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# 수분에 의존하는 단백질의 특성이 어묵의 조직에 미치는 영향

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# Moisture-dependent Gelation Characteristics of Nonfish Protein Affect the Surimi Gel Texture

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## Abstract

The moisture-dependent gelation characteristics of five different proteins are evaluated to understand the modification of gel strength when they are added in surimi gel. Compressive force and penetration force of protein gels gradually decreased with increase of moisture level, with showing markedly decrease at certain point of moisture level called critical moisture level. The critical moisture level for gelation of SPI-1, SPI-2, EW, WPC and LA were 79.4%, 81.6%, 91.4%, 87,8% and 84.7%, respectively. Beyond this critical level of water, protein gel matrix begins to lose its water binding and structural integrity. The moisture that was not retained by a protein was available to diluting the protein matrix and eventually weakened the overall gel strength. EW and MPI showed higher water retention than those of SPI, WPC and LA. The compressive force of SPI, WPC and LA-incorporated surimi gel at the varying moisture levels strongly correlated with the amount of water retained at corresponding moisture level within those protein (r=0.99).

Key words:

## I. Introduction

Non-animal proteins have been wildly used in comminuted meat and fisheries product such as sausage and surimi based product. The textural properties of surimi-based gel products have been improved by incorporating varieties of gel forming biopolymers such as starch, protein and hydrocolloid like carageenan[1]. Gel strengthening ingredient such as sodium ascobate was also used to modify textural properties of surimi-based gel product[2,3]. Nonfish protein is one of the most widely used ingredient for production of surimi based product. The reason for uses is that because some of the nonfish protein posses cooperative gel strengthening effect on the surimi gel matrix[4].

Protein gelation is based on interaction between protein molecules through hydrogen bonding, ionic bonding, disulfide bonding and hydrophobic association[4,5]. The type and extent of interaction between and within protein molecules would alter the textural properties of protein gel product. Sipos *et al.*[6] used the following commercial additives in the binder matrix for minced cod: soy protein concentrate, calcium-reduced skim milk solid, egg albumin, sodium alginate, bread crumbs and sodium tripolyphosphate. Sipos *et al.*[6] found that use of soy protein concentrate in minced cod increased total water holding capacity by 50% above that of the control. Sipos *et al.*[6]. attempted to evaluate the properties of Kamaboko product made with soybean product through both sensory testing and instrumental measurement. It was found that the "hardness" of Kamaboko made with soybean product correlated highly with the degree of denaturation of soy protein and amount of protein nondispersible in 3% sodium chloride aqueous solution. It is known that the textural properties of protein added product is differently affected by depending on their physicochemical properties of non-animal protein. Moisture dependent gelation characteristics of non-animal proteins is one of the valuable parameters to understand their behavior in protein-based gel matrix.

The objectives of this study are 1) to evaluate moisture-dependent gelation characteristics of nonfish protein and 2) to explain how these properties affect the textural properties of nonfish protein containing surimi gel.

## II. Material and Method

### 1. Preparation of Nonfish Protein Gels

Protein gels were prepared from various commercially available nonfish proteins. They included soy protein isolate (SPI-1; Pro-Fam 902, SPI-2; Pro-Fam 970), whey protein concentrate (WPC; Alacen 882), lactalbumin (LA; alpha-lactoalbumin), egg white (EW; standard albumen), milk protein isolate (MPI; TMP 1350) and wheat gluten (WG; IWGA-Comopsite Gluten Blend MX 2263). SPI-1 and 2 were obtained from Grain Processing Corp. (Muscatine, IA); WPC, LA and MPI from New Zealand Milk Products (Petaluma, CA); EW from Monarck Egg Products (Kansas city, MO) and WG from Ogilvie Milk (Minnetonka, MN).

In an attempt to find the critical gelation point and to determine the relationship between textural properties and moisture contents of protein gel, the moisture-dependent gel-forming ability of nonfish proteins was evaluated by determining measurable gelling point through Instron testing machine. Critical gelation point was assumed as a moisture content at which measurable gel is formed. Protein gel was prepared by blending each protein for 3 min in a chopper with addition of 1.5% salt on a hydrated protein weight basis and an appropriate amount of water to vary the moisture level. The moisture content of the protein gels was varied from 75 to 94%. The resulting protein paste was stuffed into a 25 mm diameter cellulose casing and cooked for 20 min in a steam cooker. Cooked protein gels were immediately cooled in cold water for 10 min, and then kept at room temperature for 24 hours prior to evaluating the textural properties.

