

The Development of Sausage Including Meat from Spent Laying Hen Surimi

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ABSTRACT The sausage samples were made from pork with spent laying hen breast surimi. The samples were divided into 4 groups [sausage made from pork (control) and sausage made from pork with 20% (T1), 40% (T2), and 60% (T3) of spent laying hen breast surimi]. In proximate compositions, the moisture and ash contents of the control were higher than sausage containing spent laying hen surimi samples in all storage periods. The pH and cooking loss were higher in T3 compared with other sausage samples. However, there was no significant difference in water-holding capacity among the sausage samples, whereas shear force was significantly higher in T2. In meat color, sausage containing spent laying hen surimi samples (T1, T2, and T3) have shown to have higher lightness (L*)

compared with control, and redness (a*) was significantly higher in control and T1. Total amino acid content and essential amino acids were increased in sausage containing spent laying hen surimi samples at 0 d of storage. In fatty acid composition, saturated fatty acid was higher in control than sausage containing spent laying hen surimi samples. Thiobarbituric acid reactive substances value was lower in sausage containing spent laying hen surimi samples than control at 2 and 4 wk of storage. Cholesterol content was lower in control compared with sausage containing spent laying hen surimi samples. In sensory evaluation, most test items were not significantly different among the sausage samples although tenderness was higher in T2 and T3 at 0 d of storage.

Key words: sausage, spent laying hen, surimi, physico-chemical characteristic, sensory evaluation

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INTRODUCTION

In the past 2 decades, the Korean poultry industry has suffered from problems of spent laying hen disposal because most of Korean meat consumers have not been consuming the spent laying hen meat. This has caused a large amount of environmental pollution and high disposal cost for carcass burning or burying. In general, a substantial proportion of these hens complete the laying cycle within 1 yr. These hens are referred to and marketed as spent hens (Haque et al., 1991). Meat consumers and processors can benefit from the development of efficient and economical technology for processing undervalued meat such as spent hen meat into value-added meat product that are palatable and reasonable in cost. Thus, Korean poultry producers have developed new methods for efficiently using or disposing of spent laying hens such as other animal feed or fertilizer; however, these methods also required a large cost. The past several years, we have developed surimi made from a chicken breast (Jin et al., 2006), which

may be one of efficient method to improve the unpopular meat consumption. Surimi is the term for minced fish where most of the water-soluble components including sarcoplasmic proteins have been removed by leaching with water (Murakawa et al., 2003). Surimi possesses functionality including gelling, binding, and emulsifying properties and can be used as a functional protein ingredient in several products (Lanier, 1986). Thus, gelling properties of surimi can be influenced by many factors causing the structural alteration in sausage. This sausage development is very important not only for consumers but also for the poultry industry in Korea. The objective of this study was to investigate the effect of spent laying hen breast surimi on sausage qualities.

MATERIALS AND METHODS

Sausage Formulation and Processing

Spent laying hen breasts for surimi were obtained from a commercial laying hen farm and then slaughtered at a commercial slaughtering house. Three batches were collected on different days for experimental replication. The skin and external fat tissue was removed from the muscles after slaughter and the lean muscle was diced into approximately 2 cubes (8 × 4 × 2 cm) and ground through a 3-

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Table 1. The formulation of sausage

Ingredient (%)	Treatment ¹			
	C	T1	T2	T3
Lean pork	60.95	50.79	39.62	27.52
Pork back fat	22.33	22.11	22.15	22.19
Surimi made with spent hen breast ²	—	12.70	26.41	41.27
Ice (water) ³	14.27	11.95	9.37	6.57
Sausage seasoning (contained 0.4% nitrite and 1% NaCl)	1.70	1.70	1.70	1.70
Phosphate	0.20	0.20	0.20	0.20
Sugar	0.50	0.50	0.50	0.50
Hexane	0.05	0.05	0.05	0.05
Total	100	100	100	100

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

²Replaced total meat with 20, 40, and 60% spent laying hen breast surimi.

³To balance the amount of total water (total water = water as ice + water content in meat).

mm diameter orifice using a mincer. Minced samples were homogenized by a Polytron homogenizer (IKA Labortechnik T25-B, Selangor, Malaysia) with distilled water at 15,000 rpm for 30 s. The slurry was filtered through a 1-mm-mesh metal screen to remove connective tissues. The filtrate was centrifuged at $10,000 \times g$ for 25 min, and the supernatant containing fat and water-soluble proteins was discarded (2 times). The resulting sediment (77.7% water, 21.2% protein, 1.1% fat, and 51.1% yield) was used for sausage manufacture. Lean pork and backfat were purchased from local meat processing plant. Excess fat was trimmed from the meat and then ground in a grinder twice through a 7-mm plate. Ingredient composition of the sausages is presented in Table 1. The emulsified meat batters were stuffed into polyvinylidene chloride casings (30-mm diameter) and cooked in a cooking chamber (programmed at 65°C for 30 min, increased to 75°C and held for 30 min, and then increased to 80°C and held for 20 min). Afterwards samples were cooled in ice water for 20 min and then stored at 4°C.

