KOREAN J. SOC. FOOD SCI.
Vol. 10, No. 2, May, 1994

Function of Nonfish Proteins in Surimi-Based Gel Products

Kang Hyun Chung and Chong Min Lee*

*Korea Food Research Institute and *Department of Food Science and Nutrition, University of Rhode Island, Kingston, RI 02881, USA.*

어묵제품에 있어서 단백질 첨가의 기능

정강현 · 이종민*

한국식품개발연구원, *미국 *Rhode Island* 주립대학 식품공학과

요 약

생선 어묵에 대두분리단백질, 난백, 유청단백질, 글르우텐과 같은 단백질들을 첨가하였을 때 그들이 어묵의 조직감을 수사하는 기능이 평가되었다. 단백질들은 어묵의 강도, 경도와 충밀립성을 감소시켰다. 단백질이 첨가된 어묵제품은 관능검사에서 제품의 질김성, 씹힘성 및 경도에 대한 강도는 감소시켜주는 반면 이들에 대한 종합적 기호도는 증가시키는 것으로 나타났다. 첨가제로 사용하였던 단백질 자체로 만든 겔의 강도는 이들 단백질을 첨가하여 만든 어묵의 겔 강도와 역비례 관계를 나타냈으며, 첨가한 단백질들이 어묵의 조직감을 수사하는 기능적 특성은 각 단백질들의 수화능력과 겔화 특성 등에 기인하는 것으로 나타났다.

Abstract

The addition of nonfish protein significantly reduced the strength of nonfish protein-incorporated surimi gel in terms of cohesiveness, rigidity and shear force. The sensory textural properties of fiberized surimi gel product was characterized as the reduction in intensity of undesirable rubberiness, chewiness and firmness, thus increasing the desirability in over all texture. Gel strength of both cohesiveness and rigidity of nonfish protein was inversely correlated with those of nonfish protein-incorporated surimi gel. The variation of texture-modifying properties of nonfish protein in surimi gel was attributed to the differences in thermal hydration and gelation properties of nonfish protein.

I. Introduction

As a result of increasing consumption of surimi-based shellfish analog products, a marked advancement in the surimi technology has been made primarily in the manufacturing of surimi and shellfish analog products.

Texture of the product made with surimi alone tends to be rubbery and less desirable to consummer's taste. Not only to ease the rubberiness but also to allow flexibility in formulation, textural modification of surimi-based product has been attempted. Modification of texture can be achieved not only by a mechanical texturization process, but also by the incorporation of gel-forming ingredients such as starch and protein. Addition of ingredients to the surimi-based product can contribute to the improvement of textural properties as well as economic and nutritional benifits (Lee[1]; Lee and Kim[2]). When nonfish proteins are incorporated into surimi, each protein contributes different functional and textural properties to the surimi gel. Therefore, understanding of the physicochemical properties of nonfish proteins and their interaction with fish protein is important to optimizing the textural properties of the surimi-based products.

There appear to be potential demands for high protein surimi-based products which stemmed from the idea of bringing the protein level of the surimi-based product (11～12%) to that of the natural product (16～17%). This may waive manufacturers an "imitation" labeling requirement according to a recent FDA ruling of "nutrition equivalency". The formulation of a high protein product needs to be developed without reducing the desirable textural quality which is normally found in the ordinary surimi-based product. The objectives of this study were: 1) to understand texture-modifying properties of nonfish proteins in surimi gels, and 2) to determine the relationship between functional properties of nonfish proteins and nonfish protein-incorporated surimi gel.

