World Journal of Fish and Marine Sciences 5 (5): 533-539, 2013
ISSN 2078-4589

DOI: 10.5829/idosi.wjfms.2013.05.05.7485

Effect of Medium Temperature Setting on Gelling Characteristics of Surimi from Farmed Common Carp (*Cyprinus carpio*, Linnaeus, 1758)

Shimazamaninejad, Bahare Shabanpour and Ali Shabani

Department of Fishery, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan, Iran

Abstract: Effect of setting time at 25°C on gelation characteristics of surimi from farmed common carp (*Cyprinus carpio*) has examined. For this goal suwari treatments consist of control (surimi sol mixed with salt) and suwari set gels at 25°C for different times (1, 2, 3, 5 and 8 h). Kamaboko treatments consist of cooked sol at 90°C in 20 minutes and cooked and set kamaboko gels (in the same condition with suwari gels). In suwari and kamaboko gels by increasing the time at 25°C the rate of protein solubility has decreased. The rate of water holding capacity and soluble peptides in TCA had no significant difference. Electrophoresis gel pattern shows that the increase of time leads to the decrease of molecule weight of myosin and actin on suwari and kamaboko gels. L* and whiteness values had decreased and gel strength had increased by increasing of the time. The research findings revealed that by increasing the time of setting at 25°C, quality of produced gel improved. The best physicochemical properties had observed in produced gels in medium temperature for 8 hours.

Key words: Common Carp (*Cyprinus carpio*) · Setting · Suwari · Kamaboko

INTRODUCTION

Surimi production is one way to manufacture various food products from the common carp. Surimi is chopped pieces of fish meat without skin and bones that are washed in cold water several steps for blood, inorganic minerals, and some fats separation as well as improving the color and reducing the odor of the product. Surimi is an intermediate product that is primarily used to produce other food products such as sausages, salami and seafood analogs. Gel forming ability, is one of the most important functional properties of surimi that is affected by various factors such as fish species, protein concentration, ionic strength, temperature and heating duration. For gel formation, proteins are partially denatured by medium heat, which results in the opening of the third structure of proteins and forming of long chains without breaking the covalent bonds. Then throughout the re-aggregation process a three-dimensional network is formed and the setting phenomenon occurs which can happen in three different heating durations of low (0-4°C), medium (25°C), and high (35-40°C) temperatures. Setting process contributes to the formation of gels with higher and greater elasticity and water holding capacity. Surimi gel strength can be enhanced by periodic heating of surimi sol below 40°C [1, 2]. Surimi gel production during the setting is closely associated with the cross-linking formation between the myosin heavy chain induced by endogenous trans glutaminase and the Thermal formation of disulfide bonds and non-covalent bonds [3, 4]. The best temperature for setting is different between various species and depends on the thermal stability of myosin; In addition, trans glutaminase is involved in the polymerization of heavy chain myosin. The rate of cross-linking by trans glutaminase mediated primarily depends on the compromise myosin substrate temperature rather than the optimum temperature of TGase [5]. Benjakul *et al*. [6] study on the effect of medium temperature setting on gelling characteristics of surimi from some tropical fish and show that increasing the setting time from 0 to 8h is effective on breaking force and deformation. Tabilo *et al*. [7] research on textural properties of Alaska pollock and pacific whiting surimi and reported that gels set at 20°C/10 minthen cooked at 90°C/ 40min had the most gel strength. Lou and others research on Gel-forming ability of surimi from silver carp (*Ctenopharyngodon idellus*) and expressed that the greatest strength was observed in the

Corresponding Author: Shima Zamaninejad, Department of Fishery, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan, Iran.

set gels at 30 and 40°C/60min and then cooked at 85°C/30min. Gelling properties of white shrimp was investigated at medium and high temperature and it was shown that gels prepared by setting at 25°C exhibited a greater breaking force than those set at 40°C [8].

Freshwater fish is used for surimi production due to the pleasant flavor, light odor, fat and whiteness. In order to diversify the food products derived from farmed carp, it can be turned into value-added and make it ready to used products. The fish surimi is the most important material and surimi gelation is a determinant factor of textural properties for these products. The current research aims at investigating the effects of setting on the properties of farmed carp surimi gelatin in medium temperature.

