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Abstract

Full Text

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ON THE CHARACTERISTIC TEMPERATURE OF SUSPENSIONS

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The velocity of ultrasound (u.s.) in a liquid is $v = (\rho\beta)^{-1/2}$, where ρ is the density and β is the adiabatic compressibility of the liquid. In a suspension of particles in a liquid satisfying the relation $\lambda \gg d$, where λ is the wavelength of the u.s. in the suspension and d is the particle diameter, the u.s. velocity v_0 is determined as in an ideal liquid mixture, the density and adiabatic compressibility of which are additive functions of the densities and compressibilities of the suspended particles and of the containing liquid ([1]).

$$v_0 = (\rho_0\beta_0)^{-1/2} = v_1[(1 + c\chi)(1 + c\xi)]^{-1/2}, \tag{1}$$

where $\chi = (\rho_2/\rho_1) - 1$, $\xi = (\beta_2/\beta_1) - 1$ (the indices 0, 1, 2 refer to the suspension, the containing liquid, and the suspension particles, respectively; c is the volume concentration of the suspension particles). For emulsions $\xi = (\rho_1/\rho_2)(v_1 - v_2)^2 - 1$.

The indicated homogeneous approximation is valid for a number of suspensions ([2]). Light aqueous suspensions follow the homogeneous approximation over a wide interval of concentrations of suspended particles ([3–6]). From formula (1) it follows that, for small χ, ξ, and c, a linear dependence of the velocity on the particle concentration is valid: $v_0 = v_1(1 - {}^1/_2 cX)$, where $X = \chi + \xi$. The quantities ρ, β, X, and c are functions of temperature.

In the case of the existence of a region of characteristic temperature, at which $\rho_1 \sim \rho_2$, $\beta_1 \sim \beta_2$, $X \approx 0$, the relation $v_0 \approx v_1$ holds, so that the u.s. velocity in a suspension with a low concentration of suspended particles at the characteristic temperature does not depend on particle concentration and differs from the u.s. velocity in the containing liquid by less than ${}^1/_2 cX$. This estimate may be used to determine the width of the characteristic-temperature interval.

Investigation of the u.s. velocity in suspensions in the region of the theoretically expected characteristic temperature is of interest both in connection with the study of the excess compressibility of suspensions and the testing of suspensions for the homogeneous approximation, and also for measuring the concentration of suspension components from the u.s. velocity (the number of components of a suspension at the characteristic temperature decreases by one).

Thus, it turned out that the u.s. velocity in milk, which is a 3-5% suspension of milk fat in plasma—a 7-9% aqueous solution of dry skim-milk residue (proteins and lactose)—under the conditions of the homogeneous approximation (at a frequency of 1 MHz, $\lambda \sim 500d$, where d is the mean diameter of the fat globules) does not depend on the concentration of milk fat at a temperature of $\sim 14°$, i.e., within the region of the characteristic temperature (13-14°) for an emulsion of milk fat in water. This region was found by us by tabulating the function X from the values of the density of distilled water ([7]), milk fat ([8]), and the u.s. velocity in distilled water ([9]) and in milk fat (Fig. 1) at different temperatures (the latter were obtained by us for dehydrated milk fat). At the same time, at the boundaries of the characteristic-temperature interval the u.s. velocity in an emulsion of fat in water should differ from the velocity in water by less than 0.01%.

Within the interval 13-14° the quantity X becomes zero, and at the boundaries it takes the values -0.006 and $+0.004$.

It is seen from Table 1 that at the characteristic temperature the ultrasonic velocity in milk samples exceeds the ultrasonic velocity in water ($\sim$ 1460 m/sec) by 30 m/sec and agrees well with data on the ultrasonic velocity in protein solutions with a concentration coefficient of the order of 4 m/sec · % ([10]). For comparison, Table 1 gives values of the ultrasonic velocity in milk measured at a temperature of 50°, at which milk fat and the dry skim-milk residue jointly affect the velocity. In the absence of an influence of variations in the relative concentration of the components of the dry skim-milk residue on the ultrasonic velocity in the region of the characteristic temperature, the ultrasonic velocity can be used to measure the content of dry skim-milk residue from the calibration graph

$$v = A + Bs, \tag{2}$$

where s is the weight concentration of the dry skim-milk residue, and A is the regression coefficient corresponding to the ultrasonic velocity in distilled water at the characteristic temperature. Differentiation of formula (2), taking into account the experimental results and reference measurements ([9]), shows that the ultrasonic method for measuring the concentration of dry skim-milk residue in milk with an error of no more than 0.1% requires measurement of the ultrasonic velocity in the samples and thermostating with accuracies no worse than 0.005% and 0.02°, respectively.

Fig. 1. Temperature dependence of the ultrasonic velocity: the upper curve is in distilled water ([9]), and the lower curve is in milk fat at a frequency of 1 MHz. *a*—velocity values obtained by the pulse method; *b*—means of measurements on the interferometer.

The ultrasonic velocity in the liquids studied was determined by a pulse method with a pulse repetition frequency of 1 MHz on a UZIS-7P instrument, from the ratio of the transit times of the ultrasonic pulse in the sample and in distilled water, with an accuracy of ±1 m/sec (the practically constant additional error caused by conversion of the instrument readings into ultrasonic velocity did not exceed 1.2 m/sec). The acoustic cuvette was thermostated with an accuracy of ±0.05°. The samples were analyzed for dry skim-milk residue and milk fat with accuracies of ±0.1 and ±0.05%, respectively. The characteristic temperature was attained by rapidly cooling the samples from the temperature of completely liquid fat (50°) in order to reach the liquid supercooled state of the fat at the characteristic temperature.

Table 1

Ultrasonic velocity in milk at 13.9 and 50.0°

Liquid	Fat content, wt.%	Dry skim-milk residue, wt.%	Ultrasonic velocity, m/sec at 13.9°	Ultrasonic velocity, m/sec at 50.0°
Skim milk	0.18	8.7	1493	1564
Mixture	0.97	8.6	1491	1561
Mixture	1.96	8.5	1491	1557
Milk	3.45	8.1	1491	1549
Milk	3.70	8.3	1491	1550
Mixture	3.08	6.9	1487	1548

The velocity values in milk fat (Fig. 1) were obtained by us by the pulse method.

and interferometric methods, the velocity in milk fat at the characteristic temperature was obtained by extrapolating the velocity for the liquid state of the fat.

Obviously, the presence of the indicated characteristic temperature in suspensions can be used for the study of a number of suspensions.

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Note: Figure translations are in progress. See original paper for figures.