The Effect of Setting on the Physical Properties of Surimi and Kamaboko under Various Water Content and Chopping Methods*

Hui-Huang Chen

Department of Food Industry, National I-Lan Institute of Agriculture and Technology, 1, Shen-Nung Road, I-Lan, Taiwan, R.O.C.

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The spotted shark surimi prepared with three different chopping methods and with 73–85% water content was setted at a temperature range of 30–90°C for 20 min and 2 h. The rigidity of surimi setted for 20 min increased with increases in the setting temperature and high values were observed for surimi setted above 50°C in the thermal gelation curve. While, the maximum rigidity of surimi setted for 2 h were obtained around 60–70°C. The maximal physical properties drop of setted surimi was observed at 79–82% water content except for cohesiveness. Although the surimi prepared with silent cutter showed excels in physical properties, the setting index at 30 and 40°C was less than those with grinder and mortar. The surimi setted at 30°C for 2 h showed suwari characteristics as well as the maximum setting induced physical properties change index. Almost of the surimi setted at 40°C for 2 h showed modori characteristics. On the other hand, the modori characteristics were not obvious for spotted shark surimi setted at 60°C.

Key words: setting, surimi, shark, suwari, modori, thermal gelation

The stronger gel can be developed by standing surimi at a low temperature. This phenomenon has been termed “setting” or “suwari”. Niwa^{1,2)} postulated the α -helix of proteins changed to random coil during 38°C incubation, then aggregation of the polypeptide chains occurred and formed the protein network. On the other hand, if surimi was incubated at around 60°C, a brittle gel may be obtained. This phenomenon has been termed “disintegration” or “modori”. The mechanism of disintegration of surimi is still not completely understood. The probabilities of surimi disintegration include: thermal coagulation of myofibrillar proteins, heat-activated proteolytic degradation of myosin or the participation of nonenzymatic modori-inducing proteins.^{3,4)}

The suwari or modori characteristics of setted surimi was ordinarily evaluated using single physical property (particular in surimi type).^{1–5)} Few studies have been reported on the variations among the different evaluation methods. Since the kamaboko type products are finally given to the consumers, determination of the physical properties of kamaboko gives more direct and significant reflections on the gelation property of setted surimi. It would also support more cautious investigation on the suwari and modori characteristics of spotted shark by evaluating with physical properties of surimi as well as kamaboko.

According the temperature-gelation curves of meat paste, Shimizu *et al.*⁵⁾ suggested that the sharks belong to a difficult-setting and difficult-disintegration species for their low setting index at 30 and 40°C and low disintegration index at 60°C. Meanwhile, the gel strength of spotted shark muscle surimi showed an intimate relationship with the changes of hydrophobic interactions and disulfide bonds

during setting.⁶⁾ The gel strength of shark surimi was also contributable to the thermal stability of surimi proteins at various setting temperatures.^{6–9)} In this study, four kinds of physical properties were determined to evaluate the gelation characteristics of spotted shark surimi during setting with various water contents and chopping methods of minces. These data were also compared with thermal gelation properties by using the method reported by Shimizu *et al.*⁵⁾

Materials and Methods

Fishes

Spotted sharks *Galeocerdo cuvier* were caught by a commercial vessel off the North-east coast of Taiwan. The fish had been frozen at –20°C for two months before use in the experiment.

Preparation of Surimi and Kamaboko

The surimi with 73–85% water content was prepared with a grinder, silent cutter and mortar according to the methods described earlier.¹⁰⁾ The surimi was injected into 10 cm circumference, 15 cm length polyvinylidene chloride casing as “surimi sausage”. The surimi sausages were then setted under 30 to 90°C, with 10°C interval, for 20 min and 2 h with water bath. The setted surimi sausages (30 and 40°C for 2 h, 60°C for 20 min and 2 h) were heated at 85°C for 30 min then cooled with cold water immediately and kept at 4°C overnight before its physical properties were measured.

Physical Properties of Surimi and Kamaboko

The measurements of physical properties (rigidity of sur-

* Gelation Properties of Spotted Shark Surimi II.

imi; gel strength, tensile strength and cohesiveness of kamaboko) were performed according to the methods described earlier.¹⁰⁾

The setting index and disintegration index of surimi were determined according to Shimizu *et al.*,⁵⁾ and calculated as follows:

$$\text{Setting index} = \frac{R_{30^{\circ}\text{C}/2\text{h}} \text{ or } R_{40^{\circ}\text{C}/2\text{h}}}{R_{60^{\circ}\text{C}/20\text{min}}} \times 100$$

$$\text{Disintegration index} = \left(1 - \frac{R_{60^{\circ}\text{C}/2\text{h}}}{R_{60^{\circ}\text{C}/20\text{min}}} \right) \times 100$$

where R is rigidity (N/m²) of surimi after setting. And the suffix means the setting temperature and the setting time.

