Analysis of Glass Transition of Food Containing Metal Ions Using Electric Modulus

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Summary

The glass transition temperature T_g for many foods has been determined by DSC, but DSC does not provide information about the molecular or ion motions. Dielectric spectroscopy is widely used to study molecular dynamics in polymeric solids. With increasing frequency, f, the dielectric constant, ε', often decreases, and the dielectric loss, ε", shows a peak due to the delay in the dipole moments. This phenomenon is the so-called dielectric relaxation, which reflects the chain motions in materials. However, at low high temperature, the peak of ε" for materials containing electrolytes and/or water is often masked due to the large dc conductivity; the ionic conductivity makes it difficult to measure the dielectric relaxation. In these cases, an electric modulus M* (= 1/(ε' - iε") = M'+iM" ; i, the imaginary unit) is often effective for analysis. In this study, we examined the dielectric properties of the gelatin films using the electric modulus M*. In addition, the mechanism of the observed relaxation of M* was discussed.

ε' and ε" for samples were measured over a frequency range from 20 Hz to 10 MHz and then transformed into the M* formalism. A non-desalted gelatin film with a water content of 0.146kg/kg of sample (Sample N; T_g, 60 °C) showed the peak of M" (relaxation of electric modulus), although the peak of ε" was masked. The value of the activation energy, E_τ, evaluated from the Arrhenius plot of the electrical relaxation time, τ_M, agreed well with that of the activation energy, E_σ, evaluated from the dc conductivity, σ_0, for Sample N, indicating that the relaxation observed for Sample N was ascribed to ionic conduction. In addition, the value of the activation energy of Sample N was close to that of the desalted glassy gelatin with a water content of 0.137 kg/kg of sample (Sample D; T_g, 60 °C). On the other hand, a glassy gelatin containing metal ions with a water content of 0.0450kg/kg of sample (Sample L; T_g, 117 °C) showed a peak for both the ε" and M" data. The value of E_τ agreed well with that of the activation energy, E_{act}, evaluated from the ε" spectra, indicating that the relaxation observed for Sample L was considered to arise from a dipole orientation.