Chemical Composition

Moisture, CP, and crude fat contents were determined according to the method described by AOAC (1990). Moisture was determined by the oven drying method at 110°C for 24 h; for cooked samples total water content was calculated as $[100 - (\text{total protein} + \text{total lipid} + \text{total ash})]$. Total protein content was determined by the Kjeldhal method. Total lipids were evaluated by the Soxhlet method. Ash was determined as the remnant weight after calcinations of a 2 g sample at 550°C during 4 h.

pH

The pH was determined according to the method described by AOAC (1990). The pH was measured using a digital pH meter (model 420A, Orion, Beverly, MA). About 5 g of sample were cut into small pieces to which 45 mL of distilled water was added, and slurry was made using a blender and the pH was recorded.

Water-Holding Capacity

The water-holding capacity (WHC) was determined by the modified method of Sutton et al. (1997). Five-gram samples were weighed into centrifugation tubes and thereafter centrifuged at 5°C at low speed ($1,000 \times g$ for 15 min). The WHC was determined as liquid loss and expressed as percentage of weight of liquid release. $\text{WHC \%} = (\text{before centrifuge weight} - \text{after centrifuge weight}) / (\text{before centrifuge weight}) \times 100$.

Cooking Loss

Cooking loss was determined by the modified method of Bertram et al. (2003). The samples were placed in polyethylene bags and cooked in a 100°C water bath until an internal temperature of 75°C was achieved. Cooking loss was calculated from differences in the weight of uncooked and cooked samples, expressed as percentage of initial weight. $\text{Cooking loss \%} = (\text{before cooking weight} - \text{after cooking weight}) / (\text{before cooking weight}) \times 100$.

Shear Force

Shear force was determined by the modified method of Shackelford et al. (1991). The samples were sheared once through the center using an Instron 3343 (US/MX50, A&D Co., Norwood, MA). Equipped with a Warner-Bratzler shearing device (100 mm/min crosshead speed).

Hardness

The hardness was measured using a texture analyzer (EZ-test, Shimadzu, Tokyo, Japan) equipped with a cylindrical plunger (diameter 5 mm, depression speed 66 mm/min).

Cholesterol

Cholesterol was determined by the modified method of Russo et al. (2005). Two-gram samples were added into a

Table 2. Proximate compositions in sausage made from spent laying hen surimi during storage at 0°C

Item (%)	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
		Mean ± SD			
Moisture	0	63.48 ± 0.07 ^{Aa}	62.79 ± 0.22 ^b	62.27 ± 0.44 ^c	61.20 ± 0.24 ^{Ad}
	2	62.37 ± 0.42 ^{Ba}	62.73 ± 1.53 ^a	61.66 ± 0.29 ^{ab}	60.21 ± 0.22 ^{Bb}
	4	62.92 ± 0.62 ^{ABa}	63.03 ± 0.46 ^a	62.26 ± 0.49 ^a	60.88 ± 0.28 ^{Ab}
CP	0	15.41 ± 0.45	15.49 ± 0.15	15.44 ± 0.08 ^A	15.06 ± 0.11
	2	15.42 ± 0.26 ^a	15.54 ± 0.32 ^a	14.58 ± 0.03 ^{Bab}	13.74 ± 0.92 ^b
	4	15.32 ± 0.28 ^a	15.25 ± 0.32 ^a	14.64 ± 0.26 ^{Bab}	13.92 ± 1.20 ^b
Crude fat	0	4.43 ± 0.13	4.35 ± 0.44	4.44 ± 0.34	4.12 ± 0.21
	2	4.61 ± 0.23 ^a	4.41 ± 0.33 ^{ab}	4.66 ± 0.08 ^a	3.87 ± 0.45 ^b
	4	4.53 ± 0.33	4.24 ± 0.27	4.19 ± 0.82	4.08 ± 0.78
Ash	0	2.13 ± 0.06 ^a	2.10 ± 0.02 ^{Bab}	2.08 ± 0.05 ^{ABab}	2.05 ± 0.02 ^{Bb}
	2	2.22 ± 0.04 ^a	2.20 ± 0.02 ^{ABab}	2.17 ± 0.03 ^{Abc}	2.14 ± 0.01 ^{Ac}
	4	2.23 ± 0.08 ^a	2.16 ± 0.05 ^{ABab}	2.06 ± 0.05 ^{Bb}	2.11 ± 0.04 ^{Ab}

