Effect of the Molecular Weight Distribution of Agar on the Gel Strength

Yuri Tashiro, Hiroo Ogawa, and Naomichi Iso
Department of Food Science and Technology, Tokyo University of Fisheries, Minato, Tokyo 108, Japan
(Received May 16, 1996)

Key words: agar, gel strength, molecular weight, molecular weight distribution, sulfate, 3,6-anhydro-L-galactose

Agar is polysaccharide extracted from red algae of seaweeds and is used for many biochemical, biological and industrial applications because of the gel forming properties. The physical properties of agar gel are believed to depend on the molecular weight and chemical components of the agar molecule. The relationship between gel strength and contents of sulfate and 3,6-anhydro-L-galactose have been reported. These two chemical components are considered having a large effect on the three dimensional structure of agar gel. In the case of containing sulfate groups in the agar molecule, water at the neighborhood of sulfate groups plays a role as a structure breaker. Also an increase of 3,6-anhydro-L-galactose has a large effect on the stabilization of the helical structure of agar gel. The relationship, however, between gel strength and molecular weight has not been confirmed. In the previous papers, we determined the weight-average molecular weight and analyzed the molecular weight distribution of six agar samples by the sedimentation method. The distribution curves were broad and asymmetrical. From the results we predicted that physicochemical properties of agar gel depend on not only the average molecular weight but also the molecular weight distribution as well as in synthesized polymers.

In this report we investigated the relationship between gel strength and each factor; content of sulfate ester, content of 3,6-anhydro-L-galactose, and molecular weight.

Agar samples which were furnished by Ina Food Industry Co., Ltd. were the same as those used in the previous papers. The characterization of the samples have been detailed in those papers. The name of six agar samples used in this report was assigned to Japanese names of raw seaweed. The samples obtained from Gelidium amansii, Pterocladiace capillacea, and Gracilaria verrucosa were named as "Makusa", "Obakusa", and "Ogonori", respectively.

Gel strength was measured at 20°C using a Tensipressor (Taketomo Electric Co., Model TTP-50 BX II). The sample gel of 1% concentration was compressed by a cylindrical plunger (diameter 40 mm) at a rate of 0.1 mm/s. The sample diameter and height were 50 mm and 15 mm, respectively.

According to the IR method of Rochas et al., concentrations of sulfate and 3,6-anhydro-L-galactose were determined by calculating. FT-IR spectra of agar films recorded on a FT-IR spectrophotometer (JASCO, model FT/IR-5300).

Fig. 1. The plot of gel strength vs. relative concentration of sulfate ester in agar samples: ●, Ogonori 1; ○, Makusa; ▲, Obakusa; ◻, Ogonori 2; ▲, Ogonori 3; ▲, Ogonori 4.

The relative concentrations are arbitrary units calculated from the ratio of FT-IR absorbances at 1250 cm⁻¹ to 2920 cm⁻¹ in the samples; the absorbance at 1250 cm⁻¹ and 2920 cm⁻¹ are attributed to total sulfate and to C-H, respectively. "Ogonori 1" is used as a standard.
Relative Concentration of 3,6-anhydro-L-galactose

Fig. 2. The plot of gel strength vs. relative concentration of 3,6-anhydro-L-galactose in agar samples.

Symbols are same as in Fig. 1. The relative concentrations are arbitrary units calculated from the ratio of FT-IR absorbances at 930 cm⁻¹ to 2920 cm⁻¹ in the samples; the absorbance at 930 cm⁻¹ is attributed to 3,6-anhydro-L-galactose. "Ogonori 1" is used as a standard.

Fig. 3. The plot of gel strength vs. weight-average molecular weight, \( M_w \), for six agar samples.

Symbols are same as in Fig. 1.

however, the correlation between gel strength and molecular weight was not clear. "Obakusa"’, the intermediate molecular weight in these samples, had the highest gel strength. Gel strength of "Ogonori 1" and "Makusa" for higher molecular weight samples were lower than that of "Obakusa". "Makusa" had a lower gel strength than "Ogonori 2" which had a lower molecular weight than "Obakusa", too. From this observation it is reasonable to suppose that the molecular weight distribution also affects the gel strength. For four higher-molecular-weight samples, the distribution curves of molecular weight showed a different shape to each other. For example, contents of higher or lower molecular-weight portion were different from each agar sample. For "Makusa", particularly, higher molecular-weight portion of the distribution curve was broader than that of the other samples. Therefore, agar gel will have a different structure for each sample and the effects are different on the gel strength for the following reason; in the case of agar with a different distribution of molecular weight, long molecular chains can make three-dimensional network structure. Short chains play as filler in bulk of the gel structure. Therefore, even an agar of low average molecular weight can make strong gel due to the molecular weight distribution.

From the above considerations, we would be able to obtain an agar with desirable gel strength by varying the extraction procedure or blending agars with different molecular characteristics to control the molecular weight distribution as well as the average molecular weight.

References