II. Materials and Methods

1. Preparation of nonfish protein gel

Nonfish proteins evaluated were soy protein isolate (SPI), whey protein concentrate (WPC), lactoalbumin (LA), egg white (frozen raw, EW), milk protein isolate (MPI) and wheat gluten (WG). SPI was obtained from Grain Processing Corporation (Muscatine, Iowa); EW from Hygrade Egg products (Elizabeth, NJ); WPC, LA and MPI from New Zealand Milk Products (Petaluma, LA); and WG from Ogilvie Mills (Minnetonkam, MN). Protein gels were prepared by blending the proteins for 10 min in a silent cutter with addition of 1.5% salt and a proper amount of water to adjust the moisture level to 78%. One portion of paste was stuffed into a 25 mm diameter cellulose casing and the other portion placed into centrifuge tubes. Casings were cooked for 20 min in a steam-cooker.

2. Evaluation of gel texture and water binding ability of nonfish protein

Gel Properties of samples were evaluated by a method reported by Lee[3] using an Instron Testing Machine (Model 1122). Protein contents of the samples were determined by the micro-Kjeldahl method[4]. Water binding ability (WBA) of the nonfish protein was determined by a centrifugation method and expressed in % amount of water retained in the sample. Centrifugation was done for 10 min at 3000g using a Sorvall centrifuge (Model RC 2B) after cooking the paste for 20 min in a steam-cooker while it was in the tube. The water binding ability of nonfish protein during heating was also determined by measuring the amount of moisture expressed from the plug of cooked protein gel (25 mm×25 mm) upon compression and expressed in % moisture retained in the sample.

3. Preparation of surimi gel

The Alaska pollock (*Theragra chalcogramma*) surimi obtained from the Alaska Fisheries Developement Foundation (Anchorage, AK) was used throughout the study. Half-thawed surimi was chopped for 10 min in a silent cutter with addition of 2% salt, 3% nonfish protein and a proper amount of water to adjust the moisture level to 78%. All ingredients were added on a surimi weight basis. The resulting paste was divided into three portions. One Part of the paste was extruded into a sheet (1.5 mm thick, 25 mm wide and 70 mm long) and partially heat-set for 15 min at 50℃ to run a tensile test. The second one was also extruded into a sheet, partially heat-set for 2 min at 110℃ , and fiberized to run sensory evaluation and shear test. The third one was stuffed into a 25 mm diameter cellulose casing. Fiberized and casing-molded samples were cooked for 15 and 20 min, respectively, in a steam-cooker. The fiberized sample was cooled and kept in a refrigerater, while the casing-molded sample was cooled down in the running cold water for 10 min and kept overnight at room temperature prior to the evaluation of the textural properties.

4. Evaluation of textural and water binding properties

Textural Properties of gels were evaluated by the method reported by Lee[3] except for shear test using an Instron Testing Machine. Testing parameters were compressive force at failure (cohesiveness), penetration force (rigidity), and % expressible moisture (water binding ability) for the casing-molded samples; tensile and shear force for the fiberized samples. In the shear test, a fiberized sample was sheared longitudinally by a descending flat blade (1 mm thick) while the sample rested on a stationary plate. Water binding of casing-molded surimi gel was determined by expressible moisture measured by the compression test.

5. Sensory evaluation of fiberized Products

Sensory evaluation of the textural properties of the fiberized surimi gel product was conducted by a groups of 14 panelists. The textural characteristics evaluated were firmness, rubberiness, chewiness, moistness and overall texture acceptability. The panel was composed of graduate students and faculty of the department who had a prior experience in evaluating the quality of surimi gel products. The panelists were asked to score the intensity and desirability of each textural characteristic on a 9-point scale.

6. Analysis of data

Analysis of variance was used to determine the statistical significance of the sample variations in physicochemical properties of nonfish protein. The degree of correlation was determined between functional properties of nonfish protein and nonfish protein incorporated surimi gel.