^{A,B}Means ± SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a-c}Means ± SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 5$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

50-mL tube with 10 mL of saponification reagent (30% KOH and ethanol with the ratio of 6:94) and a 0.5-mL internal standard (2 mg of 5 α -cholestane/sample), and then homogenized with a Polytron homogenizer (IKA Labortechnik T25-B) for 10 s, capped, and incubated for 1 h at 60°C. After cooling the sample, 8 mL of deionized distilled water and 3 mL of hexane were added and mixed thoroughly to allow separating. The top layer (hexane layer) was taken out and dried in scintillation vials, and 100 μ L of *bis*-[trimethylsilyl]trifluoroacetamide + 1% trimethylchlorosilane and 200 μ L of pyridine were added and mixed, and set overnight and then analyzed by gas chromatography (Shimadzu GC-14A). A ramped oven temperature condition (180°C for 2.5 min, increased to 230°C at 2.5°C/min, then held at 230°C for 7.5 min) was used. Temperatures

of both the inlet and detector were 280°C. Helium was the carrier gas at linear flow of 1.1 mL/min. Detector (flame ion detector) air, H₂, and make-up gas (He) flows were 350, 35, and 43 mL/min, respectively.

Color

Color [CIE lightness (L*), redness (a*), yellowness (b*)] was measured by using a Minolta colorimeter (CR-300, Tokyo, Japan), with measurements standardized with respect to the white calibration plate. Five readings were made from the surface of samples. Whiteness was determined using the following formula: $100 - [(100 - L^*)^2 + a^{*2}b^{*2}]^{1/2}$ (Park, 1994).

Table 3. Physico-chemical characteristics in sausage made from spent laying hen surimi during storage at 0°C

Item	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
Mean ± SD					
pH	0	5.90 ± 0.01 ^{Bd}	6.03 ± 0.01 ^{Bc}	6.13 ± 0.01 ^{Cb}	6.25 ± 0.01 ^{Ca}
	2	5.96 ± 0.06 ^{ABd}	6.06 ± 0.04 ^{Bc}	6.17 ± 0.01 ^{Ba}	6.30 ± 0.02 ^{Bb}
	4	6.01 ± 0.01 ^{Ad}	6.15 ± 0.01 ^{Ac}	6.25 ± 0.01 ^{Ab}	6.37 ± 0.00 ^{Aa}
Water-holding capacity (%)	0	86.98 ± 1.63	84.49 ± 5.18	87.98 ± 6.90	84.61 ± 3.71
	2	85.66 ± 2.30	86.91 ± 4.46	82.94 ± 2.83	82.08 ± 0.65
	4	86.97 ± 4.29	85.98 ± 5.90	85.12 ± 1.20	83.27 ± 1.02
Cooking loss (%)	0	6.52 ± 0.41 ^B	6.42 ± 0.58 ^B	6.16 ± 0.86 ^B	7.00 ± 0.25 ^C
	2	4.57 ± 0.18 ^{Cb}	4.74 ± 0.25 ^{Bb}	4.72 ± 0.79 ^{Bb}	10.13 ± 0.59 ^{Ba}
	4	12.71 ± 0.85 ^{Aab}	10.66 ± 1.22 ^{Ab}	12.65 ± 1.27 ^{Aab}	13.72 ± 1.20 ^{Aa}
Shear force (kg/cm ²)	0	1.31 ± 0.12 ^B	1.20 ± 0.08 ^B	1.20 ± 0.08 ^B	1.27 ± 0.10 ^B
	2	2.01 ± 0.05 ^{Aa}	2.00 ± 0.02 ^{Aa}	1.94 ± 0.10 ^{Aa}	1.81 ± 0.03 ^{Ab}
	4	1.42 ± 0.18 ^B	1.19 ± 0.05 ^B	1.42 ± 0.15 ^B	1.23 ± 0.06 ^B
Hardness (kg)	0	0.26 ± 0.02 ^a	0.20 ± 0.00 ^b	0.23 ± 0.04 ^{ab}	0.19 ± 0.01 ^{Ab}
	2	0.23 ± 0.02 ^a	0.20 ± 0.02 ^{ab}	0.21 ± 0.03 ^{ab}	0.17 ± 0.01 ^{Bb}
	4	0.28 ± 0.03 ^a	0.20 ± 0.01 ^b	0.22 ± 0.03 ^b	0.17 ± 0.01 ^{Bb}

^{A-C}Means ± SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a-d}Means ± SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 5$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; T3 = sausage made with 60% spent laying hen breast surimi.

