CHAPTER 3

RHEOLOGICAL AND TEXTURAL PROPERTIES OF PACIFIC WHITING SURIMI GELS AS INFLUENCED BY CHICKEN PLASMA PROTEIN

3.1 Abstract

Rheological and textural properties of Pacific whiting surimi in the absence and presence of chicken plasma protein (CPP) at different levels (0.3-3%, w/w) were studied by dynamic rheological and torsion measurements, respectively. The surimi paste exhibited two major distinctive rheological transitions during heating from 20 to 90°C with the peaks observed at 33 and 56°C. The abrupt loss of G' upon heating from 47 to 57°C and the occurrence of small peak of phase angle at the same temperature range were prevented by the addition of CPP. Nevertheless, the final G' of the surimi paste added with CPP was lower than that of the control. Shear stress of both kamaboko and modori gels increased as the CPP levels increased, while shear strain increased with the addition of CPP up to 2% (P<0.05). CPP inhibited the degradation of myosin heavy chains (MHC) caused by endogenous proteinases as indicated by more retained MHC and lowered TCA-soluble peptide content. However, whiteness of resulting gels decreased with increasing CPP levels. Therefore, CPP can be a potential protein additive for Pacific whiting surimi.

3.2 Introduction

Thermal gelation of muscle protein is a dynamic process which involves protein unfolding and aggregation prior to the formation of three-dimensional network structures. During gelation, myofibrillar proteins exhibited the complex rheological changes, depending on temperatures, protein concentration, pH and ionic conditions (Xiong, 1993). When myofibrillar proteins are heated at a constant rate, they usually show transitions in shear modulus development. Rheological parameter is therefore used to monitor the gel network development during thermal gelation of proteins.

Stress/strain tests are normally implemented in studying the behavior of food gels and can be categorized as two types, large strain testing and small strain testing.

Large strain testing often yields information that correlates with sensory evaluation (Hamann and MacDonald, 1992). Small strain testing is often performed for monitoring sol-gel transition and for characterizing the viscoelastic behavior of gels, though it has not been shown to highly correlate with sensory texture or rupture strength by other large strain rigidity tests (Hamann, 1988; Tabilo-Munizaga and Barbosa-Canovas, 2005). This method is suitable to study the alteration of gelation properties caused by proteolysis or affected by the addition of protein additives (Lin and Xiong, 1997). Rheological characteristics of the gel are described by three parameters; the storage modulus (G') and loss modulus (G'') are the measures of elasticity and viscosity of the gel samples, respectively. Tan δ (the ratio of G''/G') reflects the relative contribution of each to the overall rheological characteristics (Xiong, 1997).

Pacific whiting surimi represented approximately 20% of surimi production in the United States (Guenneugues and Morrissey, 2004). High proteolytic activity occurs in Pacific whiting muscle and continues after the flesh has been processed into surimi. It results in the failure of gel forming ability (Chang-Lee et al., 1989). A rapid breakdown of the myofibrillar protein inhibits the development of a three-dimensional gel network during heating of surimi based products. To improve the physical properties of surimi gels, rapid heating methods and/or non-muscle protein additives have been used. Beef plasma protein (BPP) is the most active inhibitors in whiting surimi and is commonly used at about 1% concentration (Morrissey et al., 1993). Seymour et al. (1997) reported that the gel enhancing ability of Pacific whiting surimi by BPP was due to the combined effects of proteolytic inhibition by α_2-macroglobulin (α_2M), covalent cross-linking by transglutaminase (TGase) and gel formation by bovine serum albumin or fibrinogen. Benjakul and Visessanguan (2000) reported that pig plasma protein (PPP) showed higher inhibitory activity than BPP or egg white against Pacific whiting proteinase. Recently, the addition of chicken plasma protein (CPP) was found to increase the strength of surimi gels from bigeye snapper (Rawdkuen et al., 2004a). Such gel strengthening was attributed to its proteinase inhibitory activity. However, the use of CPP in Pacific whiting surimi struggling with high proteolysis at the activated temperature has not been studied. The purpose of this study was to investigate the effect of CPP on the rheological and textural properties of Pacific whiting surimi during heat-induced gelation.

3.3 Materials and Methods

Chemicals and Surimi

Sodium chloride and trichloroacetic acid were purchased from Fisher Scientific (Pittsburgh, PA, USA). Bovine serum albumin (BSA) and *L*-tyrosine were procured from Sigma-Aldrich, Inc. (St. Louis, MO, USA). Sodium dodecyl sulfate (SDS) was obtained from Bio-Rad Laboratories (Hercules, CA, USA). Novex pre-cast gels and other electrophoresis reagents were purchased from Invitrogen life technologies (Carlsbad, CA, USA). Frozen surimi grade FA produced from Pacific whiting (*Merluccius productus*) was obtained from Trident Seafoods Corp. (Seattle, WA, USA) and kept at -25°C until used.

