Surimi Quality from Mechanically Deboned Chicken Meat as Affected by Washing Cycle, Salt Concentration, Heating Temperature and Rate*

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ABSTRACT : The effects of salt concentration and heating conditions on the thermal gelation properties of surimi produced from mechanically deboned chicken meat (MDCM) were investigated. Chicken surimi was manufactured by washing (MDCM: 0.5% NaCl=1:4), standing, straining and centrifuging. The fat, water-soluble protein and heme pigment in the MDCM were removed by increasing washing cycles. The compressive force of the chicken surimi increased as the concentration of salt was increased from 0% to 5%. Total gel strength of the surimi measured by texture profile analysis showed a maximum in the range 3-5% NaCl. Microstructural analysis showed that the unfolding network structure of the surimi gel began to appear at NaCl concentrations>2%. The optimum heating condition for gelation was 90°C for 40 min as this resulted in maximum values for measures of gel strength including compressive force, hardness, fracturability, adhesiveness, springiness, gumminess, chewiness and resilience. Chicken surimi gel formed by cooking at a heating rate of 1°C/min to 90°C showed better a texture than gels produced at 1.85°C/min. Our result show that a lower rate of heating improves chicken surimi gelation. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 1 : 131-136)***

Key Words : Chicken Surimi, Mechanically Deboned Chicken Meat, Salt Concentration, Heating Condition

INTRODUCTION

Surimi is a Japanese term for mechanically deboned fish flesh that has been washed with water and mixed with cryoprotectants to ensure a good frozen shelf life (Lee, 1984). By washing the fish flesh, undesirable materials such as fat, heme pigment (Park, 1995), skin (Ball and Motejano, 1984; Dawson et al., 1989) and water soluble proteins are removed and become a refined salt soluble protein. Like fish surimi, surimi-like materials from beef, pork (Wimmer et al., 1993) and poultry meat (Lin and Chen, 1989; Yang and Froning, 1992) have been studied as food materials. Park et al. (1996) reported that surimi-like beef or pork form elastic gels due to the high concentrations of myofibrillar protein present. The addition of salt at different concentrations influences the hardness of gel of surimi-like pork (Park et al., 1996). In the case of heat-induced gels, salt concentration and heating conditions are important factors, which influence the functional and textural properties of chicken surimi produced from mechanically deboned chicken meat (MDCM). The thermal gelation properties of protein from chicken or pork are influenced by total myofibrillar protein and also myosin alone, which can form desirable gels (Lan et al., 1995). Chicken meat has lower functional properties of protein including binding and water holding capacity than red meat. It deteriorates more readily by microbiological spoilage and chemical reactions, which reduces its consumer appeal due primarily to color changes (Baker and Bruce, 1989). Mechanically deboned chicken meat is high susceptible to deteriorative changes due to high oxidative events, which occur during storage (Dawson and Gartner, 1983). As the demand for cup-up chicken increases, the production of MDCM by the poultry industry will also increased. Therefore, a new value added product is required, such as, MDCM. The objectives of this research were to: (1) determine the optimal salt concentration for chicken surimi gel; and (2) determine optimum heating conditions and heating rates for gel formation.

MATERIALS AND METHODS

Preparation of chicken surimi

Mechanically deboned chicken meat (MDCM) produced using a deboner (Beehive deboner, RSTP06 LE Separator, USA) was obtained from a local manufacturer. The MDCM was kept in a deep freezer (-80°C) and used for experiments within 1 month. All chemicals used in this experiment were of special reagent grade.

The frozen MDCM at -80°C was thawed in air at 4°C for 18 h and chopped with 4 times its weight of washing solution using a silent cutter (Seiki Co Ltd., OSK 10600 Type A, Japan) for 2 min 30 sec. and then blended using a Kitchen Aid (Kitchen Aid Inc, USA) for 10 min. Total process of washing for the MDCM from chopping to centrifuging was repeated 3 cycles. In the washing process, the first and the second washing solutions were used with 0.5% NaCl, but the third washing was with distilled water.