Table 4. Color in sausage made from spent laying hen surimi during storage at 0°C

Item ² (%)	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
		Mean ± SD			
L*	0	76.47 ± 0.40 ^{ABd}	88.52 ± 0.69 ^{Ac}	91.54 ± 0.40 ^{Ab}	93.32 ± 0.52 ^{Aa}
	2	78.09 ± 0.28 ^{Ac}	78.07 ± 0.91 ^{Bc}	80.20 ± 1.06 ^{Bb}	82.44 ± 0.22 ^{Ba}
	4	75.72 ± 1.29 ^{Bd}	77.48 ± 0.29 ^{Bc}	79.54 ± 0.34 ^{Bb}	81.45 ± 0.74 ^{Ba}
a*	0	11.20 ± 0.26 ^b	12.61 ± 0.47 ^{Aa}	10.96 ± 0.20 ^{Ab}	10.35 ± 0.10 ^{Ac}
	2	11.21 ± 0.39 ^a	10.88 ± 0.21 ^{Ba}	9.60 ± 0.05 ^{Cb}	9.07 ± 0.18 ^{Bc}
	4	11.73 ± 0.69 ^a	11.08 ± 0.15 ^{Ba}	9.87 ± 0.07 ^{Bb}	8.89 ± 0.49 ^{Bc}
b*	0	3.89 ± 0.03 ^{Ba}	4.04 ± 0.35 ^{Ba}	3.01 ± 0.32 ^{Bb}	4.07 ± 0.41 ^{Ba}
	2	4.22 ± 0.10 ^{Bc}	5.42 ± 0.34 ^{Aa}	4.81 ± 0.31 ^{Ab}	5.71 ± 0.30 ^{Aa}
	4	4.83 ± 0.38 ^{Ab}	5.14 ± 0.05 ^{Ab}	5.02 ± 0.25 ^{Ab}	5.68 ± 0.20 ^{Aa}
W	0	65.06 ± 0.47 ^{Ac}	76.41 ± 1.65 ^{Ab}	82.50 ± 0.84 ^{Aa}	81.10 ± 1.49 ^{Aa}
	2	65.43 ± 0.28 ^{Aa}	61.82 ± 1.92 ^{Bb}	65.77 ± 1.19 ^{Ba}	65.32 ± 0.90 ^{Ba}
	4	61.24 ± 2.40 ^{Bb}	62.07 ± 0.15 ^{Bab}	64.47 ± 1.01 ^{Ba}	64.40 ± 1.17 ^{Ba}

^{A-C}Means ± SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a-d}Means ± SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 5$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

²L* = lightness; a* = redness; b* = yellowness; W = whiteness.

Thiobarbituric Acid Reactive Substances

Thiobarbituric acid reactive substances (TBARS) were determined by the modified method of Buege and Aust (1978). Five-gram samples were weighed into a 50-mL test tube and homogenized with 15 mL of deionized distilled water using the polytron homogenizer for 10 s at the highest speed. One milliliter of sample homogenate was transferred to a disposable test tube (13 × 100 mm), and butylated hydroxyanisole (50 µL, 10%) and TBA/trichloroacetic acid (2 mL) were added. The mixture was vortexed and then incubated in a boiling water bath for 15 min to develop color. The sample was cooled in cold water for 10 min, vortexed again, and centrifuged for 15 min at 2,000 × g. The absorbance of the resulting supernatant solution was determined at 531 nm against a blank containing 1 mL of deionized distilled water and 2 mL of TBA/trichloroacetic acid solution. The amounts of TBARS were expressed as milligrams of malondialdehyde per kilogram of sample.

Free Amino Acid

Free amino acid was determined by the modified method of Cordoba et al. (1994). Five grams of chopped sample were homogenized in 20 mL of deionized water with a polytron homogenizer (IKA Labortechnik T25-B). The homogenate was deproteinized by mixing it with 20 mL of 10% sulfosalicylic acid. The mixture was maintained at 4°C for 17 h and then filtered through filter paper. The filtrate was adjusted to pH 6.0 with 4 N NaOH and diluted to 50 mL with 100 mM sodium citrate buffer (pH 6.00). The diluted solution was ultra-filtrated through a 10 kDa ultrafiltration membrane with a Stirred Ultrafiltration Cell model 8200 (Millipore Co., Milford, MA) before amino acid derivatization was carried out with AccQ • Fluor Reagent Kit (P/N WAT052880, Waters Co., Milford, MA) according to the direction for use attached to the kit. External stan-