Preparation of chicken plasma protein

Chicken blood was obtained from a slaughterhouse in Hat Yai, Thailand. During collection, one-tenth volume of 3.8% (w/v) trisodium citrate was added to prevent coagulation. The blood was centrifuged twice at 1,500g for 15 min at 4°C using a Sorvall Model RC-B Plus centrifuge (Newtown, CT, USA). The supernatant was then freeze-dried and kept at -18°C until used.

Preparation of surimi paste and gel

Frozen surimi was partially thawed at 4°C for 2-3 h, cut into small pieces and chopped in a Cuisinart mixer (Cuisinart original food processor, East Windsor, NJ, USA) for 4 min with 2.5% (w/w) NaCl. CPP at different levels (0, 0.3, 0.5, 1, 2 and 3%, w/w) was added. The moisture content of surimi paste was adjusted to 80% by the addition of iced water. The paste was stuffed into stainless steel tubes with a diameter of 1.9 cm and then incubated at 55°C for 30 min, followed by heating at 90°C for 20 min in a Magni Whirl constant temperature bath (Blue M electrical company, Blue Island, IL, USA). This sample was referred to as "modori gel". Kamaboko gel was prepared by incubating the paste at 40°C for 30 min prior to heating at 90°C for 20 min. A directly

cooked gel was heated at 90°C for 20 min. After heating, all gels were immediately cooled in iced water for 30 min. The samples were removed from tubes after cooling, placed in plastic bags and kept in a refrigerator overnight prior to analysis.

Dynamic test

Rheological changes of surimi paste during gelation were continuously measured using a ATS Rheosystem Stree Tech rheometer (Stresstech, Rheologica instruments AB, Lund, Sweden). The rheometer was equipped with 40-mm, 4 degrees slope cone and plate geometry. An oscillation of 0.1 Hz with a resistance stress of 35 Pa was used for testing. This condition was determined to give a linear response in the viscoelastic region. Temperature sweeps were recorded from 20 to 90°C at a rate of 1°C/min. To avoid evaporation of the sample during heating, a lubricant and cover were used. The elastic modulus (G'), viscous modulus (G'') and phase angle were recorded. The testing was performed in duplicate.

Torsion test

After being equilibrated at 4°C overnight, gel samples were allowed to reach room temperature, and subsequently cut into the length of about 3 cm. The prepared samples were attached to mounting discs at each flat end with cyanoacrylate glue. To obtain the dumbbell-shaped samples, the gels were milled to 1 cm diameter using a milling machine (Gel Consultants Inc., Raleigh, NC, USA). For testing, 7 milled samples were vertically mounted and twisted to the point of fracture at 2.5 rpm on a Hamann Torsion Gelometer (Gel Consultants Inc., Raleigh, NC, USA). Stress (kPa) and strain (dimensionless) at fracture were calculated with the manufacturer's software for each sample, corresponding to the strength and deformability of the gels, respectively.

Whiteness measurement

Five samples from each treatment were subjected to whiteness measurement using a Chroma Meter CR-300 (Minolta Camera Co., Ltd., Osaka, Japan). CIE L^* (lightness, 0-100), a^* (red/green; "+" being toward the red and "-" being toward the

green) and b* (yellow/blue; "+" being toward the yellow and "-" being toward the blue) values were measured. Whiteness index was calculated using the following equation (Park, 1994):

$$\text{Whiteness} = 100 - [(100-L^{*})^{2} + a^{*2} + b^{*2}]^{1/2}$$

Determination of autolysis in surimi gel

To 2 g of finely chopped gel samples, 18 ml of 5% TCA were added and homogenized for 2 min using a Sorvall OMNI-MIXER (Ivan Sorvall Inc, Norwalk, CONN, USA) at the speed of 1. The homogenate was incubated at 4°C for 1 h and centrifuged at 5,000g for 5 min. TCA-soluble peptides in the supernatant were measured using the Lowry method (Lowry et $al.$, 1951) and expressed as μmole tyrosine/g sample (Morrissey et $al.$, 1993).

SDS-PAGE

The samples obtained from dynamic and torsion tests were subjected to SDS-PAGE analysis according to the method of Laemmli (1970). To 2 g of sample, 18 ml of 5% (w/v) SDS solution was added. The mixture was then homogenized using a Sorvall OMNI-MIXER (Ivan Sorvall Inc, Norwalk, CONN, USA) at a speed of 1 for 1 min. The homogenates were incubated at 85°C in a water bath for 1 h to dissolve total proteins. Solubilized samples were mixed at 1:1 (v/v) ratio with the Novex tris-glycine SDS sample buffer in the presence of reducing agent and boiled for 3 min. The samples (20 μg protein) were loaded into Novex 10% tris-glycine pre-cast gel and subjected to electrophoresis at a current constant of 30 mA/gel using a Xcell $SureLock^{TM}$ Mini-Cell (Novex, San Diego, CA, USA). After separation, the proteins were stained with SimplyBlue^{TM} SafeStain for 3 h. and destained with water. The gel was dried overnight with Gel-Dry^{TM} drying solution.