MATERIALS AND METHODS

Preparation of Surimi and Surimi Gel: To prepare surimi, a number of live farmed carps-with the approximate weight of 600-700 g, the length of 25±3 cm were placed in ice with a ratio of 3:1 to fish, were transported to the laboratory. The beheaded and gutted carp was washed with water and then filleted (only white muscle was used) by hand. Fillets were minced (Bosch, Germany) and minced fish was washed with water below 10°C with a ratio of 3:1 during three10-minutecycles. To prepare the gel the moisture of surimi was adjusted at 80% and 2.5% salt was added. To obtain a homogeneous sol paste, the mixture was chopped for 5 min at 4°C at the temperature below 10°C. The surimi sol was stuffed into laminated polyvinyl iodine casings (2.5cm diameter and 10cm length) and both ends were sealed. Suwari gels were produced by setting surimi sol in water bath (Memmert, Germany) at 25°C for different times (1, 2, 3, 5 and 8 h). After setting for allocated times, the gels was cooled immediately to stop any further action of the heat in the iced water for 60 min. The suwari control treatment was cooled sol. To prepare kamaboko gels, the suwari gels were heated at 90°C for 20 min in a water bath and then cooled. Produced gels were stored at 4°C for 24 hours before analysis.

Water-Holding Capacity: 5 g sample after weighting the filter paper was wrapped and was centrifuged (Eppendorf centrifuge 5810R) at 3000×g for 15 min then paper of the sample was again and it was weighed. Water holding capacity was calculated by the formula [9].

WHC= (M1-M2/M1) ×100
M1= the initial weight, M2= Secondary weight

Solubility studies: 1 g sample with 20 ml of solution including (20 mM Tris-HCl, pH 8.0, containing 1% (w/v) SDS, 8M urea and 2% (v/v) b-ME) was homogenized for 1 min using a homogenizer machine (IKA Labortechnik, Malaysia). The homogenate was heated in boiling water (100°C) for 2 min and was shaken at room temperature for 4 h. The sample was centrifuged at 10,000×g for 30min. 10 ml of proteins in the supernatant was deposited by adding TCA 50% (w/v). The mixture was kept for 18 h at 4°C and then was centrifuged at 10,000×g for 30 min [10]. The protein concentration was determined by Biuret test [11]. The solubility was expressed as percent of the total protein.

Determination of TCA-Soluble Peptides: 3 g of sample was homogenized with 27 ml of 5% TCA (w/v). Homogenate was kept in ice for an hour and then was centrifuged for 5 min at 5000×g. Soluble peptides in the supernatant were measured and described as μmol tyrosine/10 g muscle [12].

SDS-polyacrylamide gel electrophoresis (SDSPAGE): To prepare the protein sample, 27 ml of 5% (w/v) SDS was heated at 85°C and was added to 3g of sample and homogenized for 2 min. homogenate was incubated at 85°C for 1 h. samples were centrifuged at 3500 g for 20 min. The protein concentration was measured according to the method described by Lowry *et al* [13] using bovine serum albumin as standard. Gels protein pattern were analyzed on the SDS-PAGE using the method of Laemmli [14]. SDS-PAGE gel was 10% running gel and 4% stacking gel. After separation, the proteins were fixed and stained with Coomassie BlueR-250.

Gel Strength: Gel length 25 ml was prepared. Breaking force and deformation was measured using a texture analyzer (LFRA 4500, USA) equipped with steel probe with a spherical end with a diameter of 5 ml and 1 ml per second speed [15]. Gel strength was calculated using the following formula;

Gel strength (g.mm) = Breaking force (g) – Breaking distance (mm)

Color: Color variations studies were determined as described by Lu [16] using the Lab Scan XE Hunter Lab colorimeter (Lovibond, CAM-system 500). Average L*, a*, and b* values were determined form the 5 measurements pretreatment. L* value represents blackness (0) to whiteness (100), a* value represents redness (+) or greenness (-) and b* value represents

the yellowness (+) and blueness (-). Whiteness index was calculated according to the formula: Whiteness = (L* - 3b*)

Statistical Analysis: All experiments were performed in three repeats and results were reported as mean± standard deviation. Analysis of variance (ANOVA) was performed and mean comparisons were run by Duncan's multiple range test [17]. Significance was established at $P<0.05$.

