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RESEARCH NOTE

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Thermal Gelation Characteristics of Composite Surimi Sol as Affected by Rice Starch

Young-Hwa Jung and Byoungseung Yoo*

Department of Food Science and Technology, Dongguk University, Seoul 100-715, Korea

Abstract The effect of rice starch at different concentrations (0, 4, 6, and 8%) on dynamic rheological properties of surimi sols was investigated by small-deformation oscillatory measurements at 10°C and during heating from 10 to 95°C. Dynamic frequency sweeps at 10°C showed that the magnitudes of storage modulus (G') decreased with increasing starch concentration while those of tan δ increased. G' values of surimi-rice starch sols during heating decreased with increasing starch concentration, indicating that the pattern of G' changes during heating was influenced by the concentration of the added rice starch. In general, the characteristic G' thermograms of all samples showed a similar sol-gel transition pattern.

Keywords: surimi sol, rice starch, rheology, thermogram, storage modulus

Introduction

In surimi-based products, a variety of biopolymeric ingredients, such as starches, gums and non-fish proteins, has been used to improve texture, moistness and freeze-thaw stability, as well as to produce finished products economically (1-3). Surimi sol and gel containing ingredients were expected to show rheological properties as a composite in which particulate ingredients are incorporated in the continuous phase (protein matrix) (4, 5). Such composite characteristics were varied by dispersing varying amounts of ingredients in a surimi sol, as well as by altering the physical state of the dispersed phase through heating, as described by Lee and Kim (6). The addition of starch to surimi sol is known to modify and control the rheological properties of surimi-based products. The gelatinization of starch in the composite surimi sol also plays an important role in the modification of the rheological properties of surimi gel.

Thermal gelation characteristic of starch-incorporated surimi sol during heating has been investigated by examining changes in rheological properties using an Instron testing machine (7), a Brookfield viscometer (8), and a dynamic rheometer (9, 10). The dynamic rheological test for small-deformation oscillatory measurements has, in general, been used to obtain valuable information on the viscoelastic properties of biopolymer mixtures without breaking their structural elements. Therefore, dynamic rheological monitoring of starch-incorporated surimi sol during heating can be used to obtain qualitative and quantitative information by dynamic moduli that relate to molecular changes. However, little information is available on the effect of starch on the dynamic rheological properties of surimi sol during heating except for the study of Kong *et al.* (9) who examined the effect of gelatinized and normal wheat starches on dynamic rheological properties of surimi sols during heating. In particular, no attempt has been made to study the dynamic rheological properties of surimi sol as affected by the addition of rice starch. The objectives of the presented work were to characterize the pattern of change in dynamic moduli of surimi sol during heating as affected by rice starch with different concentrations using nondestructive dynamic rheometry, and to determine the effect of rice starch concentration on the dynamic rheological properties of surimi sols.

*Corresponding author: Tel: 82-2-2260-3368; Fax: 82-2-2264-3368
E-mail: bsyoo@dongguk.edu
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Materials and Methods

Materials Commercially frozen Alaska Pollock (*Theragra chalcogramma*) surimi (grade AA) was obtained from Alyeska Seafoods Inc. (Seattle, USA). Surimi was cut into approximately 200g blocks, vacuum-packed into cryobags and stored in a freezer at -20°C. Rice starch was obtained from Bangkok Starch Industrial Co., Ltd. (Nakornprathom, Thailand).

Preparation of surimi sol Surimi sol was prepared following the method of Lim *et al.* (11). Frozen surimi (200 g) was partially thawed at 5°C for 3 hr and chopped for 1 min to solubilize the protein with salt (2.0% of surimi weight) in a 1200 ml mini food chopper (MK-K56, National, Japan) having a 12.0 cm diameter blade, followed by additional chopping for another 1 min with rice starch at different concentrations (0, 4, 6, and 8%). The calculated amount of ice-chilled water was added to adjust the final moisture of all batches to 80% in order for the results to reflect the effect of starch added. The final surimi sol was kept below 10°C and was immediately transferred to the rheometer plate for the measurement of dynamic rheological properties.

Dynamic rheological measurements Dynamic rheological measurements were conducted with a TA AR1000 controlled stress rheometer (TA Instruments Inc., New Castle, DE), using a parallel plate system (4 cm dia.) at a gap of 1000 μm. Each surimi sol (<10°C) was transferred to the rheometer plate at 10°C and the excess material was wiped off with a spatula. The exposed sample edge was covered with a thin layer of light paraffin oil to prevent evaporation during measurements. Storage modulus (G') and tan δ were measured at 10°C from frequency sweeps over the range of 0.63 - 62.8 rad/sec at 1% strain. The following temperature sweep from 10 to 95°C was conducted at a heating rate of 1°C/min in order to monitor the change in G' and G" during the heating process at a frequency (ω) of 1 Hz and 1% strain. The 1% strain was in the linear viscoelastic region. All rheological measurements were conducted in triplicate.