### 2. Preparation of Protein-incorporated Surimi Gel

Frozen Alaska pollock (Theragra chalcogramma) surimi (A grade) obtained from the Alaska Fisheries Development Foundation (Anchorage, AK) was used through out the study. Partially thawed surimi block was chopped for 10 min in a silent cutter with addition of 1.5% salt, ingredients and 3% nonfish protein and an appropriate amount of water to adjust the moisture level to 78%. All ingredients used were added on a surimi weight basis. The rest of the procedure was the same as that for protein gel which described earlier.

### 3. Evaluation of Textural Properties of Gel Samples

Compressive force, penetration force and expressible moisture were measured as textural parameters using an Instron testing machine (Model 1122) following the procedure[7]. For all tests, cylindrical sample (25 mm diameter, 25 mm length) were used. Compressive force at failure was measured as an index of gel cohesiveness upon 90% deformation using a 10 cm diameter compression head. At the same time, the amount of moisture expressed upon compression was measured by collecting the fluid on three layers of filter paper (fast grade) and expressed as percent of the sample moisture content. This value was used as a measure of water binding ability (WBA). Penetration force at failure was measured upon 90% deformation as an index of firmness using 5 mm diameter plunger with a spherical end.

## III. Result and Discussion

In an attempt to determine the relationship between the critical moisture level for protein gelation and the strength of nonfish protein-incorporated surimi gel, the moisture-dependent gel strength of five different protein were evaluated. Compressive and penetration forces of SPI-1, SPI-2, La, EW and WPC are shown in Fig. 1 and 2, respectively. The maximum moisture level for gelation of SPI-1, SPI-2 LA, WPC and EW were 83%, 85%, 89%, 92% and 94%, respectively. These figure were

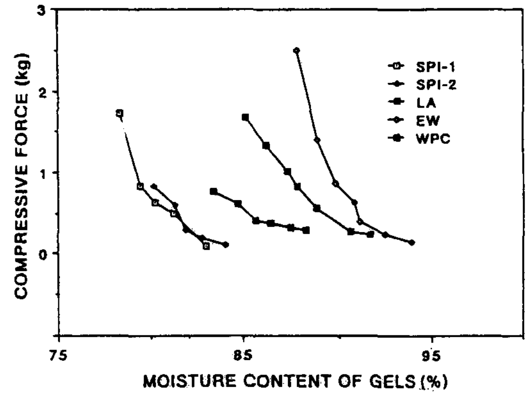

Fig. 1. Changes in compressive force of protein gels at varying moisture levels. SPI-1 and 2=soy protein isolate, LA=lactoallbumin, EW=egg white, WPC=whey protein concentrate.

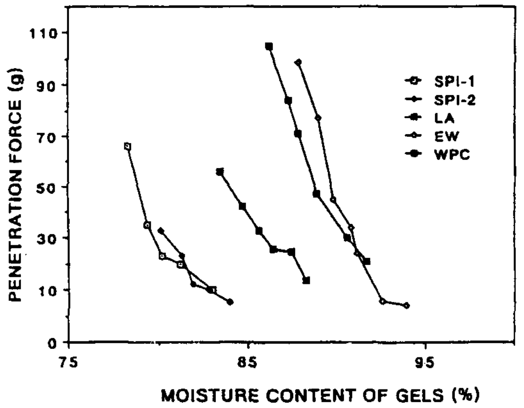

Fig. 2. Changes in penetration force of protein gels at varying moisture levels. SPI-1 and 2=soy protein isolate, LA=lactoalbumin, EW=egg white, WPC=whey protein concentrate.

determined by the basis of the measurable gelling point by an Instron Testing machine. However, if the gelation point is determined by different method such as viscosity and turbidity, it should be higher than the measured levels determined by Instron testing machine[8].

