Ultrasonic Spectroscopy in Egg white by Plano-Concave Resonator Method

Plano-concave공명법에 의한 egg white의 초음파 Spectroscopy

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ABSTRACT

For the mechanism of ultrosonic absorption in protein solutions, ultrasonic absorption in egg white has been measured in the frequency range of 0.2-10 MHz over the temperature range of 10-50℃ using the plano-concave resonator method which was used to get the absorption spectra over the range 0.2-10MHz. The results show no difference between thick and thin parts, no aging effect, and no individual difference. The absorption coefficient is found to be proportional to the 1.25(±0.02)th power of frequency over the entire temperature range.

요 약

단백질수용액중의 초음파흡수 mechanism을 규명하기 위하여 천연단백질인 egg white의 초음파흡수측정을 주파수 0.2-10MHz, 온도 10-50℃에서 행하였다. 측정방법은 0.2-10.MHz 주파수범위에서 초음파흡수측정이 가능한 plano-concave 공명법을 사용하였다. 그 결과 0.2-10MHz의 주파수범위에 대해 흡수계수는 측정한 전 온도에서 주파수의 1.25(±0.02)승에 비례하고, egg white의 농후부분과 수용성부분 및 aging효과에 대한 유향학적인 차는 나타나지 않았다.

Ⅰ. Introduction

The mechanism of ultrasonic absorption in protein solutions has attracted considerable interest. Because most protein solutions reveal broadband absorption spectra which cannot be described in terms of a single relaxation[1-3] the absorption measurement should be made over a very wide frequency range for quantitative discussion. To extend the frequency range below 1MHz is especially desirable for this purpose.

Egg white is one of the typical protein solutions in real biological system. Only a limited number of ultrasonic studies, however, have been done on egg white. Javanaud et al.[4], measured absorption in egg white and yolk in the frequency range from 2-124MHz, and determined the frequency dependence. They employed a pulse technique, whose accuracy may not be sufficient below 10MHz because of sound diffraction effects. Further, the temperature range investigated is relatively small.

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A plano-concave resonator method, which has been developed by Bae et al[5], is particularly useful for absorption measurements in the hundreds of kilohertz region. The purpose of the present paper is to determine the frequency dependence of absorption in egg white over the 0.2-10 MHz range at temperatures from 10-50℃ using the plano-concave resonator method.

Ⅱ. Methods

Details of the experimental apparatus[5,6] briefly are described here. A block diagram of the new resonator method is shown in figure 1. A quartz transducer driven by a frequency synthesiser excties continuous waves and standing waves are set up in the plano-concave cavity. We can observe the intensity of the standing waves by monitoring the Raman-Nath diffracted light.

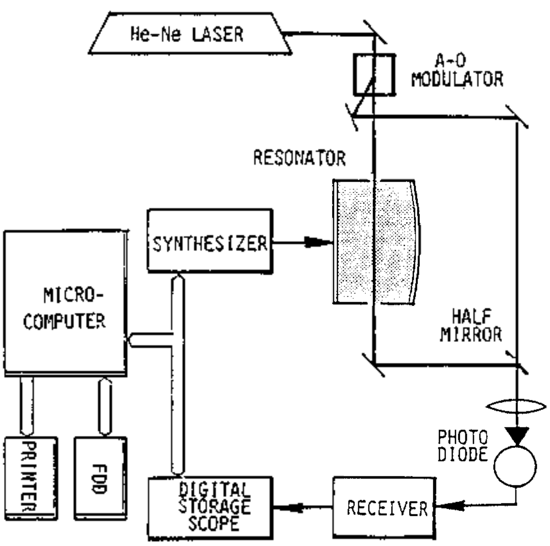

Fig. 1. Block diagram of plane-concave resonator method.