dard (Amino Acid Hydrolysate Standard, P/N WAT088122, Waters Co.) derivatization was also performed in the same way. Amino acid derivatives were detected on a Waters High Performance Liquid Chromatograph equipped with 2 pumps (Waters 515 HPLC pump) and a UV detector (Waters 2487 Dual λ Absorbance Detector, detecting at 254 nm). The column was an AccQ • Tag Column (Nava-Pak C18, 3.9 × 150 mm, interior diameter 4 µm), and column temperature was controlled to 37°C. The eluents used were (A) AccQ • Tag Eluent A (Borate buffer):water at 1:10 and (B) acetonitrile:water:methanol at 45:40:15. The flow rate was 1 mL/min, and the flowing solvent gradient was performed on the following procedure: initial 0% B, linear change to 1.0% B in 0.5 min, linear change to 7.0% B in 16.5 min, linear change to 10.0% B in 4 min, linear change to 33.0% B in 9 min and maintained 3 min at 33.0% B, then linear change to 100% B in 1 min and maintained at 100% B for 3 min, at last linear change to 0% B in 1 min and maintained for 12 min.

Fatty Acid

Lipids were extracted with chloroform and methanol as described by Folch et al. (1957). The extracted lipids were concentrated using an evaporator (Zymark turbovap 500, Hopkinton, MA). Fatty acid composition was determined by the method of Hur et al. (2004). For lipid hydrolysis, an aliquot of lipid extract (30 mg) and 3 mL of 4% H₂SO₄ in methanol were combined in a screw-cap test tube. The test tube was placed in boiling water (100°C) for 20 min and subsequently cooled at room temperature. The resulting free fatty acids were methylated with 1 mL of 14% boron trifluoride in methanol at room temperature for 30 min. Water (1 mL) and hexane (5 mL) was added. Samples were vortexed and centrifuged at 500 × g for 10 min. The upper organic solvent layer was used to determine fatty acids composition. Fatty acid methyl esters were analyzed

Table 5. Amino acid in sausage made from spent laying hen surimi during storage at 0°C