RESULTS AND DISCUSSION

Water Holding Capacity: Based on the results indicated in Table 1 suwari gel prepared by incubating the sol at 25°C for 1 h exhibited a significant ($p<0.05$) higher water holding capacity compared to the control treatment. There was a slight increase in the amount of lost water as the setting time was increased, although there was no significant ($p> 0.05$) difference. For kamaboko gels in the same setting time, the amount of lost water was substantially lower than the suwari gels but it had a similar trend with suwari gels which implies a 2-step heating increases the water holding capacity. Many proteins can form gels that are able to hold some water [18]. Factors such as pH, ionic strength, protein concentration, heating time and temperature are effective on the microscopic structure of thermal protein gels [19, 20]. Our results indicate that prolonged setting can decrease the water holding capacity. Stanley and Yada [21] stated that during gel formation by gentle heating, a three-dimensional network stabilizes water both physically and chemically way in the gel structure with minimal leakage. Heating above the temperature required to form a gel or prolonged heating causes water separation and reduces the water holding capacity in some protein gels that results in a coarse structure with large holes. If internal reactions uniformly occur within the protein-protein in the three-dimensional gel network, the gel structure will be dense [22]. Widespread protein aggregation that is associated with more sever local protein reaction, causes the loss of water holding capacity and the increase of Syneresis so that large holes are made in the gel structure during the aggregation. These holes in turn cause an easy leakage.

Protein Solubility: The results of the current study demonstrated that the solubility rate of proteins in suwari and kamaboko gels set in 25°C reduced significantly ($p<0.05$) as the setting time increased (Table 1). Major myofibrillar proteins are only solved in strong ionic buffers [23] and the highest proteins solubility in urea during gel formation in because of H/ hydrophobic bonds and disulfide bounds [10]. The solution used to determine the solubility rate of proteins included SDS, urea and b-mercaptoethanol which lead to the destruction of all bonds except non-disulfide covalent bonds, □-(γ-glutamyl) lysine linkage in particular. Thus solubility reduction indicated an extensive non-disulfide bonds formation as the setting time increased. It is essential to note that internal TGase plays an important part in □-(γ-glutamyl) lysine linkage formation [3] and that non disulfide covalent bonds are the most important contributing factor in matrix gel strength which in turn correlates with solubility reduction. According to the results, kamaboko gels exhibit a lower solubility than suwari gels due to the higher rate of non-disulfide covalent bonds formation in kamaboko gels after setting and increasing of temperature during the cooking time [6].

Table 1: Water holding capacity, protein solubility and TCA-soluble peptides in suwari and kamaboko gels from common carp surimi prepared by setting at 25°C for different times

Gels	Setting time (h)	WHC	Solubility (%)[a]	TCA-soluble peptides (mmol tyrosine/10 g)[a]
Suwari	Control	23.28^{a}±4.12	21.79^{e}±0.03	3.43^{a}±0.01
	1	14.97^{b}±0.06	22.87^{a}±0.01	1.81^{e}±0.60
	2	19.23^{ab}±3.16	22.42^{b}±0.01	2.38^{bc}±0.30
	3	20.29^{ab}±3.20	22.33^{c}±0.01	1.95^{de}±0.04
	5	21.90^{ab}±4.52	22.25^{d}±0.01	2.20^{cd}±0.06
	8	22.93^{a}±4.15	21.75^{e}±0.01	2.58^{b}±0.06
Kamaboko	Control	9.47^{a}±1.71	20.24^{e}±0.02	2.30^{b}±0.19
	1	5.88^{b}±0.83	22.89^{a}±0.02	1.98^{e}±0.24
	2	7.85^{ab}±1.70	22.40^{b}±0.01	2.36^{b}±0.02
	3	8.99^{a}±1.39	20.54^{d}±0.11	1.95^{de}±0.04
	5	10.20^{a}±1.27	21.08^{c}±0.01	2.50^{ab}±0.06
	8	10.45^{a}±1.59	16.67^{f}±0.01	2.62^{a}±0.03