Statistical analysis

Data were subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan's multiple-range test. Analysis was performed using a SPSS package (SPSS 10.0 for windows, SPSS Inc, Chicago, IL).

3.4 Results and Discussion

Effect of chicken plasma protein on rheological property of Pacific whiting surimi

Changes in storage modulus (G') and loss modulus (G'') of Pacific whiting surimi paste during transition from sol to gel as a function of temperature are presented in Figure 7. The first small peak of G' appeared at approximately 23°C and G' slightly declined to reach the minimum value at 29°C. Those changes might be owing to the partial denaturation of muscle proteins. The differences in magnitude of G' were observed when different concentrations of CPP were added. Ogawa *et al.* (1995) reported that a small drop of G' value starting at 25°C indicated the unfolding of α-helix of myosin molecules in the tail portion. G' substantially increased at 30°C and showed the highest peak at 33°C. Subsequently, G' decreased until the temperature reached 41°C. However, the rate of decrease was lowered when the concentration of CPP increased. The sharp increase in G' at the first transition indicated that myofibrillar protein in surimi started to form a gel network. Ziegler and Acton (1984) reported that heating natural actomyosin at temperature less than 40°C generally resulted in the dissociation of some myofibrillar components, for example tropomyosin from the F-actin backbone and F-actin from its super helix structure. Egelandsdal *et al.* (1986) reported that initial increase of G' was attributed to the cross-linking of myosin. Without the CPP addition, the shoulder was observed at the temperature range of 41-47°C and then markedly decreased to the minimum value at 56°C. On the other hand, the sample added with CPP had no abrupt loss of G' value in this temperature range. The lowest of G' value in surimi paste without CPP at the temperature of 56°C was most likely due to the modori phenomenon caused by proteolytic activity in Pacific whiting. The dissociation of actin-myosin complex and the

denaturation of light meromyosin led to an increased fluidity (Egelandsdal *et al.*, 1986). The unfolding of myosin probably caused an increase in fluidity of the semi-gel structure and might disrupt some protein gel networks already formed in the early stage, resulting in a decrease in G′ value (Xiong, 1997). The G′ value increased sharply in the control sample (without CPP) after modori phenomenon and reached a value of 2,970 Pa at the end of testing.
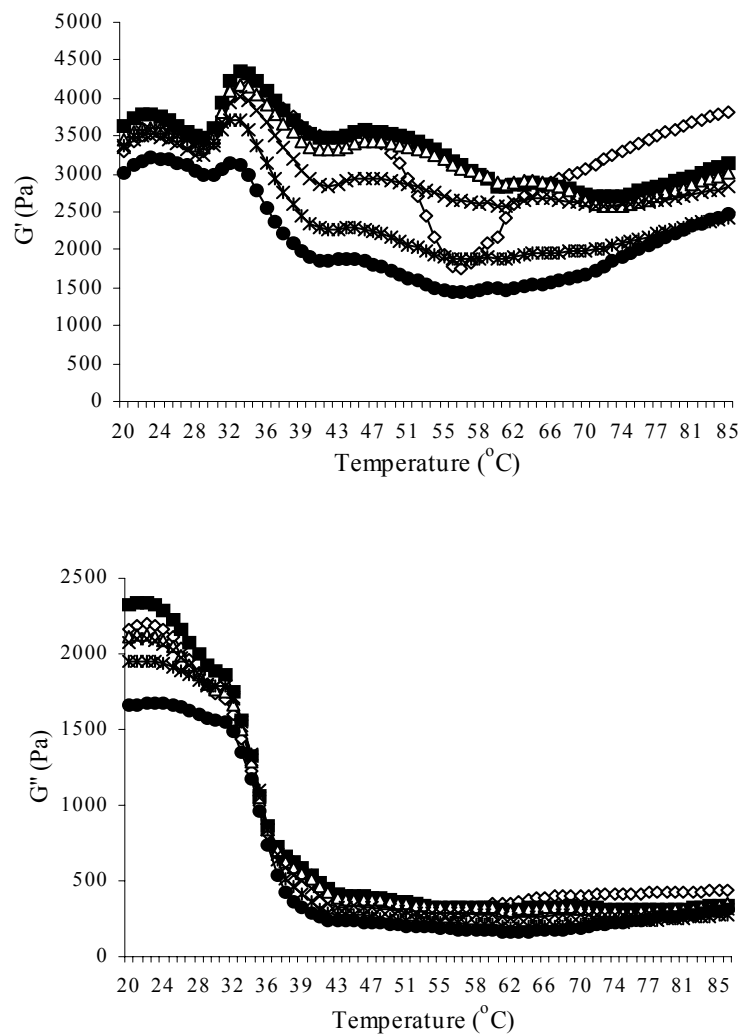