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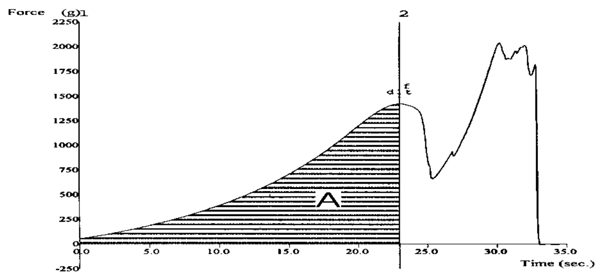

Figure 1. Result obtained for compressive force from the texture analyzer. Inner area (A) was defined as the compressive force (g) which required to break the gel, calculated as the applied pressure ×distance moved.

The blended slurry was allowed to stand for 10 min. The blended slurry was then strained by different cycles using three size meshes in the order of 2, 1 and 0.6 mm. The slurry was centrifuged (Beckman J2-21, Germany) at 3,000 rpm for 15 min and the supernatant was discarded. Finally, the residual precipitate (washed MDCM) after the third washing procedure was used as experimental materials. Moisture, crude fat, crude protein and crude ash of the washed MDCM processed by different cycles were determined by standard AOAC method (1990). The final moisture content of washed MDCM (chicken surimi) was adjusted to 90% with distilled water. All surimi processing were performed at 4°C.

Gel preparation by salt concentration, heating temperature and heating rate

The surimi produced from mechanically deboned chicken meat were mixed with salt solutions with different concentrations of NaCl (0, 1, 2, 3, 4 and 5%, respectively) using a Kitchen Aid (Kitchen Aid Inc, USA) at speed 6 for 5 min. The mixed paste was stuffed in a glass tube (length 100 mm and width 15 mm) and centrifuged at 2,000 rpm for 10 min to remove air bubble in slurry. Then, after standing at 25°C for 60 min, the samples were cooked at 90°C for 30 min in the water batch. The cooked chicken surimi samples were then cooled in ice water for 10 min and refrigerated at 4°C for 12 h. Finally, the gel was removed from the tube and used for experimentation. To investigate the effect of heating temperature, the mixed paste containing 2% NaCl was cooked at different temperatures (70, 80, 90 and 100°C) for 40 min. For the investigation of the effect of heating rate on gel formation, mixed paste containing 2% NaCl was cooked at heating rates of 1 °C/min (TB-85, Shimazu, Japan) and 1.85 °C/min (SB-9, Eyela, Japan) from 20 to 90°C in the water batch.

pH and color measurement

pH was determined by homogenizing a 10 g sample of muscle in 100 mL of distilled water for 1 min in a homogenizer (AM-7, Nihonseiki kaisha Ltd., Japan) at 8,000 rpm. The pH of the resultant suspension was measured with a pH meter (F-12, Horiba, Japan) equipped with a combination pH electrode calibrated to pH 4.0 and 7.0.

CIE (Commission Internationale de l'Eclairage) L* (lightness), a* (redness), and b* (yellowness) values of thawed chicken surimi for Illuminant C were measured using a color difference meter (CR-300, Minolta Co., Tokyo, Japan). Also, the chroma (C*) values and the hue-angles (h°) were calculated using $C^*=(a^{*2}+b^{*2})^{1/2}$, and $h°=\tan^{-1}(b^*/a^*)$, respectively (Little, 1975).

Compressive force and Texture profile analysis (TPA) of gels

Compressive force testing of chicken surimi was performed using a Texture analyzer (TA-XT2i, Stable micro systems Ltd. UK) with a 5 kg load cell. A 35 mm diameter cylinder probe (SMS P/35) was used for the samples (15 mm height, 20 mm diameter). Compressive values were described as the force (g) required to break the gel, calculated as the applied pressure×distance moved. The inner area formed until the breaking point is shown as letter “A” in Figure 1. The compressive force was defined as area “A” (Lee and Han, 1999). Test conditions were as follows; mode: measure force in compress, option: return to start, pretest speed: 5 mm/s, test speed: 0.5 mm/s, posttest speed: 5 mm/s, distance: 80% trigger type: auto, trigger force: 5 g.