III. Results and Discussion

The results of the textural evaluation of the nonfish protein-incorporated surimi gel were shown in Table

Table 1. Textural poperties of nonfish potein-incorporated casing-molded surimi gel poducts

Protein Source[1]	Compressive force(kg)	Penetration force(g)	% Expr. moist.	Tensile force(g)
Control	51.0^{a}	390.0^{a}	0.39^{bc}	41.3^{bc}
SPI-1	41.0^{b}	373.0^{a}	0.34^{cd}	43.0^{bc}
SPC-2	35.3^{b}	323.0^{bc}	0.26^{d}	44.3^{abc}
WPC	19.3^{d}	296.7^{cd}	0.33^{cd}	37.0^{c}
LA	21.0^{d}	273.3^{d}	0.48^{ab}	44.7^{abc}
MPI	16.7^{e}	213.3^{d}	0.50^{a}	42.0^{bc}
EW	38.7^{b}	400.0^{a}	0.53^{a}	51.3^{a}
WG	28.7^{c}	360.0^{ab}	0.44^{ab}	48.3^{ab}

*Means with different letters within same column are significantly different($p<0.05$)

1. SPI-1 and 2=soy protein isolate, WPC=whey protein concentrate, LA=lactoalbumin, MPI=milk protein isolate, EW=egg white and WG=wheat gluten.

Table 2. Sensory textural properties and shear force of the nonfish protein-incorporated fiberized surimi gel products

		Textural characteristics			
Protein source	Shear force(g)	Firmness	Chewiness	Rubberiness	Overall texture
Control	933^{a}	7.3^{a}	7.2^{a}	7.0^{a}	
		$(6.0)^{a}$	$(6.0)^{a}$	$(6.0)^{a}$	$(6.0)^{b}$
SPI-1	527^{a}	5.0^{c}	5.6^{b}	6.0^{ab}	
		$(6.7)^{a}$	$(6.3)^{a}$	$(6.7)^{a}$	$(6.7)^{a}$
SPI-2	750^{b}	5.6^{bc}	5.7^{b}	5.3^{b}	
		$(6.7)^{a}$	$(7.0)^{a}$	$(7.0)^{a}$	$(6.9)^{s}$
WPC	417^{e}	6.3^{b}	6.0^{b}	5.7^{ab}	
		$(7.0)^{a}$	$(6.7)^{a}$	$(7.0)^{a}$	$(6.8)^{a}$
LA	550^{d}	5.3^{bc}	5.3^{b}	5.3^{b}	
		$(6.3)^{a}$	$(7.0)^{a}$	$(6.3)^{a}$	$(6.5)^{a}$
MPI	650^{c}	5.5^{bc}	5.5^{b}	5.0^{b}	
		$(7.0)^{a}$	$(7.0)^{a}$	$(6.5)^{a}$	$(6.8)^{a}$
EW	743^{b}	5.6^{bc}	5.7^{b}	5.3^{b}	
		$(7.0)^{a}$	$(7.0)^{a}$	$(6.7)^{a}$	$(6.9)^{a}$
WG	600^{cd}	6.0^{bc}	5.7^{b}	5.3^{b}	
		$(7.0)^{aa}$	$(7.0)^{a}$	$(7.0)^{a}$	$(7.0)^{a}$

*Without parenthesis: intensity With parenthesis: desirability

**Means with different letters within same column are significantly different ($p<0.05$)

1. The control surimi gel exhibited a consistently and significantly higher compressive force (cohesiveness) than those gels with nonfish proteins ($p<0.05$). There was a significant variation in cohesiveness among the nonfish protein-incorporated surimi gels ($p<0.05$). A similar trend was found in the rigidity with exception of EW-containing surmi gel. On the other hand, the tensile force of control surimi gel was lower than that of the nonfish protein-incorporated surimi gel except WPC-containing gel. The higher gel strength shown by the control was attributed to the greater amount of gel-forming myofibrillar proteins in the control surimi gel than those in the nonfish protein-incorporated surimi gel. The decreased gel strength of the nonfish protein-incorporated surimi gel was due to a combination of reduced amount of myofibrillar proteins and the interference of nonfish protein, primarily albumin-type, with formation of cohesive gel matrix (Okada[5]). On the contrary, nonfish proteins tended to increase the tensile force of the fiberized products. It was not clear, however, whether such an increase in tensile force was an indication of stiffness or elasticity. The variation of gel properties among the nonfish protein-incorporated surimi gel was attributed to the differences in physical and functional properties of nonfish proteins (Table 3). Addition of nonfish protein having higher gel strength resulted in formation of a weaker gel. It was reported that such a result was due to a disruptive effect of nonfish protein on the network formation of surimi gel (Lanier[6]). Nonfish proteins react to various treatments in different manners depending on their physicochemical properties such as molecular size and weight, ionic effect, protein concentration, amino acid composition, and chemical bondings involved in gelation (Buttkus[7]; Beveridge et al.[8]).