Figure 7. Effect of chicken plasma protein on changes in storage modulus (G′) and loss modulus (G″) of Pacific whiting surimi paste heated from 20 to 90°C at a rate of 1°C/min. 0 (◇), 0.3 (■), 0.5 (△), 1 (×), 2 (∗), 3% CPP (●).

For the samples added with CPP, a slight increase in G' was observed and the final values were lower than that of the control. Sample added with 2 and 3% CPP showed the lowest value. Egelandsdal et al. (1986) suggested that the increase in G' after 47°C probably attributed to the formation of irreversible gel networks. When muscle proteins at high ionic strength were heated, actomyosin started to unfold and interact with water, consequently exhibiting the viscous nature of the paste. As temperature continuously increased, unfolded actomyosin entangled and formed gel networks as evidenced by an increase of G' at temperature greater than 55°C. After the gels were cooled down to 25°C, no differences in G' were obtained between the sample added with 0.3 and 3% CPP (data not shown). From the results, a lower G' was obtained when higher CPP contents were used, indicating the dilution effect of muscle proteins by CPP addition. Visessanguan et al. (2000) also reported that lower gel modulus was obtained with actomyosin added with high level of PPP.

The changes in G'' of Pacific whiting surimi during heat-induced gelation were also monitored (Figure 7). G'' value is a measure of the deformation energy used up in the sample during the shear and lost to the sample afterwards, representing the viscous behavior of a sample (Tabilo-Munizaga and Barbosa-Canovas, 2005). At the beginning, the lowest G'' was obtained in the sample added with 3% CPP, while the highest value was found with sample added with 0.3% CPP. The gradual decrease in G'' of the samples added with CPP was observed in the temperature ranges of $20-32^{\circ}$C. Thereafter, the marked decrease in G'' value was observed in all samples tested in the temperature ranges of $32-43^{\circ}$C. At the temperature higher than 45°C, no changes in G'' were observed. At the end of testing, the control sample showed a slightly higher G'', compared with those added with CPP.

The changes in phase angle of Pacific whiting surimi corresponded to those of G'' (Figure 8). The transition from sol to gel can be monitored by the changes in phase angle. Starting surimi paste exhibited a viscous material as indicated by the phase angle value of 31°. The phase angle of these samples gradually decreased at temperature ranges of $20-29^{\circ}$C and sharply decreased from 28° to 7° when heating from 30 to 43°C, indicating the formation of an elastic material. No marked changes in phase angle of all samples were observed in the temperatures ranging from 43°C to the end of testing.

However, a small peak was observed at the temperature ranges of $53-62^\circ$C in the control sample, which was coincidental with the sharp decrease in G' caused by the extensive degradation. The increase in phase angle of the control sample at $53-62^\circ$C suggested the more fluidity of samples caused by the hydrolysis. No changes in phase angle in samples added with CPP were observed, indicating the effective inhibition of proteolysis by CPP added.
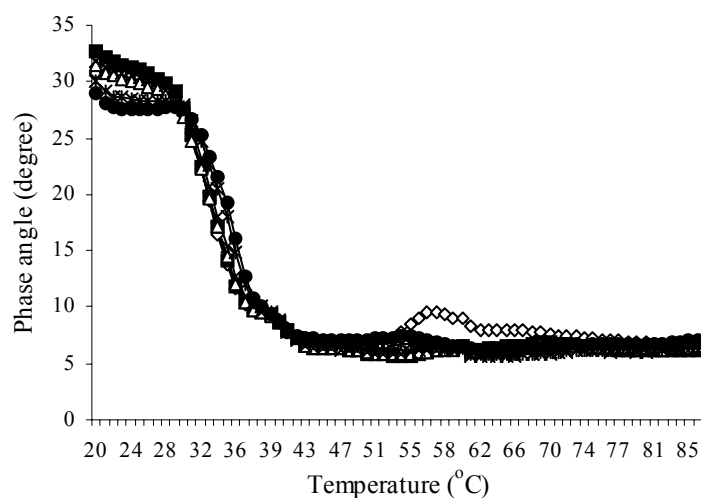

Figure 8. Effect of chicken plasma protein on changes in phase angle of Pacific whiting surimi paste heated from 20 to 90°C at a rate of 1°C/min. 0 ($\diamond$), 0.3 (■), 0.5 (∆), 1 ($\times$), 2 ($*$), 3% CPP (●).