Means with the same superscript letters at the same column are not significantly different ($P < 0.05$)

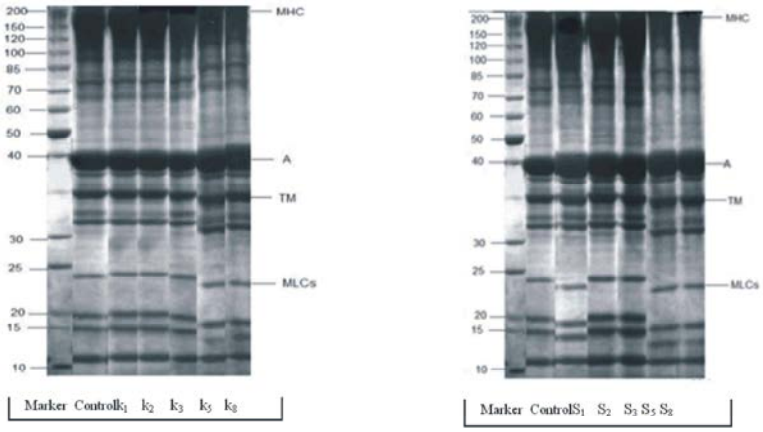

Fig. 1: SDS-PAGE pattern of kamaboko and suwari gels from common carp surimi prepared by setting at 25°C for different times

TCA-Soluble Peptides: The lowest of peptide solutions was observed in suwari and kamaboko gels set in 1h. Although an increasing trend was observed in treatments by increasing the heating time at 25°C, the difference was not significant ($p > 0.05$), which proves that proteolytic degradation occurred at 25°C during setting. The amount of TCA-soluble peptides depends on the differences in proteolytic activity, optimum temperature, and on the type of proteolytic enzyme of surimi [6]. The results indicated that slight protein degradation was observed despite the setting at 25°C that is far less than the required temperature for proteinase thermal activity (Table 1).

Protein Pattern in Suwari and Kamaboko Gels: In suwari gels electrophoresis pattern, heavy chain myosin (MHC) and actin significantly ($p<0.05$) increased in a 1h set gel compared to the control treatment and reached the highest amount. By increasing the setting time, however, MHC and actin decreased (Fig. 1). The same trend was observed in kamaboko gels. Surimi gels were solved for electrophoresis by SDS, urea, β-ME. Therefore all bonds except non-disulfide covalent bonds are destroyed. This indicates that myosin cross-linking forms through slight heating during setting. Slight heating is likely to form an enzyme cross-linking in myosin by deferring the reaction period [24]. This reaction is probably catalyzed by endogenous TGase [4, 2]. The cross-linkings formed by covalent bonds between glutamineγ-carboxamide groups and lysine □-amino groups are also catalyzed by the same enzyme [25]. Nishomoto *et al*. [26] stated that the rate of MHC reduced by increasing the setting time. □-(γ-glutamyl) lysine formation is an indicator of TGase activity and increasing the setting time increased dipeptide content and TGase activity. Gel strength increases after dipeptide content and Tgase activity. Gel strength increases after dipeptide content reaches a certain point and that. □-(γ-glutamyl) lysine bonds formation may cause the formation of bonds with a different morphology that effects gel strength [3]. Nakahara *et al*. [27] indicate that MHC in suwari and kamaboko gels reduced by increasing the setting time at 25°C which proved that MHC underwent a wide range of cross-linking. Carp endogenous TGase polymerizes MHC more than other myofibrillar proteins. According to the results more polymerization of MHC was observed in kamaboko gels than suwari gels in the same setting time. This shows that 2-step heating improves textural properties of surimi [28]. Yongsawatdigul *et al*. [29] reported that in Alaska Pollock surimi improvement of gel quality is associated with increasing the amount of □-(γ-glutamyl) lysine bonds which in turn is caused by MHC polymerization. Slight heating lets proteins have more time to deconstruct and react to each other so that a stronger gel matrix is formed. Polymerization process carries on effectively with the increase of setting time, which reduces MHC and protein solubility.