Item (mg/g)	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
Mean ± SD					
Aspartic	0	1.41 ± 0.10 ^{Bb}	1.64 ± 0.02 ^{Aa}	1.59 ± 0.03 ^a	1.62 ± 0.03 ^a
	4	1.59 ± 0.03 ^{Ab}	1.59 ± 0.01 ^{Bb}	1.61 ± 0.01 ^{ab}	1.63 ± 0.01 ^a
Threonine ^{2,4}	0	0.63 ± 0.03 ^{Bb}	0.75 ± 0.03 ^a	0.74 ± 0.02 ^a	0.73 ± 0.01 ^a
	4	0.75 ± 0.01 ^{Aab}	0.74 ± 0.01 ^b	0.74 ± 0.00 ^{ab}	0.76 ± 0.01 ^a
Serine ⁴	0	0.53 ± 0.02 ^{Bc}	0.64 ± 0.01 ^a	0.63 ± 0.01 ^{ab}	0.61 ± 0.01 ^{Bb}
	4	0.64 ± 0.01 ^{Aab}	0.63 ± 0.00 ^b	0.63 ± 0.00 ^{ab}	0.66 ± 0.02 ^{Aa}
Glutamic ³	0	2.41 ± 0.16 ^{Bb}	2.73 ± 0.04 ^a	2.77 ± 0.09 ^a	2.76 ± 0.04 ^a
	4	2.79 ± 0.04 ^A	2.77 ± 0.05	2.77 ± 0.02	2.82 ± 0.01
Proline	0	0.67 ± 0.02 ^{Bb}	0.70 ± 0.03 ^{ab}	0.70 ± 0.01 ^{ab}	0.71 ± 0.01 ^{Aa}
	4	0.72 ± 0.03 ^{Aa}	0.67 ± 0.01 ^b	0.67 ± 0.03 ^b	0.68 ± 0.01 ^{Bb}
Glycine ⁴	0	0.64 ± 0.05 ^{Bb}	0.89 ± 0.04 ^{Aa}	0.85 ± 0.03 ^a	0.83 ± 0.11 ^a
	4	0.87 ± 0.02 ^{Aa}	0.79 ± 0.00 ^{Bc}	0.83 ± 0.02 ^b	0.75 ± 0.01 ^d
Alanine ⁴	0	0.79 ± 0.07 ^{Bb}	0.99 ± 0.02 ^{Aa}	0.97 ± 0.02 ^{Aa}	0.94 ± 0.02 ^a
	4	0.95 ± 0.02 ^A	0.94 ± 0.00 ^B	0.94 ± 0.01 ^B	0.95 ± 0.02
Valine ²	0	0.91 ± 0.02 ^{Bc}	1.09 ± 0.01 ^a	1.06 ± 0.01 ^b	1.06 ± 0.01 ^b
	4	1.07 ± 0.02 ^A	1.07 ± 0.02 ^a	1.09 ± 0.00	1.07 ± 0.01
Isoleucine ²	0	0.86 ± 0.03 ^{Bb}	1.00 ± 0.02 ^a	1.01 ± 0.03 ^a	1.02 ± 0.01 ^a
	4	0.99 ± 0.01 ^{Ab}	0.98 ± 0.01 ^b	1.02 ± 0.01 ^a	1.02 ± 0.01 ^a
Leucine ²	0	1.44 ± 0.08	1.41 ± 0.04	1.40 ± 0.03	1.42 ± 0.01
	4	1.39 ± 0.02 ^b	1.38 ± 0.02 ^b	1.40 ± 0.00 ^b	1.43 ± 0.02 ^a
Tyrosine ⁵	0	0.47 ± 0.04 ^{Bb}	0.55 ± 0.01 ^a	0.54 ± 0.01 ^a	0.55 ± 0.00 ^a
	4	0.56 ± 0.01 ^{Aab}	0.55 ± 0.01 ^{ab}	0.58 ± 0.00 ^a	0.56 ± 0.02 ^b
Phenylalanine ^{2,5}	0	0.54 ± 0.02 ^{Bb}	0.68 ± 0.02 ^a	0.69 ± 0.06 ^a	0.64 ± 0.01 ^a
	4	0.70 ± 0.05 ^A	0.66 ± 0.00	0.67 ± 0.01	0.66 ± 0.01
Histidine ²	0	0.70 ± 0.02 ^{Bc}	0.80 ± 0.01 ^a	0.76 ± 0.03 ^b	0.72 ± 0.01 ^c
	4	0.88 ± 0.03 ^{Aa}	0.80 ± 0.00 ^b	0.76 ± 0.01 ^c	0.71 ± 0.01 ^d
Lysine ²	0	1.22 ± 0.03 ^{Bb}	1.54 ± 0.00 ^a	1.53 ± 0.06 ^a	1.54 ± 0.02 ^{Aa}
	4	1.55 ± 0.02 ^{Aa}	1.54 ± 0.01 ^a	1.56 ± 0.02 ^a	1.49 ± 0.01 ^{Bb}
Arginine ²	0	0.73 ± 0.06 ^{Bb}	1.09 ± 0.02 ^a	1.16 ± 0.04 ^a	1.18 ± 0.03 ^a
	4	1.16 ± 0.03 ^{Aab}	1.13 ± 0.02 ^b	1.16 ± 0.01 ^a	1.16 ± 0.01 ^{ab}
Total	0	13.96 ± 0.23 ^{Bb}	16.51 ± 0.05 ^{Aa}	16.41 ± 0.41 ^a	16.31 ± 0.14 ^a
	4	16.61 ± 0.28 ^{Aa}	16.23 ± 0.07 ^{Bb}	16.44 ± 0.06 ^{ab}	16.35 ± 0.19 ^{ab}
EAA	0	7.04 ± 0.06 ^{Bb}	8.38 ± 0.03 ^{Aa}	8.35 ± 0.26 ^a	8.30 ± 0.05 ^a
	4	8.49 ± 0.15 ^{Aa}	8.29 ± 0.01 ^{Bb}	8.41 ± 0.03 ^{ab}	8.30 ± 0.09 ^b
FAA	0	2.41 ± 0.16 ^{Bb}	2.73 ± 0.04 ^a	2.77 ± 0.09 ^a	2.76 ± 0.04 ^a
	4	2.79 ± 0.04 ^A	2.77 ± 0.05	2.77 ± 0.02	2.82 ± 0.01
SAAA	0	2.59 ± 0.11 ^{Bb}	3.27 ± 0.08 ^{Aa}	3.19 ± 0.05 ^a	3.11 ± 0.13 ^a
	4	3.20 ± 0.06 ^{Aa}	3.09 ± 0.01 ^{Bb}	3.15 ± 0.02 ^{ab}	3.11 ± 0.06 ^b
FRAA	0	1.01 ± 0.05 ^{Bb}	1.23 ± 0.02 ^a	1.23 ± 0.07 ^a	1.19 ± 0.01 ^a
	4	1.26 ± 0.05 ^A	1.22 ± 0.01	1.25 ± 0.00	1.22 ± 0.03

^{A,B}Means ± SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a-d}Means ± SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 5$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

²Essential amino acids (EAA).

³Flavor-related amino acids (FAA).

⁴Saccharinity-related amino acids (SAAA).

⁵Fragrant-related amino acids (FRAA).

on a gas chromatography equipped with an on-column injector port and flame-ionization detector. A Silar capillary column (30 m × 0.32 mm × 0.25 μm; Shimadzu) was used for the separation of the fatty acid methyl esters. The gas chromatography oven temperature was 140°C and increased at a rate of 2°C/min to a final temperature of 230°C. The temperatures of injector port and detector temperatures were set at 240 and 250°C, respectively. Fatty acid methyl ester (1 mL) was injected onto the split injection port (100:1 split ratio). The flow rate for He carrier gas was 50 mL/min. Each fatty acid was detected by the standard's retention time.