SDS-PAGE pattern revealed that the degradation of myosin heavy chains (MHC) of surimi paste was inhibited when CPP was added, while MHC was totally disappeared for the control sample (without CPP) (Figure 9). MHC band intensity of Pacific whiting surimi gel increased as the CPP concentration increased. The addition of CPP at a level of 3% almost completely recovered the MHC during gelation of Pacific whiting surimi with the heating rate of 1°C/min from 20 to 90°C. Actin was also degraded to a high extent when the samples were heated in the absence of CPP from 20 to 90°C. When MHC was completely hydrolyzed, actin became the substrate susceptible to proteolysis. Therefore, the inhibition of MHC proteolysis by CPP might be associated with

the rheological property of surimi paste, which was most likely determined by the chain length of proteins.
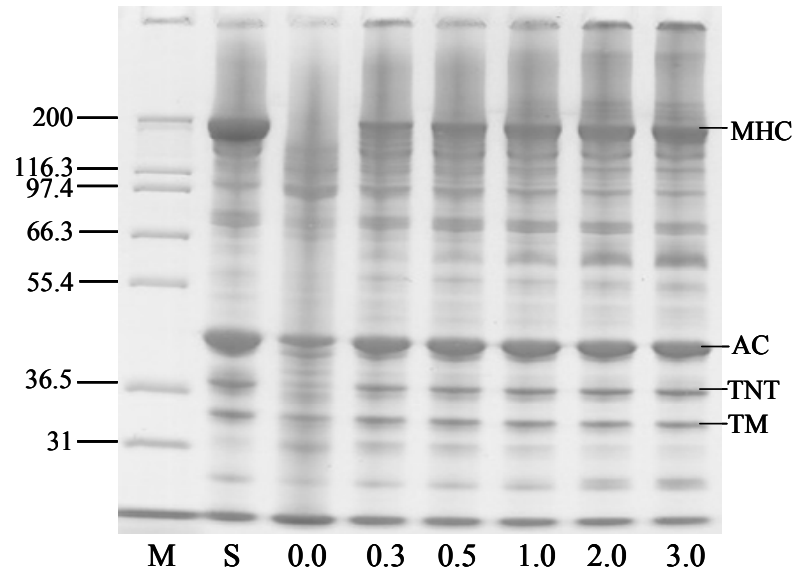

Figure 9. SDS-PAGE pattern of Pacific whiting surimi paste added with chicken plasma protein at different levels induced by linear heating from 20 to 90°C at a rate of 1°C/min. M: protein marker, S: surimi, MHC: myosin heavy chain, AC: Actin, TNT: troponin-T, TM: tropomyosin.

Effect of chicken plasma protein on textural property and whiteness of Pacific whiting surimi gel

Shear stress and shear strain of modori and kamaboko gels from Pacific whiting surimi in the presence and absence of CPP are shown in Figure 10. Shear stress of both kamaboko and modori gels from Pacific whiting surimi increased as the CPP concentration increased up to 3% (w/w) (P<0.05). The control modori gel was too weak to determine the shear stress and strain. No difference in shear stress was obtained in the control kamaboko gel and the kamaboko gel added with 0.3% CPP. With the addition of 3% CPP, the shear stress of kamaboko and modori gels increased by 3 and 27 times, respectively, compared with their corresponding controls. Reppond and Babbitt (1993) showed that addition of 2% (w/w) BPP increased the strength of arrowtooth flounder gels. Morrissey et al. (1993) also reported that BPP at a concentration as low as 1% (w/w) showed the strongest inhibition towards proteolysis and caused the increased gel strength of

Pacific whiting surimi. Proteolysis can be retarded to different degrees, depending on the protein additives used. Benjakul and Visessanguan (2000) found that PPP showed higher inhibitory activity than BPP or egg white against Pacific whiting proteinase at the same level tested. Porcine blood plasma consists of several types of proteinase inhibitors (Karlsrud et al., 1996). When comparing shear stress between directly heated gels and the control kamaboko gel, the latter was 1.2 times higher. This was possibly due to the setting phenomenon in kamaboko gel. TGase has been reported to induce the formation of ε-(γ-glutamyl) lysine linkage during setting (Wan et al. 1994; Tsukamasa et al., 2002;). This endogenous enzyme is responsible for gelation of surimi paste at low temperature (5 to 40°C) termed "setting" (Benjakul and Visessanguan, 2003).