The results of analyzing color value demonstrated that L* and whiteness values in suwari and kamaboko gels were the highest in 1h set gels and the lowest in control treatments, and that increasing the setting in general time led to a reducing trend among the treatments (Table 2). In suwari and kamaboko gels a* value did not exhibit a significant difference and by increasing the heating time b* value changes also increased. Kamaboko gels indicated higher amounts than suwari gels in the same setting time, which showed that the two-step heating improved surimi gel color properties. Park *et al*. [30] reported that L* value in set gels was significantly

Table 2: Hunter color values (L*, a*, b*) of suwari and kamaboko gels from common carp surimi prepared by setting at 25°C for different times

Gels	Setting time	L*	a*	b*	Whiteness
Suwari	Control	65.90^{g}±0.35	5.13^{a}±0.11	0.40^{d}±0.11	34.48^{g}±0.7
	1	72.91^{a}±0.40	4.30^{ab}±0.22	1.20^{c}±0.52	69.31^{a}±0.45
	2	72.03^{a}±0.11	4.83^{a}±0.46	1.21^{c}±0.43	68.43^{b}±0.74
	3	71.00^{c}±0.55	4.50^{ab}±0.00	2.02^{b}±0.00	64.94^{c}±0.69
	5	70.20^{d}±0.10	4.56^{ab}±0.43	2.05^{b}±0.37	64.05^{c}±0.01
	8	68.86^{e}±0.72	4.30^{ab}±0.15	2.46^{a}±0.31	61.44^{d}±0.45
Kamaboko	Control	71.30^{d}±0.23	4.03^{a}±0.00	1.20^{c}±0.10	68.33^{d}±0.20
	1	80.30^{b}±0.60	3.50^{ab}±0.22	2.00^{b}±0.42	74.30^{b}±0.34
	2	82.60^{a}±0.35	3.50^{ab}±0.46	2.10^{b}±0.41	76.61^{a}±0.75
	3	81.3^{a}±0.77	3.50^{ab}±0.00	2.70^{a}±0.10	73.73^{c}±0.76
	5	77.86^{c}±2.30	2.06^{ab}±0.40	2.72^{a}±0.17	69.70^{d}±0.74
	8	78.40^{c}±0.40	3.63^{a}±0.18	2.74^{a}±0.21	70.18^{d}±0.01

Means with the same superscript letters at the same column are not significantly different (P < 0.05)

Table 3: Puncture test characteristics of tested kamaboko (mean ±standard deviation) from common carp surimi prepared by setting at 25°C for different times

Gels	Setting time	Breaking force (g)	Break distance (mm)	Gel strength (g.mm)
Kamaboko	Control	223	6.83	1524.19^{f}±0.99
	1	245	7.41	1818.46^{e}±1.05
	2	245	7.43	1818.51^{d}±0.94
	3	259	7.53	1956.20^{c}±1.45
	5	263	7.56	19.94.08b±1.06
	8	264	7.60	2006.17a±1.023

Means with the same superscript letters at the same column are not significantly different (P < 0.05)

higher than that in gels not undergoing the setting process. Park and others [31] indicated that thermal process conditions influenced not only the survival of micro organisms but also the color and texture of surimi gels. The results of this study confirmed the fact that by increasing the setting time in medium temperature, the prolonged setting reduced L* and whiteness values. Shie and others [32] studied the physical properties of seafood surimi under different heating conditions and stated that no change was observed in a*value amount in different heating conditions but heating time and temperature effected b* value and that prolonged heating time and high temperature significantly increased b* value.

Gel Properties of Surimi Gels as Affected by Medium Temperature Setting: The major mechanisms in gel formation include the consistency of protein- protein reactions and the increase of TGase activity which facilitates the covalent bonds formation among polypeptides [33, 34]. In this mechanism, gel network is highly influenced by heating time and temperature [24]. Based on the results of this study, on suwari gels due to being too weak and soft, gel strength could be measured, on kamaboko gels, gel strength increased by prolonged setting time in medium temperature and the control treatment had the lowest gel strength (Table 3).Numakura *et al*. [35] found out that kamaboko gel strength of Alaska Pollock increased by the prolonged setting time at 20°C and 30°C and that gel properties improved due to the polymerization of MHC induced by TGase. The fact that the set and cooked gels had much higher gel strength than the merely cooked gels proved pre-formed gel network is more strengthened by setting and protein- protein bonds are stabilized during cooking [36]. Niwa *et al*. [22] demonstrated setting increased viscoelasticity of a set and cooked gel by extending the network structure. The three dimensional network is stabilized during the setting by protein molecules of tale bonds Through Hydrophobic reactions [37].

