Dielectric Analysis of Food Containing Metal Ions near Glass Transition Temperature

Hitoshi Kumagai
Department of Applied Biological Chemistry, The University of Tokyo

Summary

Food materials maintain their physical and chemical stability better in a glassy state than in a rubbery state. The glass transition (glass to rubber transition) temperature T_g for many foods has therefore been determined by DSC. But DSC does not provide information about the molecular motions. In this study, the dielectric behavior of gelatin, a typical polyelectrolyte was analyzed near glass transition temperature. In addition, for gelatin with high electric conductivity (eg. gelatins with high water content or containing metal ions), the dielectric properties were analyzed using the electric modulus M* ($= 1/(\varepsilon' - i\varepsilon'') = M' + iM''$; i, the imaginary unit). The dielectric constant ε' and dielectric loss ε'' were measured over a frequency range from 20 Hz to 10 MHz.

For desalted gelatin with low water content, the peak of ε'', ie., the dielectric relaxation was observed in the glassy state. The relaxation time τ was evaluated from the peak of ε''. The activation energy Eact was evaluated from an Arrhenius plot of τ. From the orders of the magnitude of Eact, the dielectric relaxation observed in the glassy state was confirmed to be β-relaxation. τ and E_{act} seem to describe the enhancement effect of water on the mobility of gelatin molecules in the glassy state; τ and E_{act} are considered to be suitable parameters for the characterization of the plasticizing effect of water on a glassy material.

The peak of ε'' for the gelatin with high water content was masked, probably due to dc conduction. Therefore, ε' and ε'' of the gelatin were transformed into M* formalism. The peak of M'', ie., the relaxation was observed both in the glassy and rubbery states. By fitting the M'' data to the Havriliak-Negami type equation, the relaxation time, τ_M was evaluated. The value of the activation energy, $E\tau$, evaluated from an Arrhenius plot of $1/\tau_M$, agreed well with that of E_σ evaluated from the dc conductivity σ_0 both in the glassy and rubbery states, indicating that the relaxation observed was ascribed to ionic conduction. The value of the activation energy in the glassy state was larger than that in the rubbery state.