq. (6) is defined as

$$m^{2\omega} = \frac{U^{2\omega}}{U^0} \tag{7}$$

where $U^{2\omega}$ is the rms voltage measured at the second harmonic of the modulated emerging light intensity and U^0 is the voltage proportional to the constant component in the light intensity transmitted by the system. The fitting given by Eq. (6) was used to minimize the effect of the experimental errors in $U^{2\omega}$, U^0 and U_m on the final results.

Previously, a noticeable dispersion in the dielectric properties in the castor oil has been reported [11]. Therefore in this work the effect of the aging on the changes in the Kerr constant with the frequency is considered. In our measurements the length of parallel-plane electrodes made of stainless steel and immersed in the oil was 50 mm and the distance between them was 4 mm. The modulating voltage of various frequencies, as listed below, was applied to the electrodes and U_m was in the range 200 V-2500 V. As the light source, the He-Ne laser (λ = 0.633 μm) was employed. The measurements were performed within the temperature range 293-323 K employing a lock-in technique using a computer controlled data acquisition and processing system.

The castor oil under investigation was produced by Farmina Corporation (Lipska Street 44, 30-721 Kraków, Poland, number of licence/authority IL-4113/LN). The aging process was simple keeping the oil in a closed bottle 6 months longer than its expiry date reported by the producer.

3. RESULTS

The measurements were perfomed within the temperature range 296÷323 K employing the modulating field of frequencies 117 Hz, 217 Hz, 417 Hz, 617 Hz, 817 Hz, 1017 Hz and 1217 Hz. In Fig. 1 an example of results obtained at RT (297 K) is presented.

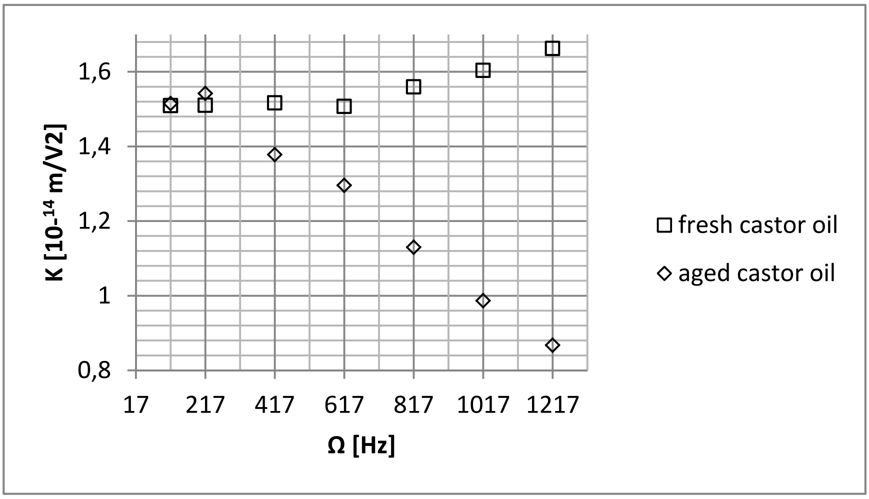

Fig. 1. Changes in the Kerr constant with the modulating field frequency in the fresh and aged castor oil at *R*T (297K).

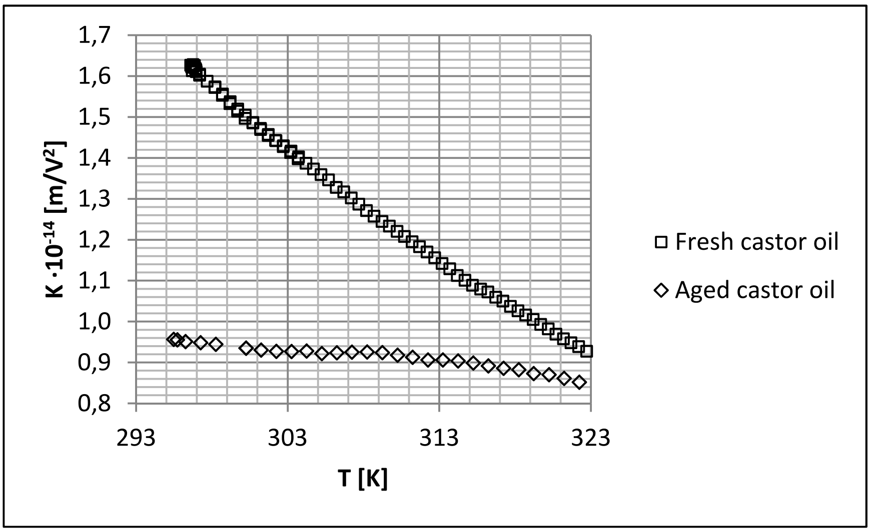

Fig. 2. Temperature changes in the Kerr constant measured at 1217 Hz in the fresh and aged castor oil.

An example of the temperature dependencies of *K* measured at 1217 Hz is shown in Fig. 2. To compare the changes in the Kerr constant measured in the fresh and aged oil, the temperature dependence of K was approximated by the linear relationship

$$K(T) = a_{F,A}T + b_{F,A} \ , \qquad (8)$$

where the subscripts F and A corresspond to the fresh and aged oil, respectively. The parameters of this aproximation for fresh and aged oil are compared in Table 1 and Fig. 3. The results presented in Table 1 and Fig. 3 show that the difference between the changes in K with temperature observed for the fresh and aged oil decreases for lower frequencies of the modulating field.