The amplitude of the first-order diffracted light is proportional to that of the sound. A resonance spectrum is obtained with an optical heterodyne system. The bandwidth of one resonance curve

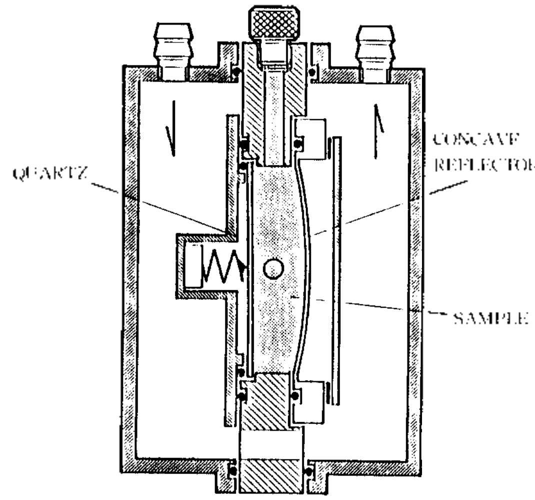

Fig. 2. Cross section of the plane concave resonator.

gives absorption coefficient of the sample liquid. The high quality factor attained with this resonator made possible the reliable absorption measurement in the frequency range from 0.2-10MHz. A pulse echo method[6] was also used to measure absorption at 3MHz. Figure 2 show a cross section of the resonator. The cylindrical cell is made of stainless steel and has two glass windows to allow the laser beam to pass through. An X-cut quartz transducer with a fundamental frequency of 2 MHz and a 56mm effective diameter, and a concave reflector of stainless steel, are mounted at each end of the cell wall. The distance between them is about 9 mm, and this cell contains approximately 25ml of sample liquid. The cell wall was made taking special care that the cell ends be parallel ; therefore, no extramechanism to adjust the parallelism between the quartz and reflector was necessary.

White leghorn eggs were obtained from a farm. The age of the eggs at the time of experiment was 2 day. Only the thin part was carefully taken out by filtering with a 1-mm mesh screen, degassed under vacuum, and used as a sample. The sample volume required was 25ml which was taken from three eggs. The temperature was controlled to within ±0.1℃ throughout the experiment.

Ⅲ. Results and Discussion

The results of absorption measurement are shown in Fig.3. The absorption coefficient divided by the square of frequency α / f^2 is plotted as a function of the logarithm of frequency f. The experiment was repeated at 20℃ after 8 days to find the aging effect, and no change in absorption was observed within the experimental error of 5%. We used different samples for the measurements below and above 2 MHz, but the data in both regions are smoothly connected to each other. There seems to exist negligible differences in ultrasonic properties among eggs if they belong to the same breed. The results suggest that the relaxation region extends to lower frequencies beyond 100kHz.

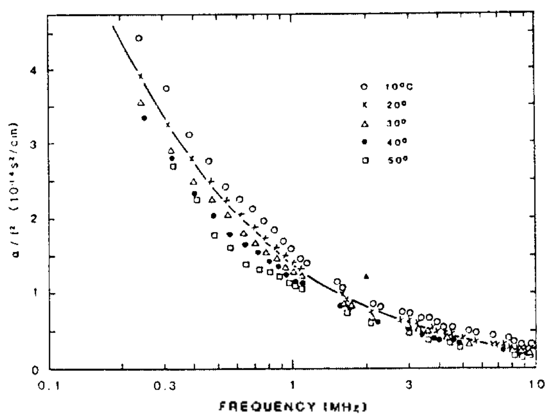

Fig. 3 Frequench dependence of absorption coefficient divided by the square of frequency in the temperature range 10-50℃. The solid line represents the curve fitted to the data of 20℃.

Javanaud et al.reported that the temperature coefficient of absorption is positive at 2 MHz and changes its sign near 4MHz. Howerver, the present results demonstrate the small negative temperature coefficient throughout the frequency range mesured. This may have resulted from the decrease in relaxation strength with temperature. The negative temperature coefficient is also observed in hemoglobin and serum albumin solutions by Carstensen et al[6].