CONCLUSION

According to the results of the current research set gels exhibited better physical and chemical strength and properties than gels that do not undergo the setting process. It was also concluded that two-step heating gels proved to have a stronger gel formation properties. At 25°C by increasing the setting time gel properties improved and the highest quality gel was found in the set gels at 25°C for 8 hours.

REFRENCES

1. An, H., M.Y. Peters and T.A. Seymour, 1996. Roles of endogenous enzymes in surimi gelation. Journal of Food Science and Technology, 7: 321-326.
2. Kimura, I.M., M. Sugimoto, K. Toyoda, N. Seki, K. Arai and T. Fujita, 1991. A study on the cross-links reaction of myosin in kamaboko ''suwari'' gels. Journal of Food Biochemistry, 57: 1386-1396.
3. Kamazawa, Y., K. Nakanishi, H. Yasueda and M. Motoki, 1995. Suppression of surimi setting by transglutaminase inhibitors. Journal of Food Science, 60: 715-717.
4. Seki, N., H. Uno, N.H. Lee, I. Kimura, K. Toyoda, T. Fujita and K. Arai, 1990. Transglutaminase activity in Alaska pollock muscle and surimi, and its reaction with myosin B. Journal of Food Chemistry, 56: 125-132.
5. Kamath, G.G., T.C. Lanier, E.A. Foegeding and D.D. Hamann, 1992. Nondisulfide covalent cross-linking of myosin heavy chain in ''setting'' of Alaska pollock and Atlantic croaker surimi. Journal of Food Biochemistry, 16: 151-172.
6. Benjakul, S., W. Visessanguan and C. Chantarasuwan, 2003. Effect of medium temperature setting on gelling characteristic of surimi from some tropical fishes. Journal of Food Chemistry, 82: 567-574.
7. Tabilo, G. and V. Gustavo, 2004. Color and textural parameters of pressurized and heat-treated surimi gels as affected by potato starch and egg white. Journal of Food Research, 37: 767-775.
8. Tammatinna, A., S. Bengakul, W. Visessanguan and M. Tanaka, 2006. Gelling properties of white shrimp meat as influenced by setting condition and microbial transglutaminase. Journal of Food Science, 40: 1489-1497.
9. Himonides, A., K.A. Taylor and M.J. Knowles, 1999. The improved whitening of cod and haddock flaps using hydrogen peroxide. Journal of the Science of Food and Agriculture, 79: 845-850.
10. Chawla, S.P., V. Venugopol and P.M. Nair, 1996. Gelation of proteins from washed muscle of threadfin bream (*Nemipterus japonicas*) under mild acidic conditions. Journal of Food Science, 54: 362-366.
11. Robinson, H.W. and C.G. Hodgen, 1940 . The biuret reaction in the determination of serum protein. I. A study of the condition necessary for the production of the stable color which bears a quantitative relationship to the protein concentration. Journal of Biological Chemistry, 135: 707-725.
12. Morrissey, M.T., J.W. Wu, D. Lin and H. An, 1993. Protease inhibitor effects on torsion measurements and autolysis of Pacific whiting surimi. Journal of Food Science, 58: 1054-1059.
13. Lowry, O.H., N.J. Rosebrough, A.L. Fan and R.J. Randall, 1951. Protein measurement with Folin phenol reagent. Journal of Biological Chemistry, 193: 256-275.
14. Laemmli, U.K., 1970. Cleavage of structural proteins during the assembly of head of bacteriophage T4. Journal of Food Science, 227: 680-685.
15. Jafarpour, A. and E.M. Gorczyc, 2008. Characteristics of sarcoplasmic proteins and their interaction with surimi and kamaboko gel. Journal of Food Science, Engineering and Technology, 91: 750-841.
16. Lou, Y.K., D.D. Pan and B. Ji, 2004. Gel properties of surimi gel from bighead carp: Influence of setting and soy protein isolate. Journal of Food Science, 69: 374-378.
17. Steel, R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics; a biometrical approach (2nd Ed.). New York: McGraw Hill
18. Hermansson, A.M., 1986. Water and fat-holding. In: Mitchell JR, Ledward DA, editors. Functional properties of food macromolecules. London: Elsevier Applied Science Publishers, pp: 273-314.
19. Offer, G. and J. Trinick, 1983. On the mechanism of water holding in meat. Journal of Meat Science, 8: 245-81.
20. Schmidt, R.H., 1981. Gelation and coagulation. In: Cherry JP, editor. Protein functionality in foods. Washington, D.C.: American Chemical Society, ACS Symposium Series 147: 131-47.
21. Stanley, D.W. and R.Y. Yada, 1992. Physical consequences of thermal reactions in food protein systems. In: Schwartzberg HG, Hartel RW, editors. Physical chemistry of foods. New York: Marcel Dekker, pp: 669-733.
22. Niwa, E. and C. Lanier, 1992. Chemistry of surimi gelation. Journal of Surimi Technology, 78: 389-428.
23. Suzuki, T., 1981. Fish and krill protein: processing technology. Essex, England: Applied Science Publishers Ltd.
24. Yongsawatdigul, J. and J. Park, 1996. Liner heating rate affects gelation of Alaska pollock and pacific whiting surimi. Journal of Food Science, 61: 149-153.
25. Folk, J.E. and S.I. Chung, 1983. Molecular and catalytic properties of transglutamase. Journal of Advance in Enzymology, 38: 109-191.