Texture profile analysis (TPA) test for the heat-induced gel strength was also performed using a Texture analyzer (TA-XT2i, Stable micro systems Ltd., UK). A spherical gel (20 mm height, 15 mm diameter) was measured using a cylindrical stainless-steel probe(diameter 5 mm) attached to a 5 kg load cell on the analyzer. The texture parameters were defined by TPA method (Bourne, 1982).

All parameters were calculated by the texture analyzer software (version 1.12) from MHK Trading Co. (UK). The test conditions were; mode: TPA, pretest speed: 5 mm/s, test speed: 2 mm/s, posttest speed: 5 mm/s, distance: 15 mm, trigger type: auto, trigger type force: 5 g.

Scanning electron microscopy

To observe the gel cut section, samples were treated as described by Alvarez et al. (1999). Cooked gels were cut into square sections (0.5 cm×0.5 cm×0.1 cm) and rinsed with 0.07 M phosphate buffer (pH 6.8). The samples were fixed in 2% glutaraldehyde for 1 h. After rinsing with buffer again, the samples were post-fixed with 2% osmium tetroxide (OsO_4) for 1 h and rinsed with 60% ethanol. Fixed samples were then dehydrated in a graded ethanol series (60, 70, 80, 90, 95, 99, 99.9 and 100%) for 10 min and finally with tert-butyl alcohol. The prepared samples were dried using a freeze dryer. Dried samples were mounted on the

Table 1. Chemical composition of chicken surimi by washing cycles

Composition	Washing cycle[1]			
	0	1	2	3
pH	6.5±0.1[a, 2]	6.6±0.1[a]	6.6±0.1[a]	6.7±0.2[a]
Moisture (%)	66.8±0.4[d]	83.8±0.2[c]	87.3±0.2[b]	89.3±0.2[a]
Crude protein (%)	16.4±0.3[a]	12.8±0.9[b]	10.9±0.1[c]	9.9±0.1[c]
Crude lipid (%)	15.1±0.2[a]	0.8±0.1[b]	0.34±0.11[c]	0.17±0.1[c]
Crude ash (%)	1.15±0.02[a]	0.78±0.01[b]	0.55±0.01[c]	0.34±0.01[d]

[a-d] Means within row with different superscripts are significantly different (p<0.01).
[1] The first and the second MDCM washing cycles were with 0.5% NaCl (1:4), and the third with distilled water.
[2] Means of 3 replications per washing cycle batch.

Table 2. Color changes of chicken surimi by washing cycle

Color[1] Items	Washing cycle [2]			
	0	1	2	3
L*	54.1±0.5[d, 3]	66.8±0.4[c]	72.1±0.5[b]	74.1±7.1[a]
a*	25.9±0.9[a]	13.5±0.5[b]	8.1±0.4[c]	7.1±0.6[d]
b*	16.9±0.4[a]	15.0±0.4[b]	14.5±0.5[b]	14.5±0.7[b]
C	30.9±1.0[a]	20.2±0.6[b]	16.6±0.7[c]	16.2±0.8[c]
h°	33.2±0.6[d]	48.0±0.5[c]	60.9±0.6[b]	63.8±0.6[a]

[a-d] Means within row with different superscripts are significantly different (p<0.01).
[1] L*: lightness, a*: redness, b*: yellowness, c: chroma value, h°: hue angle.
[2] The first and the second washing cycles were used MDCM with 0.5% NaCl (1:4), the third cycle was only rinsed with distilled water.
[3] Means of 3 replications per washing cycle batch.

specimen holders, sputter-coated with gold and examined in a SEM 3,500 (Hitachi, Japan) at up to 15 kV. Replications were performed at different magnifications (×500).

Statistical analysis

The statistical analysis system (SAS Institute, Inc., 1996) was used to determine means, standard deviations, and to perform analyses of variance. Data were analyzed by ANOVA and Duncan's multiple range test (mean comparison) using the general linear model in the statistical analysis system program.