Table 2 showed the results of the textural evaluation of fiberized products. The shear force of the control surimi gel was significantly greater ($p<0.05$) than all nonfish protein-incorporated surimi gels. The intensity of sensory score of the control showed the same trend as the shear force. The desirability in terms of three textural characteristics and overall texture, on the other hand, showed an opposite trend. The lower score shown by the control was due to a higher intensity, but less desirable sensory score. However, addition of nonfish protein reduced the intensity score and thus increased the desirability score.

In an effort to determine what caused such variations in the textural properties of nonfish protein-incorporated surimi gel, the relationship of the functional properties of nonfish protein to the properties of nonfish protein-incorporated surimi gel was studied. The functional properties studied were water binding ability and gel strength. Woodward and Cotterill[9] and Hermansson[10] claimed that water binding ability of protein is one of the most important factors which control the textural and structural properties of heat-induced protein gel. There was a great deal of variation in water binding ability among proteins, where WPC showed

Table 3. Gel strength and water-binding ability of nonfish protein gels

Protein source	Compressive force (kg)	Penetration force (g)	Water 1 binding (%)	Thermal 2 hydration (%)
SPI-1	0.06^{d}	25.0^{d}	98.3^{d}	100
SPI-2	0.61^{d}	29.0^{d}	97.4^{d}	100
WPC	3.08^{a}	275.0^{a}	76.1^{a}	79
LA	1.2^{c}	107.7^{c}	78.2^{b}	80
EW	1.98^{b}	116.0^{b}	91.27^{c}	100
WG	No failure	108.0^{c}	Trace	60.3

*Means with different letters within same column are significantly different ($p<0.05$)

1. $\left(1-\frac{\text{the amount of water upon compression}}{\text{moisture content of sample}}\right)\times 100$
2. $\left(1-\frac{\text{the amount of water upon centrifugation}}{\text{moisture content of sample}}\right)\times 100$

Table 4. Correlations among the water binding ability, gel strength of nonfish protein and nonfish protein-incorporated surimi gel

1. $r=-0.65$ between thermal hydration (centrifugation) and compressive force of nonfish protein gel (Table 3).
2. $r=0.94$ between water binding based on expressible moisture of nonfish protein by compression (Table 3) and compressive force of nonfish protein-incorporated surimi gel.
3. $r=0.97$ between thermal hydration (Table 3) and compressive force of nonfish protein-incorporated surimi gel, WG excluded (Table 1).
4. $r=-0.68$ for rigidity between nonfish protein-incorporated surimi gel and nonfish protein gel.
5. $r=-0.63$ for cohesiveness between nonfish protein-incorporated surimi gel nonfish protein gel.

the least water binding ability, but with the highest gel strength for both cohesiveness and rigidity (Table 3). Such a low moisture absorption by WPC may have facilitated more protein-protein interaction, resulting in the development of a firmer gel.