26. Nishimoto, S., A. Hashimoto, N. Seki, I. Kimura, K. Toyoda, T. Fujita and K. Arai, 1987. Influencing factors on changes in myosin heavy chain and jelly strength of salted meat paste from Alaska Pollock during setting. Nippon Suisan Gakkaishi, 53: 2011-2020.
27. Numakura, T., N. Seki, I. Kimura, K. Toyoda, T. Fugita, K. Takama and K. Arai, 1985. Cross-linking reaction of myosin in the fish paste during setting (suwari). Journal of Scientific Fisheries, 51: 1559-1565.
28. Montejano, J.G., D.D. Hamann and T.C. Lanier, 1984. Thermally induced gelation of selected comminuted muscle systems: Rheological changes during processing, final strengths and microstructure. J. Food Sci., 49: 1496-1505.
29. Yongsawatdigul, J., A. Worratao and J.W. Park, 2003. Effect of endogenous transglutaminase on threadfin bream surimi gelation. Journal of Food Science, 67: 3258-3263.
30. Park, J.W., 1995. Surimi gel colors as affected by moisture content and physical conditions. Journal of. Food Science, 60: 15-18.
31. Park, J.W., J. Yongsawatdigul and T.M. Lin, 1994. Rheological behavior and potential cross-linking of Pacific whiting surimi gel. Journal of. Food Science. 59: 773-776.
32. Shie, J.S. and J.W. Park, 1999. Physical characteristics of surimi seafood as affected by thermal processing conditions. Journal of Food Science, 64: 287-290.
33. Joseph, D., T.C. Lanier and D.D. Hamann, 1994. Temperature and pH affect transglutaminase catalyzed “setting” of crude fish actomyosin. Journal of Food Science, 59: 1018-1023.
34. Wu, M.C., T.C. Lanier and D.D. Hamann, 1991. Rigidity and viscosity changes of croaker actomyosin during thermal gelation. Journal of Food Science, 50: 14-19.
35. Numakura, T., N. Seki, I. Kimura, K. Toyoda, T. Fujita, K. Takama and K. Arai, 1999. Cross-linking reaction of myosin in the fish paste during setting (suwari). Nippon Suisan Gakkaishi, 53: 633-639.
36. Alvarez, C., I. Couso and M. Tejada, 1999. Thermal gel degradation (Modori) in sardine surimi gels. Journal of Food Science, 64: 633-637.
37. Stone, A.P. and D.W. Stanley, 1992. Mechanisms of fish muscle gelation. Journal of Food Research, 25: 381-388.