Sensory Evaluation

Sensory evaluation was performed by a panel of 15 semi-trained tasters. Panel development followed the prescreening, screening, training, and performance evaluated phases proposed by Cross et al. (1978). The panel evaluated each treatment within each replication in quintuplicate, and the evaluation was performed with the samples at room temperature. Triplicate responses were taken to monitor the inherent texture variability associated with this sample. One slice, 0.5 cm thick and 5 cm in diameter, was cut into 6 pie-shaped wedges and presented to each panelist. The

Table 6. Fatty acid composition in sausage made from spent laying hen surimi during storage at 0°C

Item (%)	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
		Mean ± SD			
Myristic acid	0	1.06 ± 0.17	1.06 ± 0.19	0.95 ± 0.27	0.88 ± 0.13
	4	0.95 ± 0.02 ^b	1.05 ± 0.04 ^{ab}	1.07 ± 0.04 ^a	1.14 ± 0.05 ^a
Palmitic acid	0	17.31 ± 0.75 ^a	15.70 ± 0.14 ^b	15.66 ± 0.53 ^a	15.76 ± 0.16 ^{Bb}
	4	16.85 ± 0.16 ^b	16.01 ± 0.11 ^c	16.82 ± 0.08 ^a	16.65 ± 0.14 ^{Ab}
Palmitoleic acid	0	1.64 ± 0.30 ^b	2.17 ± 0.06 ^{Ba}	1.63 ± 0.26 ^b	1.78 ± 0.27 ^{Bab}
	4	1.65 ± 0.06 ^c	2.41 ± 0.07 ^{Aa}	2.13 ± 0.08 ^b	2.54 ± 0.01 ^{Aa}
Stearic acid	0	10.49 ± 0.44 ^{ab}	9.71 ± 0.21 ^c	10.17 ± 0.18 ^{Aa}	10.30 ± 0.09 ^b
	4	11.36 ± 0.11 ^a	9.38 ± 0.04 ^c	9.26 ± 0.06 ^{Bb}	9.20 ± 0.20 ^c
Oleic acid	0	38.93 ± 0.99 ^{Bb}	44.29 ± 0.10 ^{Ba}	38.16 ± 0.54 ^{Bc}	39.34 ± 0.81 ^{Bb}
	4	42.29 ± 0.23 ^d	49.71 ± 0.11 ^{Ab}	48.53 ± 0.37 ^{Ac}	50.55 ± 0.33 ^{Aa}
Linoleic acid	0	23.13 ± 0.60 ^{Aa}	19.32 ± 0.17 ^{Ac}	21.21 ± 0.48 ^{Ab}	19.33 ± 0.19 ^{Ac}
	4	21.31 ± 0.06 ^{Ba}	17.44 ± 0.01 ^{Bc}	18.86 ± 0.33 ^{Bb}	16.81 ± 0.03 ^{Bd}
Arachidonic acid	0	7.43 ± 0.12 ^{Ab}	7.75 ± 0.25 ^{Ab}	12.22 ± 0.15 ^{Aa}	12.61 ± 0.59 ^{Aa}
	4	5.60 ± 0.20 ^{Ba}	4.00 ± 0.25 ^{Bb}	3.35 ± 0.03 ^{Bc}	3.10 ± 0.33 ^{Bc}
SFA ²	0	28.87 ± 0.47 ^a	26.47 ± 0.19 ^b	26.78 ± 0.89 ^b	26.94 ± 0.63 ^b
	4	29.15 ± 0.03 ^a	26.45 ± 0.20 ^c	27.14 ± 0.10 ^b	27.00 ± 0.01 ^b
UFA ²	0	71.13 ± 0.47 ^b	73.53 ± 0.19 ^a	73.22 ± 0.89 ^b	73.06 ± 0.63 ^a
	4	70.85 ± 0.03 ^c	73.55 ± 0.20 ^a	72.86 ± 0.10 ^b	73.00 ± 0.01 ^b
EFA ²	0	30.56 ± 0.70 ^{Ac}	27.07 ± 0.09 ^{Ad}	33.42 ± 0.59 ^{Aa}	31.93 ± 0.40 ^{Ab}
	4	26.91 ± 0.26 ^{Ba}	21.44 ± 0.24 ^{Bb}	22.21 ± 0.36 ^{Bb}	19.91 ± 0.35 ^{Bb}

^{A,B}Means ± SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a-d}Means ± SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 5$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

²SFA = saturated fatty acid; UFA = unsaturated fatty acid; and EFA = essential fatty acid.

panelists chose 3 of the most characteristic wedges to avoid a sample containing large pieces of connective tissue. The aroma, flavor, color, juiciness, tenderness, and overall acceptability were evaluated using a 9-point scale.