Cohesiveness of nonfish protein-incorporated surimi gel was highly correlated with thermal hydration ($r=0.97$, WG excluded), as well as with water binding based on the expressible moisture ($r=0.94$) of nonfish protein gel. This result suggests that both thermal hydration and expressible moisture of nonfish protein are good indices of protein functionality to be related to the textural properties of nonfish protein-incorporated surimi gel. Thermal hydration of nonfish proteins inversely correlated with cohesiveness ($r=-0.65$), rigidity ($r=-0.46$), and % expressible moisture ($r=-0.97$) of nonfish protein gel. In summary , nonfish protein with less thermal hydration and greater expressible moisture produced a stronger nonfish protein gel due to protein interaction, but it made surimi gel weaker when nonfish proteins were incorporated. Unlike cohesiveness, rigidity was poorly correlated with thermal hydration ($r=0.26$) as shown in Table 4. Cohesiveness is the degree of protein binding in the matrix and its value is better considered for the gel forming ability than rigidity value (Lee and chung[11]). This may explain the discrepancy between two correlation coefficients.

The result of protein analysis suggested that water binding ability of nonfish protein was dependent upon its protein content. WPC having 74% protein content showed the least WBA, while SPI having 89% showed the highest WBA. The protein concentration of SPI is higher than that of WPC. It means that SPI has more amount of protein content and thus more water molecules for absorption.

IV. Conclusions

Addition of nonfish protein to the surimi-based products improved the textural properties by reducing the intensity of undesirable rubberiness, chewiness and firmness, thus increasing the desirability of overall texture. The reduction in the intensity of such undesirable textural characteristics resulted in a soft mouthfeel in the surimi gel.

Thermal hydration of nonfish protein inversely correlated with the cohesiveness of nonfish protein gel, but it was moderately correlated with the cohesiveness of nonfish protein-incorporated surimi gel. Gel strength of both cohesiveness and rigidity of nonfish protein gel showed an inverse correlation with those of nonfish protein-incorporated surimi gel. It was concluded that the main cause of variations in the texture-modifying effects of different nonfish proteins was the differences in thermal hydration and gelation properties of nonfish proteins. Therefore, thermal hydration and gelation properties can be effectively used in determining texture-modifying ability of nonfish proteins.

References

1. Lee, C.M.: Surimi manufacturing and fabrication of surimi-based products, *Food Technol.*, 40(3): 115 (1986).
2. Lee, C.M. and Kim, J.M.: Texture and freeze-thaw stability of surimi gel in relation to ingredients and formulation. Proc. of Inter. Symp. on Engineered Sea-

food Including Surimi (R. Martin and R. Collete, Ed) National Fishies Institute, Washingston, DC, p168 (1986).

3. Lee, C.M.: Surimi process technology, *Food Technol.,* **38**(11): 69 (1984).
4. AOAC.: Official Method of Analysis, 12th ed. Assoc. Off. Anal. Chem., Washington, D.C. (1975).
5. Okada, M.: Effect of washing on the jelly forming ability of fish meat, *Bull. Jap. Soc. Sci. Fish.,* **30**: 255 (1964).
6. Lanier, T.C.: Functonal properties of surimi, *Food Technol.,* **40**(3) : 107 (1986).
7. Buttkus, H.: On the nature of the chemical and physical bond which contribute to some structural properties of protein foods: A hypothesis, *J. Food Sci.,* **39**: 484 (1974).
8. Beveridge, S., Ko, S.A.S. and chung, J.K.H.: Firmness of heat induced albumim coagulum, *Poultry Sci.,* **59**: 1229 (1980).
9. Woodward, S.A. and Cotterill, O.J.: Texture and microstructure of heat-formed egg white gel, *J. Food Sci.,* **51**: 333 (1982).
10. Hermasson, A.M.: Functional properties of added proteins correlated with properties of meat system. "Effect of concentration and temperature on water-binding properties of Model Meat Systems." *J. Food Sci.,* **40**: 603 (1975).
11. Lee, C.M. and Chung, K.H.: Textural analysis of surimi gel Properties by compression and Punch tests. paper No. 572 , presented at 47th Annual Meeting of Institute of Food Technologists, Las Vegas, Nevada, June 16-19 (1987).