Compressive and penetration forces of protein gels gradually decreased with increased moisture level. However, at the certain point of moisture level, gel strength markedly decreased. The degree of decrease varied with the type of protein. The level of moisture showing a big decrease was same as the critical moisture level of protein gel determined by the expressible moisture (Fig. 3). Beyond this point,

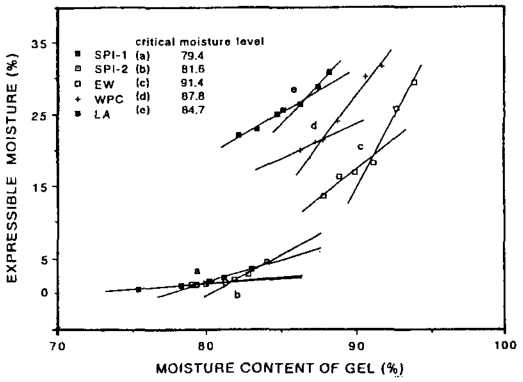

Fig. 3. Changes in expressible moisture of protein gels at varying moisture levels. SPI-1 and 2=soy protein isolate, LA=lactoalbumin, EW=egg white, WPC=whey protein concentrate.

proteins formed a soft gel. For WPC, beyond 92% of moisture level, it formed a transparent and weak gel such that the measurement of gel texture was not possible, while gels with moisture levels less than 92% were opaque and the gel strength decreased with increased the moisture level. Hermansson[9] reported that more protein-protein interaction occurred at the level of moisture content than protein-protein interaction at the higher level of moisture, resulting in formation of a coarser and phase separated gel structure. These gels immobilize less water than highly ordered gels. Kalab *et al.*[10] reported a similar explanation for the concentration-dependent gelation characteristics of milk protein.

At the moisture levels of higher than 94%, no free-standing gel could be obtained from EW. Shimada and Matsushita[11] reported that at low protein concentrations, coagulation of EW occurred within the narrow pH range around the isoelectric point, but in a wider pH range at higher concentrations. This is a good evidence for moisture-dependent characteristics of protein gelation and suggests that coagulation of EW is affected by other physical factors such as protein-protein interaction rather than pH. Protein gelation can be therefore achieved through protein-protein interaction at a relatively higher concentration and is highly moisture-dependent.

Woodward and Cotterill[12] reported that as the protein level of EW increased, gel hardness increased

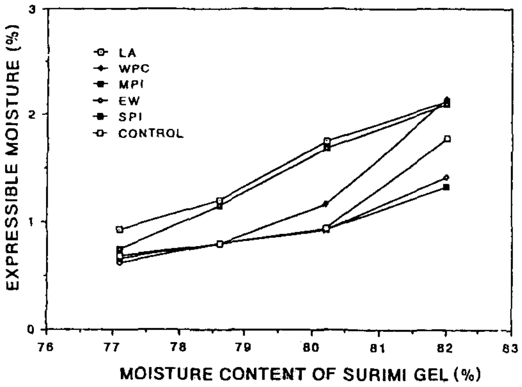

**Fig. 4. Changes in expressible moisture of nonfish protein-incorporated surimi gel at varying moisture levels. SPI=soy protein isolate, LA=lactoalbumin, EW=egg white, MPI=Milk protein isolate, WPC=whey protein concentrate.**

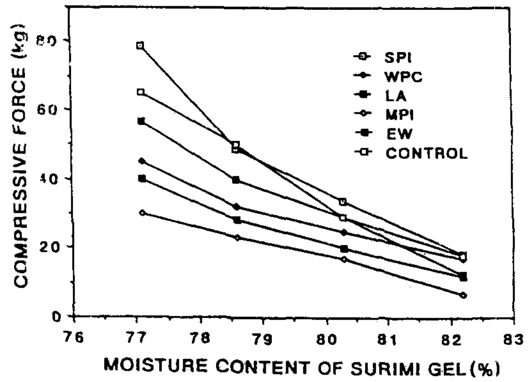

**Fig. 5. Changes in compressive force of nonfish protein-incorporated surimi gel at varying moisture levels. SPI=soy protein isolate, LA=lactoalbumin, EW=egg white WPC=whey protein concentrate, MPI=milk protein isolate.**

exponentially. Similar results were obtained by Beveridge *et al.*13,14) who reported that dilution of EW with water resulted in an exponential decrease in the shear force of the resulting coagulum.