The slight increase in shear strain was observed when the CPP added increase up to 1%. No changes were observed when higher levels were added. Shear strain of kamaboko and modori gels added with 1% and 2% increased by 1.44, 1.45 and 2.37, 2.33 times, compared with the corresponding controls, respectively. Shear strain of kamaboko gels of Pacific whiting surimi was also higher than that of the directly heated gels. Slight decreases in shear strain of both modori and kamaboko gels were observed when CPP at a level of 3% was added. It was possibly caused by the lower content of myofibrillar proteins as affected by the addition of CPP at the high content. From the results, the addition of CPP to prevent proteolysis in combination with a setting was thus an effective means to improve the gel-forming ability of surimi from Pacific whiting.

Though the addition of CPP resulted in the increase in stress and strain of resulting gels, the lowered final G' was observed when the surimi paste was added with CPP, especially with the higher amount (Figure 7). Liu and Xiong (1997) mentioned that the gel strength data did not necessarily agree with the finding of the final G' in dynamic rheological measurements. The final G' is the measurement of elasticity of myofibrillar gels when the sample is still hot, while gel strength is determined after the formed gel is cooled down. Also, dynamic rheological measurement is non-destructive, whereas gel penetration force measurement is destructive. Both measurements represent different aspects between the rheological profile of protein and textural property of gels and hence both may not be simply related.
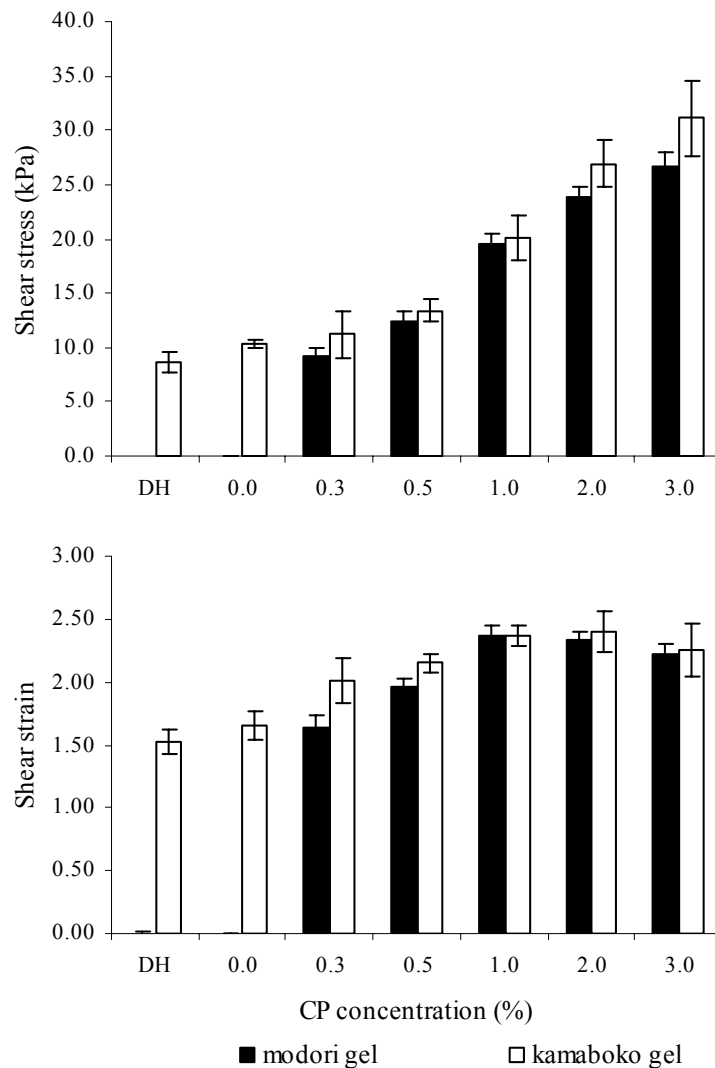
Figure 10. Effect of chicken plasma protein on the textural properties of Pacific whiting surimi gels. DH: directly heated gel prepared by heating the sol at 90°C for 20 min. Modori and kamaboko gels with various levels of chicken plasma protein were prepared by incubating the sol at 55°C and 40°C for 30 min, respectively, prior to heating at 90°C for 20 min. Bars represent the standard deviation from five determinations.

The whiteness of both kamaboko and modori gels decreased when CPP was added, especially at higher CPP concentrations ($P<0.05$) (Figure 11). With the addition of 3% (w/w) CPP, whiteness of kamaboko and modori gel decreased by 16.37 and 16.28%, respectively, compared with that of kamaboko and modori gels without CPP. This result was in accordance with Benjakul *et al.* (2001c) who reported that the increase in PPP

