Ultrasonic Attenuation of Edible Oils

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ABSTRACT: The frequency dependence (1–60 MHz) of the ultrasonic attenuation coefficient of canola oil, corn oil, olive oil, peanut oil, safflower oil, soybean oil, and sunflower oil was measured at 25°C. The attenuation coefficient of all the oils could be described by the relation: $\alpha \sim Af^n$ (with A between 6 and 40×10^{-12}, and n between 1.74 and 1.86).
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KEY WORDS: Attenuation, edible oils, frequency dependence, ultrasound.

Ultrasonic spectroscopy is finding increasing use to characterize food emulsions (1,2). It can be used to monitor dispersed phase volume fraction, particle size distribution, physical state, and gravitational separation (2). Ultrasonics has advantages over many alternative technologies because it can be applied to emulsions that are concentrated and optically opaque without any sample preparation. One of the major limitations of the ultrasonic technique is that a great deal of information about the physical properties of the component phases is needed to interpret the ultrasonic measurements (3). Many ultrasonic and thermophysical properties of edible oils have been tabulated previously (4–9). Nevertheless, there is a lack of information about the attenuation coefficient of edible oils (9). In addition, information about the ultrasonic attenuation frequency dependence can be correlated with the dynamic shear and volume viscosity of edible oils. It may therefore prove to be a useful means of characterizing their properties (6). For this reason, the authors decided to measure and tabulate the ultrasonic attenuation spectra of a range of commonly used edible oils.

EXPERIMENTAL PROCEDURES

Materials. Food oils were purchased from a local retailer in Amherst and used without further purification.

Ultrasonic measurements. Ultrasonic attenuation spectra of the food oils were measured in the frequency range 1–60 MHz using a commercially available instrument (Ultrasizer U96; Malvern Instruments, Malvern, Worcester, United Kingdom). This device measures the ultrasonic attenuation coefficient by an interferometric technique. The oil to be analyzed is placed in a thermostated measurement chamber that contains two pairs of broad-band ultrasonic transducers: one pair covering the low-frequency range (1–15 MHz), the other covering the high-frequency range (15–60 MHz). For each transducer pair, one transducer acts as a generator of ultrasound, while the other acts as a receiver. The attenuation coefficient (α) is determined by measuring the amplitude of the ultrasonic wave as the separation between the generator and receiver transducers is varied using a stepper motor:

$$\alpha = \frac{1}{d_2 - d_1} \ln \frac{A_1}{A_2} \qquad [1]$$

where A_1 and A_2 are the amplitudes of the ultrasonic wave measured at transducer separations of d_1 and d_2. The amplitudes have to be corrected for diffraction and transducer alignment losses prior to carrying out Equation 1 (2). The attenuation coeffcient is determined as a function of frequency by successively applying sinusoidal waves of differing frequency to the transducers.

About 3000 cm^3 of food oil was placed in the measurement cell of the instrument and left for approximately 6 h to equilibrate to the measurement temperature ($T = 25.0 \pm 0.5$°C) and to allow any air bubbles to escape that would otherwise interfere with the measurements. Oils were then stirred at a speed of 150 rpm during the ultrasonic measurements to ensure homogeneity. Each oil was measured three times, and there was less than 1% difference between successive attenuation spectra.

RESULTS AND DISCUSSION

The frequency dependence of the ultrasonic attenuation coefficient of three of the food oils is shown in Figure 1. There was a linear relationship between log (α) and log (f) for all of the oils ($r^2 > 0.993$), meaning the spectra could be represented by the equation: $\alpha = Af^n$. The values of the exponent n and coefficient A of the oils were determined by regression analysis of plots of log (α) vs. log (f) (Table 1). The attenuation spectra of the various oils were fairly similar, with all of the oils having attenuation coefficients within approximately 10% of each other.

The overall attenuation coefficient of a pure liquid is a combination of classical and molecular relaxation mechanisms (10). In the absence of molecular relaxation mechanisms, the exponent n is equal to 2. The fact that n was less than 2 for all of the oils indicates that some form of molecular relaxation process occurred in the frequency range used in this study. It

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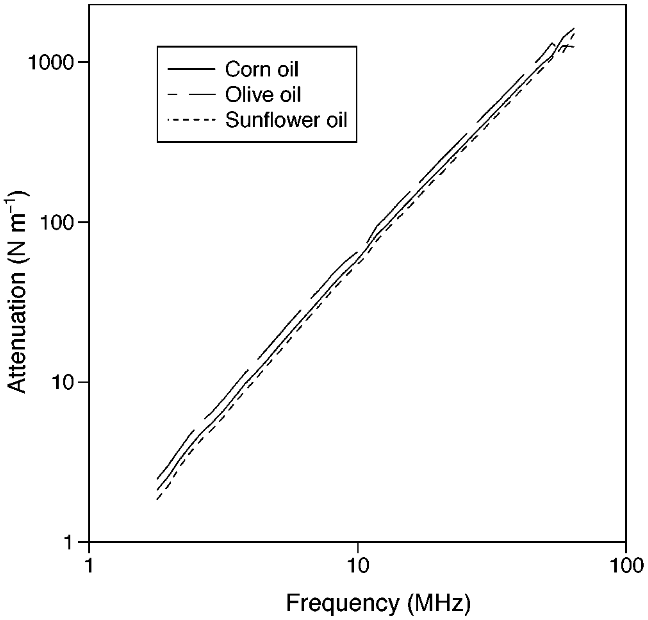

FIG. 1. Comparison of ultrasonic attenuation spectra of corn, olive, and sunflower oils at 25°C.

TABLE 1
Ultrasonic Attenuation Properties of a Variety of Edible Food Oils at 25°C

Oil type	$A \times 10^{-12}$	n	r^2	α_{10MHz}/Np m^{-1}
Canola	7.83	1.84	0.9986	58.1
Corn	6.43	1.85	0.9930	57.6
Olive	11.4	1.82	0.9983	61.9
Peanut	13.2	1.81	0.9985	65.5
Safflower	40.2	1.74	0.9980	61.1
Soybean	6.28	1.85	0.9991	56.1
Sunflower	5.68	1.85	0.9998	52.8

has been suggested that the most likely cause of this phenomenon is molecular rearrangements that occur during the compression and shearing of oils in the ultrasonic field (6).

In conclusion, the measurements indicate that the ultrasonic attenuation coefficients of a wide range of edible oils are fairly similar and can be described by a simple power law function.

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