Gel properties change with an increase in the moisture level. Initially, the change is gradual and linear until the moisture level reaches a certain point. Beyond that point, a sharp change in gel properties occurs. The deflection point, where a change in the linear rate occurs, shall be called "critical moisture level". This critical moisture level may indicate the index of tolerance beyond which the gel matrix begins to lose its water binding and structural integrity. Critical moisture levels for gelation of SPI-1, SPI-2, EW, WPC and LA were 79.4%, 81.6%, 91.4%, 87.8% and 84.7%, respectively. As can be seen in Fig. 3, the amount of expressible moisture of protein gels gradually increased up to the critical point (a, b, c, d and e) with increased moisture content. However, beyond the critical points, slopes of the graph in expressible moisture became more steeper than those before critical points, indicating a decreasing water binding ability of the gel. From this result, it can be concluded that each protein has different tolerance for the water binding in the protein gel system. Beyond the tolerance level, the excess amount of water available to protein gelation, may reduce the protein-protein interaction, leading to a soft gel. Fig. 4 shows the changes in expressible moisture of nonfish protein-incorporated surimi gels at varying moisture level. Although the location of critical point for expressible moisture is not as clearly visible as in protein gels themselves, the difference in the amount of expressible moisture between the moisture level of 80% and 82% was consistently large enough to consider 80% as critical point. The critical moisture level between protein and protein-incorporated surimi gels did not coincide, indicating different gelation behavior of protein in a single and mixed system.

Fig. 5 shows the changes in compressive force with an increased moisture level of the protein-incorporated surimi gel. The increase in the moisture level of surimi gels resulted in gradual decrease in compressive force, indicating a decrease in the structural integrity of the protein gel matrix. A decrease in the structural integrity of the protein gel can be caused by dilution effect of the added water on gel forming myofibrillar protein. Rizvi15) reported that the increase in water level enlarged the particle size of comminuted meat by diffusion osmosis, as well as resulted in thicker layer between particulates, thus weakening the structural links.

In an attempt to examine the hydrodynamic properties of nonfish protein in terms of water binding and distribution and how they affect the textural properties of surimi gel, the amount of water retained in the protein at varying moisture level (Fig. 6) was determined by a centrifugation method16). The slope of each line represents the degree of water retention

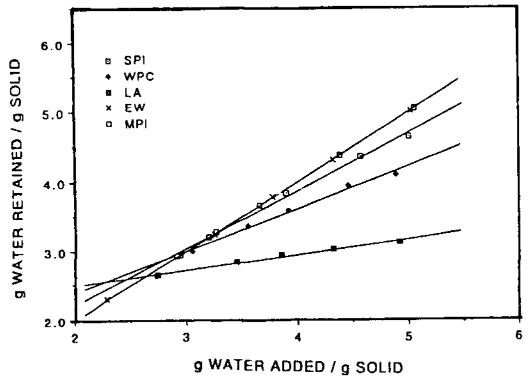

**Fig. 6. Water retention of various nonfish proteins at varying moisture levels. SPI=soy protein isolate, LA=lactoalbumin, EW=egg white, MPI=milk protein isolate, WPC=whey protein concentrate.**

for each protein. EW and MPI showed higher water retention than those of SPI, WPC and LA. The compressive force of SPI, WPC and LA-incorporated surimi gel at the varying moisture levels strongly correlated with the amount of water retained at corresponding moisture level within those protein (r=0.99). A reason for such a strong correlation between compressive force and water retention can be explained by a good correlation between the difference in compressive force of surimi and the difference in amount of water retained (r=0.99). These result support the role of hydrodynamic properties of protein in a given moisture level. The moisture that was not retained by a protein, was available to diluting the protein matrix and weakened the overall gel strength. The extent of gel weakening with respect to the moisture retention somewhat varied with the type of protein used. For instance, despite moisture retention in EW and MPI being higher than SPI, they produced a gel with greater compressive force.

## IV. Conclusion

Protein gelation is achieved through protein-protein interaction at a relatively higher concentration of protein with less amount of water within a critical moisture level. The critical moisture level may imply the index of tolerance for formation of gel, beyond that moisture level, the gel matrix begins to lose its water binding and structural integrity.

The tolerance for water binding in the protein gel system would be varied with the types of protein used. Dilution of protein with water resulted in an exponential decrease in water binding and gel strength of protein.

All nonfish proteins and protein-incorporated surimi gels studied showed moisture-dependent gelation characteristics. Gel strength was decreased with increasing moisture level of protein gel. The critical moisture level for gelation of nonfish protein did not coincide with those of nonfish protein-incorporated surimi gel. The gel strength of nonfish protein-incorporated surimi gel strongly correlated with the amount of water retained by the protein.

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