Int J Thermophys (2009) 30:1396–1399
DOI 10.1007/s10765-009-0628-9

Monitoring the Thermal Parameters of Different Edible Oils by Using Thermal Lens Spectrometry

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Received: 15 October 2008 / Accepted: 14 July 2009 / Published online: 11 August 2009

Abstract Several vegetable edible oils (sunflower, canola, soya, and corn) were used to study the thermal diffusivity of edible oils. Thermal lens spectrometry (TLS) was applied to measure the thermal properties. The results showed that the obtained thermal diffusivities with this technique have good agreement when compared with literature values. In this technique an Ar^+ laser and intensity stabilized He–Ne laser were used as the heating source and probe beam, respectively. These studies may contribute to a better understanding of the physical properties of edible oils and the quality of these important foodstuffs.

Keywords Thermal diffusivity · Thermal lens spectrometry · Vegetable oils

1 Introduction

Vegetable edible oils have impacted humanity in diverse aspects of its life; besides being used in the culinary arts, they have been offered to the Gods. Nowadays we

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appreciate them for their nutritional and therapeutic importance. In general, the oils (lipids) contribute to the constitution of all tissue; in addition, our organisms use them as energetic reserves in case that the daily contribution is insufficient. On average, it is estimated that 1 g of fat provides 9 cal. Nevertheless, although all oils that are obtained from seeds (sunflower, soya, peanut, and corn) are used for consumption and facilitate the absorption of liposoluble vitamins (A, D, E, and K), there are important differences as soon as their nutritional value, culinary uses, and their effects on health are considered.

Physical properties of edible oils have been the subject of intensive research both in industry and academic institutions. Once known and their behavior properly understood, such properties may be used to benefit industrial manufacture in order to suit specific applications in food products and production processes as well as to control the product stability and shelf life. For many products there still is a lack of data on the thermal properties at various stages of processing. One of the most important dynamic physical properties is the thermal diffusivity, D, often called the heat diffusion coefficient, which is defined as $D = k/(\rho c)$ where k is the thermal conductivity, ρ is the density, and c is the specific heat. For oil samples where the surface experiences a sudden temperature increase over a certain period of time, it is the thermal diffusivity that determines the amount of heat that has diffused into the material. The thermal diffusivity is difficult to measure; generally it is easier to measure static thermal parameters (such as specific heat, for example) than the dynamic ones [1]. In this sense thermal lens spectrometry (TLS), a very sensitive technique, has been used to obtain the thermal diffusivity of transparent and semi-transparent liquids. This technique is attractive because it is non-destructive, non-invasive, and very sensitive [2]. Recently, Albuquerque et al. [3] applied TLS to study edible oils such as soya, sunflower, canola, and corn oil; however, they did not report thermal-diffusivity values of these oils. In this paper the authors were focused on optical properties and photochemical reactions studied by thermal lens spectrometry, where the laser power was changed to study the photosensitivity of the samples. Also, in previous research we studied some samples of avocado oils [4]. These samples were subjected to different temperatures in order to study the degradation of this oil by means of their thermal diffusivity. In this paper TLS has been applied to measure the thermal diffusivity of vegetable oils such as soya, sunflower, canola, and corn oil, and the results have been compared with thermal diffusivity values reported in the literature, obtained by other photothermal techniques. The measured thermal property may contribute to a better understanding of the quality of edible oils, which is very important in the medical, cosmetic, and food industries [5].

2 Experimental Setup

The thermal lens (TL) effect of such oils was based on their laser-induced heating and time-resolved monitoring of the thermal effects. A schematic diagram of the TLS experimental setup and theoretical model for a continuous-wave (CW) laser-induced mode mismatched dual-beam TLS is described in Refs. [2] and [4]. In the dual-beam thermal lens measurements, a sample is placed in a TEM_{00} Gaussian laser beam

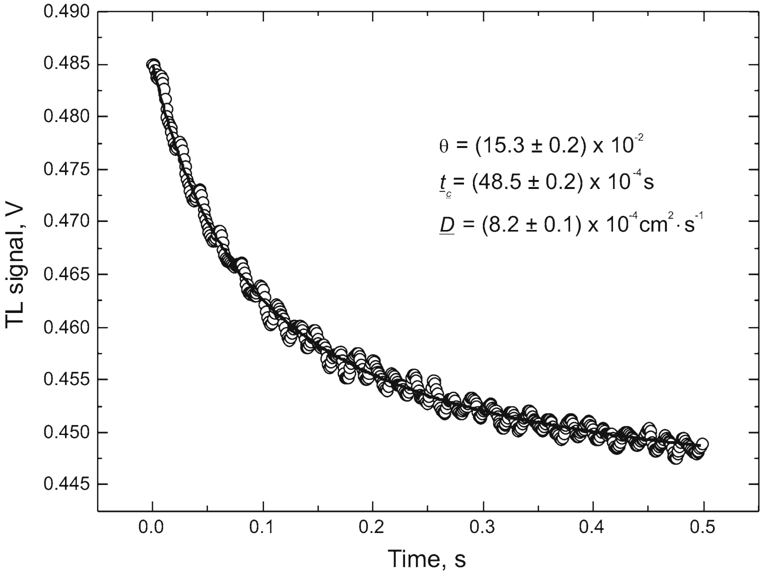

Fig. 1 Time evolution of the TL signal for corn oil. Symbols represent the experimental data, and solid line corresponds to the best fit of Eq. 4 (Ref. [4]) to the experimental points