RESULTS AND DISCUSSION

Chemical composition and color changes by washing cycles

The chemical composition of the chicken surimi changed according to the washing cycles. Moisture content of the non-washing cycle (MDCM) was 66.8%, (Table 1) and this tended to increase with increasing washing cycles. After the third cycle, the moisture content reached 89.3%. The crude protein content of the surimi decreased because the sarcoplasmic protein was removed by increasing washing cycles. The crude lipid content also decreased below 1% after the first cycle. Crude ash content decreased significantly as the washing cycles were increased (p<0.01).

The color changes of chicken surimi are shown in Table 2. CIE L^* value and hue angle (h°) of the chicken surimi increased significantly as the number of washing cycles increased, but the CIE a* value decreased significantly (p<0.01). This result can be explained because fat, heme pigment, and water-soluble compounds in the MDCM were removed by the washing process (Ball, 1988; Dawson et al, 1989; Froning and Nieman, 1989; Yang and Froning, 1992a).

Gel strength by salt concentration

It is very important to confirm the optimal salt concentration to improve the gelation of chicken surimi, because the formation of gel can not occur without the addition of salt. Table 3 shows that chicken surimi with different levels of NaCl and cooked at 90°C for 30 min containing different salt concentration has different maximum gel strengths. Compressive force of the chicken surimi gels tended to increase as salt concentration increased. The compressive force of gels with 2% NaCl was higher than those with 0 or 1%, and 5% NaCl produced the highest value (p<0.05). The control with 0% NaCl had the lowest gel strength. Hardness and fracturability of the chicken surimi gels were highest value with 1% NaCl (p<0.05). Park et al. (1996) reported that surimi gel with 3% NaCl from beef and pork was 2 times harder than the control gel with 0% NaCl. In our experiment, however, the hardness didn't increase further at >3% NaCl. The cohesiveness of gel containing more than 2% NaCl was significantly higher than those containing 0 and 1%, and maintained a high level until 5% NaCl. Gumminess and chewiness showed very high values at >3% NaCl. Generally, gel strengths of the surimi improved as the salt concentration increased (Table 3). It is well known that salt makes myofibrillar protein unfold during surimi processing. Also, it plays an important role in the formation of a gel

Table 3. Textural properties of chicken surimi by salt concentration

Textural properties	Salt concentration (%)					
	0	1	2	3	4	5
Compressive force (g·cm)	277.3[d]	314.1[d]	454.7[c]	680.1[b]	661.2[b]	840.4[a]
	(36.0)	(88.3)	(109.7)	(83.0)	(45.2)	(85.1)
Hardness (g)	112.1[d]	119.8[cd]	124.4[bcd]	153.1[a]	133.6[bc]	139.0[ab]
	(10.7)	(11.6)	(1.5)	(20.6)	(9.1)	(7.7)
Fracturability (g)	112.1[cd]	109.1[d]	124.7[bcd]	153.1[a]	130.2[bc]	134.5[b]
	(10.7)	(11.0)	(3.6)	(20.6)	(12.6)	(9.3)
Adhesiveness (g·s)	-16.3[d]	-94.8[c]	-284.4[b]	-300.2[a]	-259.5[b]	-271.1[ab]
	(3.5)	(23.1)	(20.8)	(20.9)	(18.7)	(26.1)
Springiness	0.591[c]	0.806[b]	0.922[a]	0.942[a]	0.939[a]	0.939[a]
	(0.061)	(0.099)	(0.018)	(0.011)	(0.016)	(0.01)
Cohesiveness	0.130[c]	0.181[b]	0.390[a]	0.405[a]	0.388[a]	0.404[a]
	(0.033)	(0.04)	(0.024)	(0.039)	(0.015)	(0.02)
Gumminess	15.1[d]	24.0[c]	46.6[b]	53.9[a]	53.9[a]	56.3[a]
	(2.7)	(4.9)	(4.9)	(4.5)	(4.5)	(5.3)
Chewiness	8.9[d]	19.0[c]	42.5[b]	50.9[a]	50.9[a]	52.8[a]
	(1.5)	(5.5)	(4.5)	(4.4)	(4.4)	(5.2)
Resilience	0.022[b]	0.032[a]	0.038[a]	0.039[a]	0.037[a]	0.038[a]
	(0.003)	(0.007)	(0.005)	(0.004)	(0.002)	(0.003)

[a-d] Means within a row without a common superscript letter are significantly different ($p<0.05$). ( ): Standard deviation.