amount added resulted in the decreased whiteness of surimi gels. The whiteness of directly heated gels was slightly lower than that of kamaboko or modori gels ($P<0.05$). With the incubation at 40 or 55°C for 30 min, the pigments could undergo the denaturation to some extent. Denaturation of pigment could be more pronounced with the subsequent heating. The plasma proteins contained some hemoglobin as well as other pigments with a pale straw color (Benjakul *et al.*, 2001c). These pigments possibly reduced the whiteness of resulting gels.
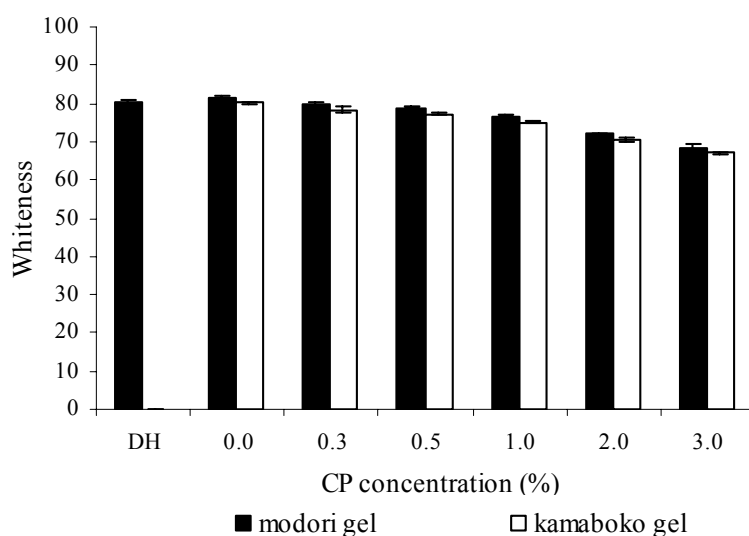

Figure 11. Whiteness of surimi gels from Pacific whiting added with various levels of chicken plasma protein. Bars represent the standard deviation from five determinations.

Effect of chicken plasma protein on protein patterns of Pacific whiting gel

Protein degradation of kamaboko and modori gels was monitored in term of TCA-soluble peptides (Table 10). The highest TCA-soluble peptide content was observed for modori gels without CPP addition, indicating the highest degradation caused by endogenous proteinases in the muscle. TCA-soluble peptide content in the kamaboko gels decreased as the CPP concentration increased up to 1% ($P<0.05$), whereas CPP was added up to 2% to prevent the formation of TCA-soluble peptides in modori gel. The result suggested the greater proteolysis in the modori gels. In general, modori gels exhibited the greater degradation than kamaboko gels as indicated by higher TCA-soluble peptide

content. From the result, CPP showed inhibitory activity towards degradation of myofibrillar proteins at 55°C effectively. Dried beef plasma hydrolysate prevented modori phenomenon in surimi gels precooked at 60°C with the final cooking at 90°C (Hamann et al., 1990). Directly heated gels contained the higher TCA-soluble peptide content, compared with the control kamaboko gel, but lower than the control modori gel. Among all samples, the control modori gel showed the highest TCA-soluble peptide content. It has been known that $50-60^{\circ}$C was the optimum temperature for heat-activated fish proteinases, especially cathepsin L in Pacific whiting (An et al., 1996; Choi et al., 2004).

Table 10. TCA-soluble peptide content of surimi gels from Pacific whiting added with different levels of chicken plasma protein.

Sample	TCA-soluble peptide content (μmole tyrosine /gm. sample)*	
	Kamaboko gel	Modori gel
Directly heated gel	$0.196 \pm 0.029^{e**}$	0.196 ± 0.029^{d}
Control (without CPP)	0.106 ± 0.012^{d}	0.620 ± 0.003^{e}
0.3% CPP	0.066 ± 0.006^{c}	0.078 ± 0.002^{c}
0.5% CPP	0.051 ± 0.007^{bc}	0.075 ± 0.002^{c}
1% CPP	0.034 ± 0.010^{ab}	0.058 ± 0.004^{b}
2% CPP	0.021 ± 0.001^{a}	0.049 ± 0.001^{ab}
3% CPP	0.015 ± 0.002^{a}	0.042 ± 0.001^{a}

* Values are given as means $\pm$ SD from triplicate determinations.

** Different superscripts in the same column indicate significant differences ($P < 0.05$).

The protein patterns of modori gels with and without CPP addition are shown in Figure 12. For modori gel, the complete disappearance of MHC band was observed in the control modori gel (without CPP addition), while MHC was retained to a small extent in directly heated gel. Apart from MHC, actin was also hydrolyzed to some extent in the gels without CPP addition. MHC was the primary target and most extensively