On the other hand, the setting induced physical property change index (SPI) was calculated as follows:

$$\text{SPI} = \left(\frac{P_{s1} - P_{s0}}{P_{s0}} \right) \times 100$$

where P is the physical property (include gel strength, tensile strength and cohesiveness), *s*₀ represents the surimi without setting and *s*₁ represents the surimi setted at 30°C/

2h, 40°C/2 h, 60°C/20 min or 60°C/2 h.

Statistical Analysis

Statistical analysis of the physical properties' data was performed using the system developed by SAS institute, Inc.¹¹⁾ When analysis of variance (ANOVA) revealed a significant effect (*P* < 0.05), data means were compared with the least significant difference (LSD) test.

Results

Rigidity Changes of Surimi with Setting

The rigidity of surimi setted for 20 min increased with increases in setting temperature and relative high rigidity was observed for surimi setted above 50°C (Fig. 1). The maximal rigidity of surimi setted for 2 h was obtained around 60–70°C. An interesting point was the rigidities of surimi setted for 20 min were lower than those for 2 h when the heating temperature below 80°C at lower water contents (73–79%), while it occurred only below 50°C at higher water content (82–85%). A remarkable rigidity drop of setted surimi was observed between 79% and 82% water con-

Fig. 1. The thermal gelation curves of rigidity for spotted shark surimi setted under 30 to 90°C, with 10°C interval, for 20 min and 2 h. Character G, S and M represented those surimi which were chopped with a grinder, silent cutter and mortar, respectively, and the followed number representing the water content.

tent, that agreed with the result without setting.¹⁰⁾ However, The surimi prepared with a silent cutter had higher rigidity than those with grinder or mortar under each water content.

For representing the suwari or modori characteristics of spotted shark surimi after setting, the evaluated method developed by Shimizu *et al.*⁵⁾ was used. The rigidity of setted surimi was then used to calculate the setting index and disintegration index. The surimi with 73% water content showed maximal setting index then decreased with an increase in water contents in either chopping methods when surimi was setted at 30°C (Fig. 2a). The similar results were obtained for the surimi that was setted at 40°C, but the setting indices were higher than that at 30°C (Fig. 2b). Though the rigidity of surimi prepared with a silent cutter were higher, the setting indices were lower than that with a grinder and mortar in either setting temperature at 30 or 40°C.

The disintegration index increased with increases in water content for the setted surimi prepared with these chopping methods (Fig. 2c). Obviously, the change of disintegration indices for the setted surimi prepared with a grinder were smaller than those with silent cutter and mortar. The setted surimi prepared with a grinder and mortar showed the highest and lowest disintegration index among three different chopping methods at 73% water content, respectively. Since negative disintegration index represents that the rigidity of surimi setted at 60°C for 2 h is higher than that setted for 20 min, it means that no modori occurred in rigidity at 60°C setting for 2 h. Therefore, it could be found that the spotted shark surimi with water content lower than 82% had suwari characteristics rather than modori, when they were setted at 60°C for 2 h. It suggested that the spotted shark surimi was difficult to disintegrate when setted at 60°C.

Effects of Setting on the Physical Properties of Kamaboko

The gel strength of kamaboko prepared with setted surimi decreased with increases in the water content for three chopping methods (Table 1). The surimi setted at 30°C for 2 h changed to kamaboko with higher gel strength compared with that without setting. On the contrary, the gel

Table 1. The gel strength (breaking force(gw) × deformation(cm)) of kamaboko prepared from spotted shark with setting under various water content and chopping methods