The thick part of egg white has different rheological properties than the thin part. On the other hand, ultrasonic absorption showed no difference between thick and thin parts. The measurement in the thick part was made below 2 MHz at 20℃ in the same way as in thin part except for the detection method. The probing laser is partially scatterd from the fibrous structure of the thick part and the optical detection method loses its advantage. Instead, a piezoceramic transducer was used for receiving the sound waves. The 1MHz transducer was contacted by a point with the center of the back surface of the concave reflector using three adjustable screws. No glue was used, because the use of glue may reduce the quality factor of the resonator. A preliminary experiment on methanol with this method showed negligible

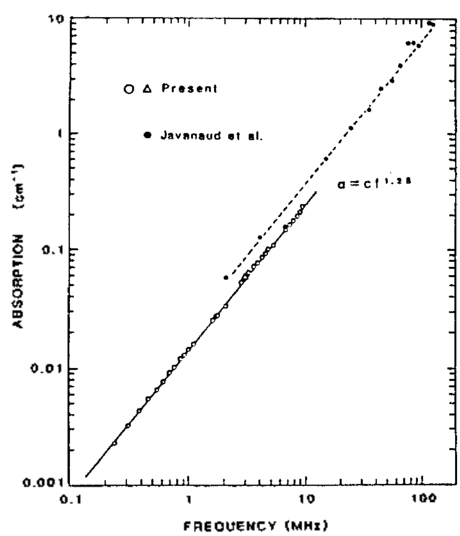

Fig 4. Log log plot of absorption coefficient versus frequency. The open circles and the triangle denote the present results, and the closed circles indicate theresults by Javanaud et al. All the data are expressed as $\alpha = CF^{1.25}$, as represented by the solid and dashed lines, though the value of C is defferent between two works.

reduction of the quality factor compared with the optical detection method.

Figure 4 shows the log-log presentation of the observed absorption coefficient versus frequency. The open circles and the triangle denote the present results at 20℃, and the closed circles indicate the data of 22.5℃ by Javanaud et al., whose sample included both thick and thin parts. The lack of agreement in absolute value between the two works is not clear at present. It cannot be accounted for by the difference in temperature, nor by the effect of the thick part, but might be due to the origin of egg samples. Our experimental values are well fitted over the temperature range investigated to the equation.

$$\alpha = Cf^{1.25 \pm 0.02} \tag{1}$$

which is indicated by the solid lines in Figs. 3 and 4. Here, the constant C is obtained to be 4.45×10^{-10} at 20℃ if α is expressed in cm^{-1} and f in Hz

The dashed lines is drawn assuming the same frequency dependence as Eq.(1), and the agreement with Javanaud's work is seen to be very good. On the basis of te present work and Javanaud's work, it is concluded that absorption in egg white is proportional to the 1.25th power of frequency over the range from 0.2-124MHz. Carstensen et al.Studied the ultrasonic absorption in hemoglobin and serum albumin solutions in the 0.8-3MHz range and found that the absorption is proportional to the 1.2th power of frequency. The values of absorption as well as its frequency dependence are close to the present results in egg white. This suggests that the mechanism of relaxation occurring in egg white involving several kinds of proteins is essentially the same as that in a single kind of protein solution such as albumin.

Ⅳ. Conclusion

Ultrasonic absorption measurements were carried out over the frequency range of 0.2-10MHz in egg white using the plano-concave resonator method to investigate the acoustic properties of the natural protein solution. The ultrasonic absorption in egg white show no difference between thick and thin parts, no aging effect, and no individual coefficient difference. The absorption coefficient is found to be proportional to the 1.25(±0.02)th power of frequency over the entire temperature range. This result suggests that the mechanism of relaxation occuring in egg white involving several kinds of proteins is essentially the same as that in a single kind of protein solution such as hemoglobin.

Acknowledgment

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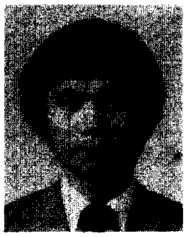

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