hydrolyzed, followed by troponin-T and tropomyosin (An *et al.*, 1994b). From the result, MHC was more retained as the concentration of CPP increased up to 1% and no changes were observed although the higher levels of CPP were added. This result was in agreement with the lower TCA-soluble peptide content observed in modori gels containing high levels of CPP. The changes in actin, troponin and tropomyosin were not found in the samples added with CPP; however the intensity of those bands decreased to some extent when compared with that found in the starting surimi.
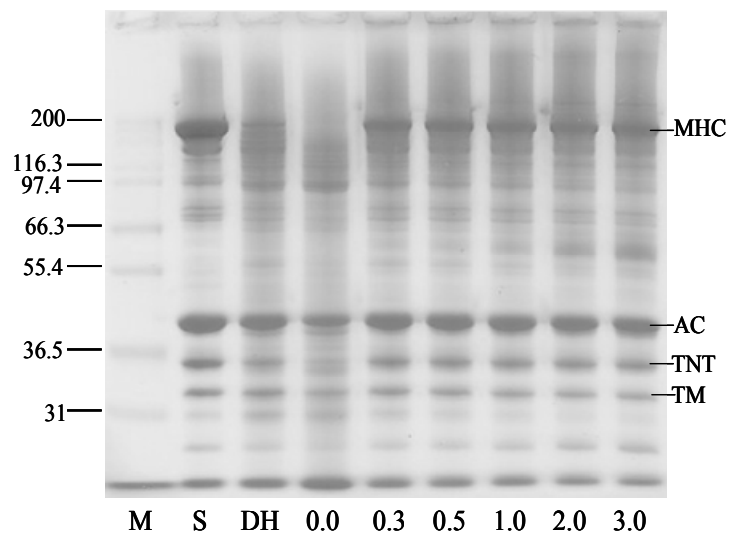

Figure 12. SDS-PAGE pattern of modori gels from Pacific whiting surimi added with various levels of chicken plasma protein. M: protein marker, S: surimi, DH: directly heated gel without CPP, Numbers designate the level of chicken plasma protein added. MHC: Myosin heavy chain, AC: Actin, TNT: troponin-T, TM: tropomyosin.

In kamaboko gels, the increase in MHC band intensity was also observed when the CPP concentration increased (Figure 13). Moreover, the cross-linked proteins was observed on the top of SDS-PAGE gel, which possibly caused by polymerization of MHC during high temperature setting (Benjakul and Visessanguan, 2003; Rawdkuen *et al.*, 2005a). It was noted that some MHC was retained in the control sample (without CPP addition) and directly heated gel. It was suggested that polymerized MHC was more resistant to proteolysis. As a result, some MHC was still found in the resulting gels. For

directly heated gel prepared by cooking at 90°C, MHC band intensity decreased to a lesser extent, compared with modori gel. No changes in actin, troponin and tropomyosin were found in the sample with and without CPP addition. However, actin band intensity slightly decreased, when compared with that of starting surimi. This was possibly caused by the dilution effect of CPP addition. Thus, the addition of CPP could prevent the degradation of proteins in surimi, which in turn allowed a stronger three-dimensional gel network to be formed.
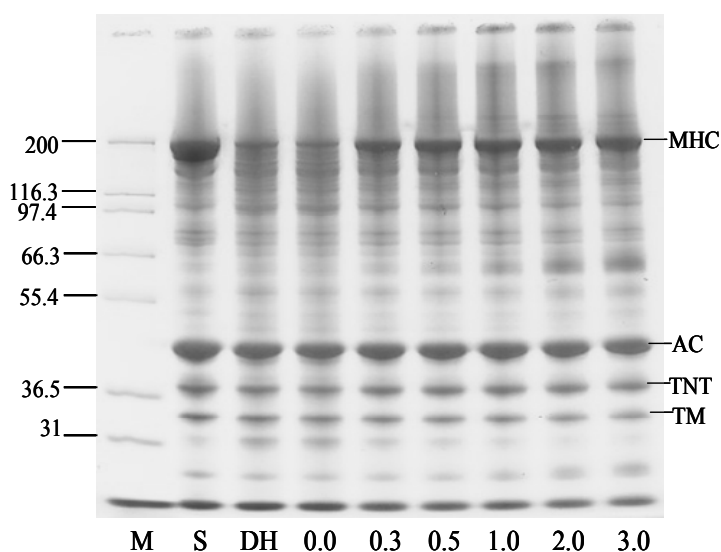

Figure 13. SDS-PAGE pattern of kamaboko gels from Pacific whiting surimi added with various levels of chicken plasma protein. M: protein marker, S: surimi, DH: directly heated gel without CPP, Numbers designate the level of chicken plasma protein added. MHC: Myosin heavy chain, AC: Actin, TNT: troponin-T, TM: tropomyosin.

3.5 Conclusion

Addition of chicken plasma protein directly affected the rheological and textural property of Pacific whiting surimi gel. Though CPP addition resulted in the lowered G$'$, it caused the increase in shear stress and strain of resulting gels, both kamaboko and modori gel. The gel enhancing effect was most likely due to the inhibition of degradation caused by endogenous proteinase in the surimi. However, CPP addition caused the reduced whiteness of resulting gels.