	Water content (%)				
	73	76	79	82	85
Grinder					
Without setting	808.2 ^{b,v}	693.7 ^{ab,w}	478.4 ^{b,x}	140.0 ^{b,y}	87.4 ^{b,z}
30°C/2 h	904.1 ^{a,v}	738.2 ^{a,w}	542.1 ^{ab,x}	181.9 ^{ab,y}	93.0 ^{b,z}
40°C/2 h	688.6 ^{cd,v}	555.5 ^{cd,w}	386.1 ^{cd,x}	130.2 ^{b,y}	0
60°C/20 min	727.1 ^{c,v}	739.4 ^{a,v}	476.0 ^{b,w}	205.4 ^{a,x}	81.2 ^{b,y}
60°C/2 h	727.1 ^{c,v}	651.9 ^{b,w}	392.0 ^{cd,x}	196.2 ^{a,y}	0
Silent cutter					
Without setting	690.3 ^{cd,v}	632.9 ^{b,vw}	477.4 ^{b,w}	183.8 ^{ab,x}	119.0 ^{ab,y}
30°C/2 h	790.5 ^{b,v}	746.1 ^{a,vw}	590.0 ^{a,w}	228.2 ^{a,x}	152.1 ^{a,y}
40°C/2 h	561.7 ^{e,v}	560.6 ^{cd,v}	391.6 ^{cd,w}	179.3 ^{ab,x}	0
60°C/20 min	765.4 ^{bc,v}	680.7 ^{ab,w}	488.1 ^{b,x}	224.2 ^{a,y}	90.8 ^{b,z}
60°C/2 h	621.8 ^{d,v}	607.4 ^{bc,v}	460.2 ^{bc,w}	193.5 ^{a,x}	0
Mortar					
Without setting	741.0 ^{bc,v}	595.2 ^{c,w}	412.1 ^{c,x}	119.0 ^{bc,y}	87.4 ^{b,z}
30°C/2 h	776.0 ^{bc,v}	649.9 ^{b,w}	440.6 ^{c,x}	152.1 ^{b,y}	93.0 ^{b,z}
40°C/2 h	576.2 ^{e,v}	501.4 ^{d,w}	361.1 ^{d,x}	0	0
60°C/20 min	683.9 ^{cd,v}	581.4 ^{c,w}	400.5 ^{cd,x}	90.8 ^{c,y}	77.6 ^{b,z}
60°C/2 h	627.9 ^{d,v}	554.4 ^{cd,w}	396.0 ^{cd,x}	0	0

^{a-c} Means of six determines with different superscripts for each column are different ($P < 0.05$).

^{v-z} Means of six determines with different superscripts for each row are different ($P < 0.05$).

strength of kamaboko prepared from those surimi setted at 40°C for 2 h were lower than that without setting. No gel strength was observed for the surimi with 85% water content when setted at 40°C for 2 h, probably because of inadequate sensitivity of the instrument. When the surimi setted at 60°C for 2 h, the gel strength of kamaboko with water content $\leq 79\%$ was lower than that without setting. Meanwhile, the gel strength of kamaboko with water content $\geq 82\%$ was unmeasurable. In general, the maximal gel strength drops occurred when the water content increased from 79% to 82% for all the setted surimi.

The setting induced physical properties change index (SPI) was determined to simplify the suwari and modori characteristics of setted surimi. Positive SPI reflected

Fig. 2. Setting and disintegrating index of spotted shark surimi calculated from rigidity changes during setting.

suwari and negative SPI reflected modori. Results showed that SPI for gel strength (SGI) distributed from 4 to 28 for the surimi setted at 30°C for 2 h (Fig. 3a). It suggested that the spotted shark surimi setted at 30°C for 2 h behaved with suwari characteristics in gel strength. However, the SGI of each surimi setted at 40°C for 2 h was negative (Fig. 3b) and that reflected the modori characteristics. For the surimi prepared with a grinder or silent cutter followed by setting at 60°C for 20 min, the SGI located around zero, but the SGI of each surimi prepared with mortar was negative at such setting condition (Fig. 3c). It reflected that the surimi prepared with mortar had no suwari characteristics in gel strength under such setting condition. The SGI of surimi with 73–76 water content setted at 60°C for 2 h behaved similarly as that at 40°C (Fig. 3d). It suggested that the spotted shark surimi mostly showed modori characteristics in gel strength at a temperature above 40°C for 2 h.