Results and Discussion

Dynamic rheological properties Figure 1 shows the changes in G' and tan δ as a function of frequency (ω) for surimi-rice starch sol samples at 10°C. The magnitude of G' decreased with increasing starch concentration while that of tan δ increased, indicating that the effect of rice starch on the viscoelastic properties of surimi sols depended on starch concentration. A tan δ smaller than one indicates predominantly elastic behavior while that greater than one indicates predominantly viscous behavior. The tan δ values of all surimi-rice starch sol samples were in the range of 0.13 - 0.43 over a wide range of frequency. This observation confirmed the weak gel-like behavior of the surimi-rice starch sols, which showed a higher elastic character with tan δ values much smaller than one. This tendency is similar to that found in surimi sols mixed with different sugars (11). The tan δ values of surimi-rice starch sols also were higher than those of the control (0% starch concentration), and increased with increasing starch concentration. This indicates that the loss modulus (G") increases much more than G' after the addition of rice starch to surimi sol. This dependence on starch concentration of the increase of viscous properties (G") in the surimi sol state can be explained by the result of impeded cohesion in the surimi sol matrix and also the dilution effect of the starch, as suggested by Yoo and Lee (4).

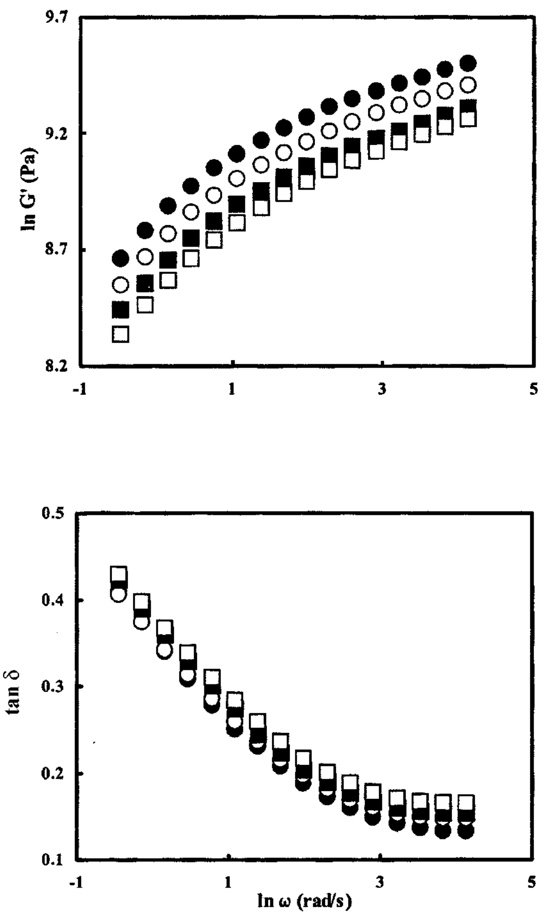

Fig. 1. Plot of ln G' and tan δ vs. ln ω for surimi-rice starch sols as a function of starch concentration at 10°C : (●) 0%, (○) 4 %, (■) 6%, (□) 8%.

Dynamic moduli thermogram The characteristic G' and G" thermograms of a representative surimi sol (designated as 4% starch concentration) as a function of temperature were monitored (Fig. 2). The G' values showed little decrease up to around 25°C, followed by a rapid increase, and then a transition peak at around 38°C (Table 1). The transition patterns in respect to G' were similar to the results reported by Yoo and Lee (8) and Lim *et al.* (11). The abruptly increased G' values can be associated with a setting phenomenon due to the entanglement of partially unfolded actomyosin molecules, as suggested by Montejano *et al.* (12). However, no noticeable differences in G" values were observed between 10 and 38°C, indicating that rice starch had a neutral effect on the viscous property of surimi sol below the transition peak of G'. Immediately after the transition peak, the G' and G" values decreased up to around 50°C. Above 50°C, the G' value increased continuously with increasing temperature, while the G" value was maintained nearly constant, indicating that G' was more dependent on the heating temperature. Such increase in G' values above 50°C can be attributed to the transition from a loose network to a compact network formation in which the surimi sol was no longer in a sol state for measurements of viscous property, as indicated by Yoo and Lee (8). As shown in Fig. 2, G' also showed higher values with a more distinct transition peak than G", suggesting that G' is more responsive to dynamic rheological changes during heating

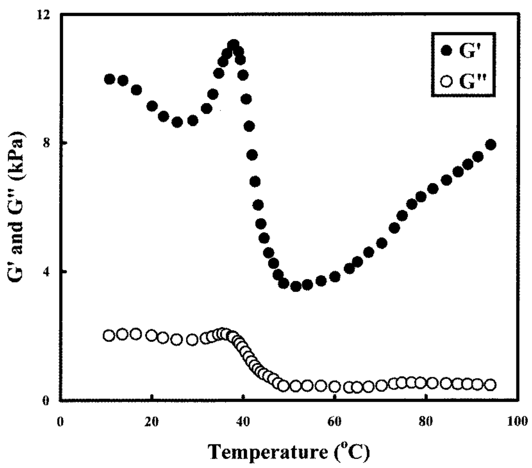

Fig. 2 . Change in G'(●) and G"(○) during heating from 10 to 95°C at 1°C/min for a surimi sol containing 4% rice starch.

