Elegant Approach to the Controllability of the Mechanical Properties of a Microgel via the Self-Assembly of Internal Molecules

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Gelatin microgels synthesized inside droplets and stabilized by lipid membranes could move the field of protein-like polymer microgels.

To date, microgel particles have quite successfully been synthesized in a variety of ways, including emulsion polymerization and microfluidics. Unfortunately, studying the principles of the changes in mechanical properties of microgel particles has been difficult until now due to the lack of a reliable measurement method. Yanagisawa and colleagues propose a method for the measurement and characterization of the mechanical properties of gelatin-based microgels of various sizes and show new possibilities for microgels and their applications.

Microgels composed of various materials are widely used in many applications, including foods, cosmetics, and products of the chemical industry. In particular, materials with high biocompatibility and stability in the medical and pharmaceutical fields, such as tissue engineering, drug delivery, and biomaterials, have received exceptional attention. As the number of fields for these applications expands, so do their required characteristics. These include necessarily and importantly their mechanical properties. Available methods are not efficient at measuring the physical and mechanical properties of micrometer- and sub-micrometer-sized biomaterials and hydrogel-based materials with nonplanar structures such as spherical, capsular, or more complex three-dimensional (3D) structures. These methods are based on the control and improvement of the mechanical properties of the biomaterial-based microgels, and they depend strongly on chemical analysis or other indirect methods.

For this reason, various attempts have been made to measure the mechanical properties of microgels directly, which led to the development of a method that can predict the mechanical properties of microgel particles by observing their deformation under the pressure created inside a micropipette. This method is particularly valuable in that the analysis can be performed when the microgel is dispersed or suspended in a liquid medium. Other methods have since been suggested, presenting the possibility for the further enhancement of the accuracy of the measurement of the mechanical properties of soft microgels. Despite these achievements, there are unmet challenges related to the use of these methods as tools for characterization, the combination of various methods and principles, and the ultimate control and improvement of the characteristics of the microgels.

Gelatin is a common protein-like polymer material derived from collagen, and the potential of gelatin microgels in the biological field may be immense. A recent study by Yanagisawa and co-workers published in "ACS Central Science" on the improvement of the elasticity of gelatin microgels proposed an excellent methodology for microgel studies. The authors used two phospholipids, the constituents of cell membranes, to stabilize droplets of gelatin solution in water at a temperature above the gelation temperature. Cooling emulsified gelatin droplets below this temperature produced microgels. The mechanical properties of the gelatin microgels were characterized by a micropipette aspiration method. The reliability of the micropipette aspiration method was confirmed by comparing the elasticity of the microgels with the results obtained by atomic force microscopy. The measurements of the elasticity were highly reliable for various ratios of the micropipette tip inner radius to the microgel particle radius, as well as when the ratio of the radius to the distance between the micropipette tip and the microgel was 0.4 or less.

The method will be helpful in measuring the elasticity of spherical particles composed of soft materials. The authors found that the elasticity of a gelatin microgel, prepared using a phospholipid membrane, increased at least eight times. Published: April 5, 2018
In addition, it was revealed that the change in the elasticity of the gelatin microgels by the introduction of the phospholipid occurs only during the gelation process, regardless of the affinity between the phospholipid and gelatin. The series of experiments empirically demonstrated that the increase of the elasticity of the gelatin microgel was extremely dependent on the size of the droplet. This opens up many possibilities for controlling the physical/mechanical properties of protein-derived polymer microgels and using them in applications that require highly elastic microgels.

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The team also investigated the causes of the elasticity changes of gelatin microgels. They showed that the increase in the elasticity was caused by the existence of a secondary structure in the gelatin, as shown by the spectral differences in circular dichroism spectroscopy. Using a fluorescence assay, the authors found that smaller gelatin microgel particles contain greater degrees of self-assembled beta sheets. The formation and growth of the self-assembled beta sheets in the gelatin microgel were further confirmed by Fourier transform infrared analysis. The increased rigidity in secondary structure resulted in an increase in both the melting point of the gelatin microgels and the gelation rate, as compared to the gelatin microgel that only has a triple helix structure. These additional changes in the physical properties may also be useful in other applications. This study presents a method for the control of the physical and mechanical properties of gelatin microgels and can enable the production of materials with improved properties that cannot be obtained using the conventional chemical synthesis method.

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Notes
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