The tensile strength of kamaboko prepared with three chopping methods and setted at 30°C for 2 h increased up to 76% water content then decreased at higher water contents (Table 2). The maximal tensile strength drop was observed between 79% and 82% water content. There were the same tendencies for the other setting conditions. However, the setted surimi prepared with a silent cutter showed an excel in tensile strength of kamaboko. The surimi setted at 30°C for 2 h showed the highest tensile strength of kamaboko among these setting conditions. Meanwhile, the SPI for tensile strength (STI) was positive when the surimi was setted at 30°C for 2 h and it reflected the suwari characteristics in tensile strength (Fig. 4a). When the surimi was setted at 40°C for 2 h, the STI was positive for the kamaboko prepared with a grinder (Fig. 4b). It is worth to mention that the STI was negative for setting at 60°C for 20 min (Fig. 4c). It suggested that the surimi setted at 60°C for 20 min showed modori characteristic when it was evaluated with tensile strength. On the other hand, the tensile strengths of kamaboko that pre-

Table 2. The tensile strength (N/m²) of kamaboko prepared from spotted shark with setting under various water content and chopping methods

	Water content (%)				
	73	76	79	82	85
Grinder					
Without setting	38.24 ^{c,w}	61.68 ^{c,v}	25.45 ^{a,x}	11.34 ^{cd,y}	6.72 ^{cd,z}
30°C/2 h	71.18 ^{ab,v}	71.62 ^{b,v}	43.46 ^{d,w}	18.93 ^{b,x}	7.34 ^{cd,y}
40°C/2 h	42.46 ^{de,w}	67.82 ^{bc,v}	27.95 ^{a,x}	12.39 ^{c,y}	6.92 ^{cd,z}
60°C/20 min	37.92 ^{c,w}	60.04 ^{c,v}	23.11 ^{ab,x}	9.06 ^{cd,y}	5.54 ^{d,z}
60°C/2 h	46.80 ^{d,w}	66.26 ^{c,v}	27.14 ^{a,x}	9.07 ^{cd,y}	5.89 ^{d,z}
Silent cutter					
Without setting	59.58 ^{b,w}	71.89 ^{b,v}	59.87 ^{b,w}	18.03 ^{bc,x}	9.90 ^{c,y}
30°C/2 h	76.47 ^{a,v}	78.53 ^{a,v}	74.78 ^{a,v}	30.87 ^{a,w}	21.20 ^{a,x}
40°C/2 h	49.60 ^{d,w}	71.52 ^{b,v}	49.53 ^{c,w}	13.70 ^{c,x}	15.62 ^{b,x}
60°C/20 min	49.06 ^{d,w}	58.08 ^{d,v}	54.44 ^{bc,vw}	14.17 ^{c,x}	8.92 ^{c,y}
60°C/2 h	49.58 ^{d,w}	56.89 ^{d,v}	55.29 ^{bc,v}	13.80 ^{c,x}	7.08 ^{cd,y}
Mortar					
Without setting	34.79 ^{e,w}	62.45 ^{c,v}	35.01 ^{e,w}	6.88 ^{d,x}	4.96 ^{d,x}
30°C/2 h	55.46 ^{bc,w}	76.60 ^{a,v}	45.90 ^{d,x}	11.52 ^{c,y}	6.03 ^{d,z}
40°C/2 h	34.39 ^{e,vw}	37.82 ^{d,v}	32.69 ^{f,w}	9.59 ^{cd,x}	5.16 ^{d,y}
60°C/20 min	28.38 ^{f,w}	38.94 ^{d,v}	25.25 ^{f,w}	6.49 ^{d,x}	4.29 ^{de,y}
60°C/2 h	21.29 ^{g,w}	35.87 ^{d,v}	31.30 ^{ef,vw}	6.84 ^{d,x}	3.50 ^{e,y}

^{a-h} Means of six determines with different superscripts for each column are different ($P < 0.05$).

^{v-z} Means of six determines with different superscripts for each row are different ($P < 0.05$).

pared with a grinder and setted at 60°C for 2 h were higher than that setted at 60°C for 20 min (Table 2). However, the STI of the surimi setted at 60°C for 2 h was negative except the surimi prepared with grinder at lower (73–79%) water content (Fig. 4d).

There was no significant difference in cohesiveness between 73% and 76% water contents but the cohesiveness decreased significantly with increased water contents when they were higher than 76% for all the setted surimi. The maximal cohesiveness drop was observed between 76%

Fig. 3. Setting induced gel strength change index of kamaboko prepared from spotted shark. Where a, b, c and d were surimi setted at 30°C/2 h, 40°C/2 h, 60°C/20 min and 60°C/2 h.