Table 1. Comparison of parameters a and b in Eq. (8) for the fresh and aged castor oil. The subscripts F and A stand for the fresh and aged oil, respectively.

$\Omega\ [Hz]$	$a_F \left[10^{-16}\frac{\mathrm{m}}{\mathrm{KV^2}}\right]$	$b_F \left[10^{-14}\frac{\mathrm{m}}{\mathrm{KV^2}}\right]$	$a_A \left[10^{-16}\frac{\mathrm{m}}{\mathrm{KV^2}}\right]$	$b_A \left[10^{-14}\frac{\mathrm{m}}{\mathrm{KV^2}}\right]$
117	-2.56±0.02	9.11±0.06	-2.523±0.017	8.99±0.05
217	-2.56±0.02	9.09±0.06	-2.69±0.03	9.54±0.08
417	-2.57±0.19	9.14±0.06	-1.85±0.03	6.88±0.08
617	-2.59±0.02	9.21±0.07	-1.37±0.03	5.32±0.10
817	-2.65±0.02	9.43±0.06	-0.79±0.03	3.47±0.08
1017	-2.72±0.02	9.67±0.06	-0.43±0.02	2.24±0.07
1217	-2.82±0.02	10.02±0.07	-0.22±0.02	1.48±0.07

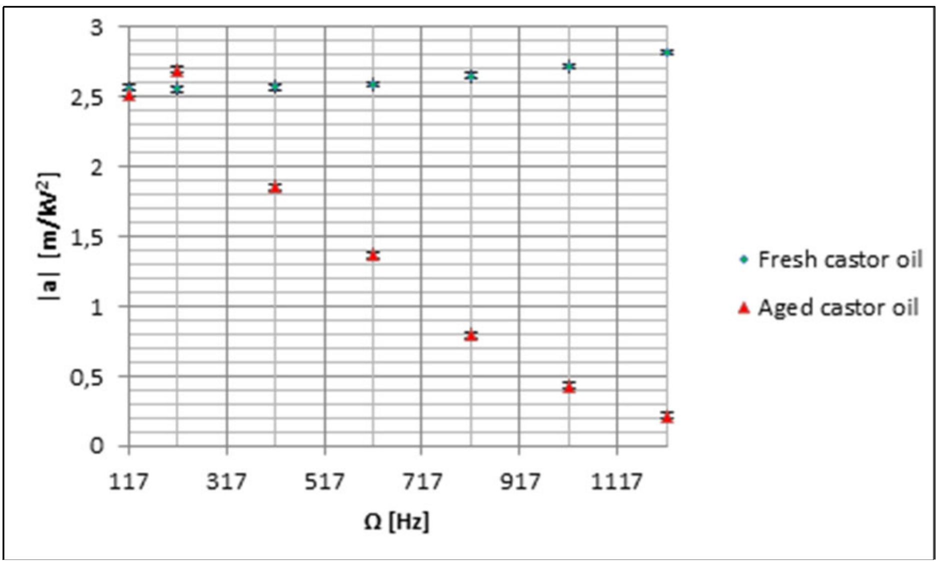

Fig. 3. The frequency dependence of the coefficient a in Eq. (8) found for the fresh and aged castor oil.

Finaly, the values of Kerr constant obtained in this work at RT for the fresh and aged castor oil are compared in Table 2.

Table 2. The Kerr constant for fresh and aged castor oil in room temperature (24˚C).

	Fresh castor oil	Aged castor oil
$\Omega\ [Hz]$	$K\ \left[10^{-14}\,\frac{\mathrm{m}}{\mathrm{V}^2}\right]$	$K\ \left[10^{-14}\,\frac{\mathrm{m}}{\mathrm{V}^2}\right]$
117	1.509±0.007	1.5378±0.007
217	1.511±0.007	1.537±0.007
417	1.516±0.007	1.411±0.006
617	1.531±0.007	1.367±0.007)
817	1.560±0.007	1.173±0.006
1017	1.602±0.007	1.025±0.006
1217	1.659±0.007	0.905±0.006

4. CONCLUSIONS

The results obtained in this work show that measurents of the Kerr constant, particurarly at frequencies higher than 400 Hz, are be useful in estimations of the aging process on properties of the castor oil and, probably, other oils obtained from plants. Maybe a continuos monitoring of the magnitude of the constant and the rate of its changes with temperature would be useful in industrial applications to indicate changes in the oils quality.

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WPŁYW PROCESÓW STARZENIA NA WIELKOSĆ ORAZ ZALEŻNOŚĆ TEMPERATUROWĄ STAŁEJ KERRA W OLEJU RYCYNOWYM STOSOWANYM W FARMACJI

Streszczenie

Przedstawiono wyniki pomiarów stałej Kerra oraz jej zależności temperaturowej otrzymane dla świeżego oleju rycynowego oraz oleju poddanemu procesowi starzenia. Pokazano, że proces starzenia znacząco modyfikuje jego właściwości elektrooptyczne.