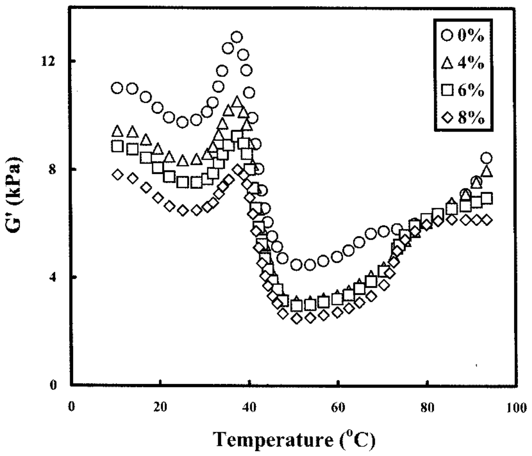

Fig. 3. Change in G' during heating from 10 to 95°C at 1°C/min for surimi-rice starch sols as a function of starch concentration.

(8, 11). Therefore, in the present study only G' changes of surimi-rice starch sols during heating are shown because the reinforcing effect of starch in the composite system was more pronounced in G', which represents the elastic property.

Effect of rice starch on storage modulus (G') during heating The characteristic G' thermograms of the surimi sols containing rice starch at concentrations ranging from 0-8% are presented in Fig. 3. The following G' magnitudes observed during heating are shown in Table 1: G' at 10°C (G'_{10}), G' at 95°C (G'_{95}), and the maximum G' (G'_{max}). In general the G' values of surimi-rice starch sols decreased with increasing starch concentration. The decrease also was more pronounced at G'_{10} and G'_{max}. As discussed previously, such decrease of G' values after rice starch addition in the low temperature range can be explained by the dilution effect of the starch and also by the impeded cohesion in the surimi sol matrix (4). The transition peak temperatures occurred at around 38°C, with very little difference of the transition peak temperatures between samples (Table 1). However, the extent of the height reduction of the transition peak decreased with increasing starch concentration. Such reduction of transition peak with addition of rice starch may be explained by impeded protein aggregation (8). These observed results followed similar trends to those previously found in rotational viscometric measurements (8).

The continuous increase in G' values was also found in the temperature range from 50 to 95°C, indicating the thermally-induced, gel network formation. The G' values of the surimi-rice starch sol samples between 50 and 80°C were much lower than those of surimi sol (0% starch). Such reduction of G' of the surimi-rice starch sols can be due to an increased concentration of rice starch, which is much weaker than myofibrillar proteins, as suggested by Yang and Park (13). Yoo and Lee (4) and Lee and Kim (6) also reported that the composite reinforcing effect of starch could not be achieved if the protein matrix was filled with too many starch globules as in the case of concentrations higher than 4%. In the temperature range of 50 - 70°C, G' values were maintained nearly constant and there were no major differences between surimi-rice starch samples, indicating that the formation of protein network led to constant elastic properties for the surimi sol, irrespective of the starch concentration. Such constant G' values can be explained by the unswollen (inactive filler) starch granules in the protein gel network in the temperature range of 50 - 70°C, as explained by Yang and Park (13). They reported that when the starch granules in the surimi composite system could not absorb enough water to produce reinforcement in the gel matrix, they inactively filled into the network and could not give pressure to the matrix, resulting in a weak gel such as in the corn starch at 70°C. The G' values (G'_{95}) at 95°C with completion of the network formation also decreased with increasing starch concentration. A similar trend was also observed for G'_{10} and G'_{max} values, as shown in Table 1 and Fig 2. From these observations, it was concluded that the observed pattern of G' changes during heating was influenced by the addition of rice starch and the starch concentration.

Table 1. Values of G' (Pa) at 10 °C (G'_{10}) and 95°C (G'_{95}), maximum values of G' (G'_{max}) and corresponding temperature for surimi-rice starch sols with different starch concentrations

Rice starch concentration (%)	G'_{10} (kPs)	G'_{95} (kPa)	G'_{max} (kPa)	Temperature (°C)
0%	11.1±0.21	8.38±0.51	12.9±0.19	37.5
4%	9.64±0.28	8.20±0.25	10.7±0.28	37.7
6%	8.87±0.20	7.04±0.12	0.95±0.22	37.9
8%	8.05±0.28	6.41±0.31	8.47±0.40	37.9

Acknowledgments

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