Fig. 4. Setting induced tensile strength change index of kamaboko prepared from spotted shark. Where a, b, c and d were surimi setted at 30°C/2 h, 40°C/2 h, 60°C/20 min and 60°C/2 h.

and 79% water content for all setting conditions. While, the surimi prepared with a silent cutter showed an excel in cohesiveness when compared with a grinder and mortar particularly at higher water contents (Table 3). The SPI for cohesiveness (SCI) was positive for surimi setted at 30°C for 2 h (Fig. 5a). On the other hand, SCI distributed around zero for the other setting conditions (Fig. 5b, c, d). In general, the SCI reflected that the spotted shark surimi

did not show obvious suwari or modori characteristics when it was evaluated with cohesiveness.

Discussion

A similar tendency was observed in the thermal gelation curves of rigidity for setted shark surimi under different chopping methods as well as the curves fitted by gel strength of shark surimi (same calculation method as tensile strength used in this study) reported by Shimizu *et al.*⁵⁾ Though 60°C suggested the disintegration temperature for many kinds of fish surimi,⁵⁾ a dramatic rise of rigidity was observed when the setting temperature was higher than 50°C in thermal gelation curves (Fig. 1). A change in the inter- and intramolecular bonds in muscle protein accompanied conformational change during heating and its hydrophobic character is increased.¹²⁾ Heat coagulation of myofibrils is associated with intermolecular linkages, such as hydrogen bonds and ionic bonds, then disulfide bridges occurred when the temperature was higher than 70°C. The rigidity of surimi gel increased with an increase in setting time accompanied by the participate of these binding in the protein network.^{12,13)} While, the rigidity of shark surimi setted for 2 h increased up to 60 or 70°C and then decreased in this study. Since surimi gel is prepared by direct cooking at high temperature, a different gel structure formed. Rapid unfolding of proteins results in more tense coagulation and more water is released from the gel as well as the protein dispersion becomes very uneven.¹³⁾ Upon extended heating, the excess energy might break some binding among protein molecules and deteriorated the gels.^{13,14)} The surimi gel deteriorated by directly heating at high temperatures seemed to be more marked with increases in water content. Anyway, the gel forming ability of protein gel increases proportionally about square of protein concentration.^{12,15)} Apparently the frame-work of surimi is weaker at higher water content and shows lower

Table 3. The cohesiveness (%) of kamaboko prepared from spotted shark with setting under various water content and chopping methods

	Water content (%)				
	73	76	79	82	85
Grinder					
Without setting	94.1 ^{ab,v}	94.1 ^{b,v}	81.2 ^{ef,wx}	79.5 ^{cd,x}	69.7 ^{d,y}
30°C/2 h	94.6 ^{a,v}	94.1 ^{b,v}	84.2 ^{c,w}	81.6 ^{b,x}	72.8 ^{c,y}
40°C/2 h	94.1 ^{ab,v}	93.8 ^{b,v}	79.9 ^{f,w}	80.2 ^{c,w}	62.6 ^{g,x}
60°C/20 min	94.8 ^{a,v}	93.8 ^{b,v}	79.2 ^{f,w}	78.0 ^{d,w}	65.9 ^{f,x}
60°C/2 h	95.2 ^{a,v}	93.4 ^{c,w}	81.3 ^{c,x}	77.0 ^{c,y}	69.7 ^{d,z}
Silent cutter					
Without setting	93.2 ^{c,v}	94.3 ^{b,v}	87.6 ^{b,w}	81.8 ^{b,x}	75.4 ^{b,y}
30°C/2 h	95.4 ^{a,v}	95.6 ^{a,v}	89.7 ^{a,w}	84.9 ^{a,x}	76.4 ^{b,y}
40°C/2 h	94.8 ^{a,v}	94.9 ^{a,v}	81.5 ^{c,w}	80.6 ^{c,w}	66.9 ^{f,x}
60°C/20 min	94.9 ^{a,v}	93.8 ^{b,v}	87.6 ^{b,w}	79.9 ^{cd,x}	70.9 ^{d,y}
60°C/2 h	95.6 ^{a,v}	95.3 ^{a,v}	83.9 ^{c,w}	80.7 ^{c,x}	80.2 ^{a,x}
Mortar					
Without setting	93.3 ^{c,v}	94.8 ^{ab,v}	80.4 ^{f,wx}	77.6 ^{de,x}	66.9 ^{f,y}
30°C/2 h	93.9 ^{b,v}	95.0 ^{a,v}	82.8 ^{d,w}	78.0 ^{d,x}	68.6 ^{e,y}
40°C/2 h	94.2 ^{ab,v}	95.3 ^{a,v}	82.6 ^{d,w}	74.9 ^{f,x}	58.4 ^{b,y}
60°C/20 min	94.0 ^{ab,v}	93.1 ^{c,v}	80.4 ^{f,w}	72.2 ^{g,x}	66.1 ^{f,y}
60°C/2 h	94.4 ^{ab,v}	93.9 ^{b,v}	79.9 ^{f,w}	79.0 ^{cd,w}	67.6 ^{ef,x}

^{a-b} Means of six determines with different superscripts for each column are different ($P < 0.05$).