(excitation beam) with a 40 μm spot size, and a temperature rise is produced by nonradiative decay processes following the optical energy absorption. Since the sample refractive index changes with temperature, a refractive index gradient is produced, creating a lens-like optical element, the so-called thermal lens. A weak TEM_{00} Gaussian laser beam (probe beam), with a 160 μm spot size, which is co-linear with the excitation beam, passing through the thermal lens, will be affected, resulting in a variation in its spot size and hence intensity at the beam center. By measuring these changes, information on the thermal and optical properties of the sample can be obtained.

3 Results and Discussion

Thermal lens measurements were made on different edible oils such as sunflower, canola, soya, and corn for the determination of the thermal-diffusivity values. The experimental TL signal evolution has a behavior as described by the theoretical expression for TL (Eq. 4 of Ref. [4]). Figure 1 shows the typical evolution of the TL signal intensity: the symbols (o) represent the experimental points, and the solid line corresponds to the best fit of the theoretical TLS signal amplitude [4] to the experimental data. The t_c (critical time) value obtained from the best fit was $t_c = (4.8 \pm 0.02) \times 10^{-3}$ s, which corresponds to the thermal diffusivity $D = (8.2 \pm 0.1) \times 10^{-4} \text{cm}^2 \cdot \text{s}^{-1}$ for corn oil. Good agreement was obtained when compared with a literature thermal diffusivity value reported for corn oil ($D = 8.9 \times 10^{-4}\ \text{cm}^2 \cdot \text{s}^{-1}$) [6]. The same procedure was carried out for the other samples in order to determine the thermal diffusivity of sunflower, canola, and soya edible oils. Table 1 summarizes the thermal-diffusivity

Table 1 Adjustable parameter, t_c, obtained from the best fit of Eq. 4 in Ref. [4] to TL experimental data, and the corresponding D values

Oil samples	Experimental thermal diffusivity D (10^{-4} cm$^2 \cdot$ s^{-1})	t_c (10^{-3}s)	Literature thermal diffusivity D (10^{-4} cm$^2 \cdot$ s^{-1})
Corn	8.2 ± 0.1	4.8 ± 0.0	8.9 [6]
Soya	5.0 ± 0.2	8.0 ± 0.4	–
Canola	9.6 ± 0.1	4.2 ± 0.0	8.9 [6]
Sunflower	8.8 ± 0.1	4.5 ± 0.0	8.9 [6]

values obtained for the studied oils; in all cases the experimental TL data were fitted with Eq. 4 of Ref. [4]. In the last column of this table, we show the corresponding literature values for these oils [6].

4 Conclusions

The dual beam thermal lens technique was successfully employed for determination of thermal diffusivity values of vegetable edible oils. From TL spectrometry the thermal diffusivity of different oils such as sunflower, canola, soya, and corn was obtained. The results demonstrate that the thermal diffusivities of the different oils show good agreement when compared with literature values. This measured thermal property may contribute to a better understanding of the quality of edible oils, which is very important in the medical, cosmetic, and food industries.

Acknowledgments We would like to thank Conacyt and SIP-IPN, México for their partial financial support. The authors are also grateful to Ing. E. Ayala Maycotte, Ing. A. B. Soto, Ing. D. Jacinto Méndez, and Ing. M. Guerrero of the Physics Department, CINVESTAV-IPN, for their technical assistance.

References

1. D. Dadarlat, H. Visser, D. Bicanic, Meas. Sci. Technol. **6**, 1215 (1995)
2. J. Shen, R.D. Lowe, R.D. Snook, Chem. Phys. **165**, 385 (1992)
3. T.A.S. Alburquerque, P.R.B. Pedreira, A.N. Medina, J.R.D. Pereira, A.C. Bento, M.L. Baesso, Rev. Sci Instrum. **74**, 694 (2003)
4. R. Carbajal Valdez, J.L. Jiménez Pérez, A. Cruz-Orea, E. San Martin Martinez, Int. J. Thermophys. **27**, 1890 (2006)
5. M.J. Navas, A.M. Jiménez, Crit. Rev. Anal. Chem. **33**, 77 (2003)
6. J.A. Balderas Lopez, A. Mandelis, J.A. Garcia, Rev. Sci. Instrum. **74**, 700 (2003)