Table 4. Textural properties of chicken surimi by different heating temperature

Textural properties	Heating temperature (°C)			
	70°C[1]	80°C	90°C	100°C
Compressive force (g·cm)	292.3[d]	453.8[c]	1205.6[a]	673.2[b]
	(19.8)[2]	(22.1)	(89.9)	(123.2)
Hardness (g)	107.6[c]	131.4[b]	158.8[a]	120.3[b]
	(4.7)	(12.6)	(12.4)	(11.8)
Fracturability (g)	83.2[c]	109.7[b]	143.5[a]	120.4[b]
	(2.4)	(13.3)	(4.6)	(11.2)
Adhesiveness (g·s)	-217.8[c]	-302.0[b]	-336.7[a]	-251.6[c]
	(15.4)	(28.3)	(17.3)	(31.5)
Springiness	0.931[a]	0.925[ab]	0.935[a]	0.922[b]
	(0.015)	(0.01)	(0.012)	(0.016)
Cohesiveness	0.377[a]	0.369[a]	0.361[a]	0.378[a]
	(0.02)	(0.015)	(0.01)	(0.024)
Gumminess	38.3[c]	47.4[b]	56.9[a]	45.5[bc]
	(5.6)	(5.2)	(5.7)	(5.9)
Chewiness	35.4[c]	43.9[b]	53.1[a]	41.9[b]
	(5.1)	(5.0)	(3.0)	(4.8)
Resilience	0.038[b]	0.033[b]	0.052[a]	0.035[b]
	(0.006)	(0.005)	(0.004)	(0.007)

[a-d] Means within a row without a common superscript letter are significantly different ($p<0.05$).
[1] Heating time of all treatments was 40 min. [2] ( ): Standard deviation.

matrix by swelling the myofibrillar protein and helping to hydrophilize the protein connection with water (Park et al., 1996). Most parameters of gel strengths including compressive force, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience values were highest at 3-5% NaCl. This result agrees with that of Lee (1984) who reported that 2-3% NaCl added to chicken surimi produced the best optimal textural properties. In conclusion, maximal gel strength is attained by chicken surimi gels containing 2-5% NaCl.

Scanning electron micrograph of gels by salt concentration

Scanning electron microscopy was used to observe the surface structures of cooked gels, produced at different salt concentrations (Figure 2). All gels were cooked at 90°C for 40 min. The cut section of gels with 0 and 1% NaCl had an irregular rough shape, and was very brittle. It showed aggregation in the divisional area and did not have a detectable network structure (×500).

Cavities on the surface began to form in surimi containing above 2% NaCl. The cavity size was relatively