^{w-x} Means of six determines with different superscripts for each row are different ($P < 0.05$).

Fig. 5. Setting induced cohesiveness change index of kamaboko prepared from spotted shark. Where a, b, c and d were surimi setted at 30°C/2 h, 40°C/2 h, 60°C/20 min and 60°C/2 h.

resistance to deteriorate by long heating time at high temperature.

In addition, the dispersion of the network structure is important to the viscoelasticity of heat-set surimi gels, as well as the number and type of cross-links.¹³ Since the homogeneous surface structure was observed for the surimi prepared with a silent cutter,¹⁰ consequently the setted surimi prepared with a silent cutter had higher rigidity than that with a grinder or mortar. However, though the setted surimi prepared with silent cutter showed high rigidity, the setting indices at 30 and 40°C were lower than that of surimi prepared with a grinder or mortar. In general, spotted shark surimi with lower water content ($\leq 79\%$) showed marked suwari property than that with higher water content ($> 79\%$) (Fig. 2). Though 60°C was suggested as the suitable temperature for modori, the suwari characteristics still observed for the surimi with lower water content. The modori characteristic was observed only for the surimi with higher water content. The 79% water content was thus suggested as a critical point of rigidity of the spotted shark surimi with setting.

According to the study of various meats paste,⁵ the setting and disintegration indices of shark surimi prepared with a grinder at 82% water content distributed around 0–4 and 9–13, respectively. Therefore, sharks were regarded as the difficult setting and disintegration group. The setting and disintegrating indices in this study were vary from those reported by Shimizu *et al.*,⁵ that might be due to the different physical property use. However, the same gelation properties of shark surimi during setting were concluded to have the difficult suwari and modori characteristics. The proteins of shark muscle showed higher thermal stability than that of teleost.^{7,16,17} The higher thermal stability of muscle required more quantity of heat to change the protein structure.^{16,18} These results suggest a relationship between the high thermal stability and difficult suwari and modori characteristics of spotted shark surimi.

The gel strength of setted surimi decreased with an in-

crease of water content. Meanwhile, the tensile strength and cohesiveness increased up to 76% water content then decreased at a higher water content for the surimi after setting. The maximal physical properties drop for setted surimi occurred at 79–82% water content except for cohesiveness. The 79% water content was also suggested as a critical point for the physical properties of kamaboko prepared from spotted shark surimi with setting.

According to the results of the physical properties change of kamaboko, suwari characteristics were observed for the surimi setted at 30°C for 2 h evaluated with both SGI and STI. These results agreed with a setting index evaluated with rigidity. It suggested that the interaction among the protein molecules accelerated to form the network structure and improved the physical properties of surimi setted at 30°C. On the other hand, the SGI and STI reflected modori characteristics of setted surimi at 40°C/2 h and 60°C/2 h. The suwari characteristics were observed for the surimi setted at 60°C for 20 min evaluated with SGI except for the surimi prepared with mortar. While, the modori characteristics were observed for the surimi setted at 60°C for 20 min evaluated with STI. Since SCI distributed around zero in either setting conditions, the suwari or modori characteristics could not be represented markedly with the change of cohesiveness.

Comparing the results of thermal gelation curves of rigidity with the SPI, it indicated that some variations of suwari and modori characteristics existed when different chopping methods were used as well as when there were different water contents of surimi. It might be due to the different mechanical force which causes changes in surimi conformation and their water holding ability.¹⁰ The concentration of myofibrils in surimi also behaved differently in gelation properties during setting caused by the dispersion degree of proteins in gel. Variations of suwari and modori characteristics also existed among different determined methods of physical properties, because each physical property could only reflect a certain texture property of

surimi. Thus, it is important and still a challenge for the researchers to choose appropriate processing condition and physical property for evaluating the suwari or modori characteristics of surimi during setting. For examples, SPI method is unsuitable when spotted shark surimi was evaluated with cohesiveness because of the indefinite difference among the SCI. On the other hand, the gel strength of spotted shark surimi with higher water content was so low that it will affect the judgment of the gelation properties during setting.

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