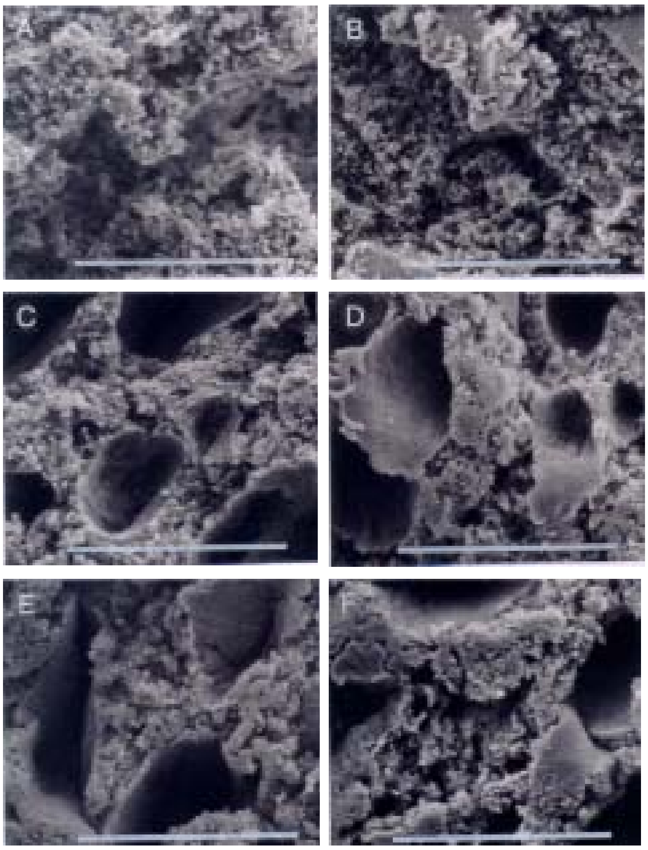

Figure 2. Scanning electron micrographs of chicken surimi gel at different salt concentration; A: 0%, B: 1%, C: 2%, D: 3%, E: 4%, F: 5%. All surimi gels were heated at 90°C for 40 min. Bar=200 μm.

small and the material formed a more uniform dispersion. The unfold gel network had formed well and was globular in appearance. The structure was stable with uniform distribution. Therefore, it seems that at least 2% NaCl is needed for stable and uniform gelation by observing a gel section by SEM.

Gel strength by heating temperature

To confirm optimal heating conditions, gels were prepared with 2% NaCl and cooked at 70, 80, 90 and 100°C for 40 min (Table 4). Most parameters such as compressive force, hardness, fracturability, adhesiveness, springiness, gumminess, chewiness and resilience were at a maximum for gels cooked at 90°C for 40 min. Conversely, those gels cooked at 70°C showed minimal values and the parameters were lower at 100°C than 90°C showing that the textural properties of the gel were improved by heating at 90°C. Choi and Lee (1998) reported that excessive cooking of surimi gel produced a rough and leather-like product, i.e., the product became harder and more opaque as heating continued. The gel strength of chicken surimi in this study began to decrease sharply at 70°C. From these results,

Table 5. Textural properties of chicken surimi by different heating rate

Textural properties	Heating rate (°C/min)	
	1	1.85
Compressive force (g·cm)	1,399±67.3[a]	1,010.4±70.2[b]
Hardness (g)	189.0±14.9[a]	157.8±8.5[b]
Fracturability (g)	189.4±12.3[a]	148.1±10.0[b]
Adhesiveness (g·s)	-336.8±43.4[a]	-318.2±17.5[a]
Springiness	0.941±0.008[a]	0.940±0.009[a]
Cohesiveness	0.410±0.019[a]	0.388±0.025[a]
Gumminess	79.8±5.9[a]	61.1±4.7[b]
Chewiness	75.0±5.7[a]	57.4±4.4[b]
Resilience	0.046±0.003[a]	0.045±0.005[a]

[a-b] Means within row with different superscripts are significantly different ($p<0.05$). [1] ( ): Standard deviation.

apparent modori (gel degradation) phenomena occur in chicken surimi at different temperatures. It appears that the proper temperature for best quality chicken surimi gel is 90°C for 40 min.

Gel strength by heating rate

Table 5 shows the gel strengths of chicken surimi heated at different rates. The surimi, which all contained 2% NaCl, were cooked from 20 to 90°C at heating rates of 1 and 1.85°C per minute. The gel which was cooked at a heating rate of 1°C per min was found to have higher strength than gel cooked at 1.85°C per min. The compressive force, hardness, fracturability, gumminess, chewiness and resilience of gel cooked at a heating rate 1°C were higher than those of the gel cooked at 1.85°C/min ($p<0.05$). Smyth and O'neill (1997) reported that the gel characteristics of surimi manufactured from mechanically deboned chicken meat improved as the heating rate was lowered from 5°C/min to 2.5°C/min and 1°C/min. Also, Yongsawatdigul and Park (1999) reported that a good storage modulus was obtained in gels on heating at a low rate. They examined rates of 0.5, 1 and 2°C/min. Therefore, the textural properties of a gel can be improved by cooking at a low heating rate. In conclusion, quality of surimi from mechanically deboned chicken meat was affected by washing cycle, salt concentration, heating temperature and rate.

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