Statistical Analysis

Statistical analyses were done for 3 batches for spent laying hen breast. Data for each batch of spent laying hen breast collected for proximate composition, physical characteristics, meat color, amino acid, fatty acid, TBARS, cholesterol, and sensory evaluation were analyzed using SAS software (SAS Inst. Inc., Cary, NC) by the Duncan's multiple range test were used to compare the differences among means. Significant differences ($P < 0.05$) between mean values of quintuplicate samples were determined for physical characteristics, meat color, amino acid fatty acid, TBARS, and cholesterol. Significant differences ($P < 0.05$) between sensory evaluations were determined ($n = 15$).

RESULTS AND DISCUSSION

Proximate Composition

Chemical compositions are presented in Table 2. Moisture content was significantly lower in sausage containing spent laying hen surimi samples than control sample in all storage periods. Especially, sausage containing 60% spent laying hen surimi (T3) had a significantly lower moisture content compared with other samples. Ash content was significantly higher in control than sausage containing

spent laying hen surimi samples in all storage periods. However, CP and crude fat showed no significant difference among the sausage samples in all storage periods. Present study showed that addition of spent laying hen breast surimi had the greatest influence on proximate composition of the sausage; however, storage time had minor effects on proximate composition of the spent laying hen breast surimi sausage samples. Thus, we assume that the qualities of sausage made by spent laying hen breast surimi should be stable during storage.

Physical Characteristics

The physical characteristics results are presented in Tables 3, 4, and 5. The pH significantly increased with storage period in all sausage samples. Especially, pH was significantly higher in T3 compared with other sausage samples. However, WHC were not significantly different among the sausage samples. Cooking loss significantly increased in T3, whereas shear force was higher in sausage containing 40% spent laying hen surimi (T2). In general, postmortem changes, particularly glycogen breakdown and anaerobic respiration, lead to the accumulation of lactic acid and a decrease in pH of muscle after that pH is increased by aging. Honikel (1987) reported that pH has a profound effect on the physical properties such as WHC, tenderness, and color in meat. Usually, high pH, high protein content, and low water content are closely related to the high WHC, hardness, and shear force in meats. In this study, pH also increased in T3. Our results agree with Nowsad et al. (2000) who reported that pH was increased by washing spent

Table 7. Sensory evaluation in sausage made from spent laying hen surimi during storage at 0°C

Item ² (%)	Storage (wk)	Treatment ¹			
		C	T1	T2	T3
		Mean $\pm$ SD			
Aroma	0	6.50 $\pm$ 0.76 ^{AB}	6.75 $\pm$ 0.71	6.25 $\pm$ 0.71 ^B	6.13 $\pm$ 0.83
	2	7.13 $\pm$ 0.35 ^{Aa}	7.25 $\pm$ 0.46 ^a	7.13 $\pm$ 0.64 ^{Aa}	6.38 $\pm$ 0.52 ^b
	4	6.00 $\pm$ 0.82 ^B	6.71 $\pm$ 0.76	6.57 $\pm$ 0.79 ^{AB}	6.43 $\pm$ 0.79
Flavor	0	7.00 $\pm$ 0.93 ^b	7.38 $\pm$ 0.52 ^{ab}	7.50 $\pm$ 0.53 ^{ab}	7.88 $\pm$ 0.83 ^{Aa}
	2	6.88 $\pm$ 0.64	7.50 $\pm$ 0.53	7.50 $\pm$ 0.53	7.25 $\pm$ 0.89 ^{AB}
	4	6.57 $\pm$ 0.79	7.00 $\pm$ 0.82	7.00 $\pm$ 0.58	6.86 $\pm$ 0.69 ^B
Color	0	6.75 $\pm$ 0.89 ^{ABa}	6.38 $\pm$ 0.52 ^{ab}	5.75 $\pm$ 0.89 ^{Bb}	5.75 $\pm$ 0.71 ^{Bb}
	2	7.25 $\pm$ 0.46 ^{Aab}	6.50 $\pm$ 0.53 ^b	7.50 $\pm$ 0.53 ^{Aa}	7.13 $\pm$ 1.25 ^{Aab}
	4	6.14 $\pm$ 0.69 ^B	6.14 $\pm$ 0.90	6.43 $\pm$ 0.98 ^B	6.14 $\pm$ 0.90 ^{AB}
Juiciness	0	6.50 $\pm$ 0.53 ^A	7.13 $\pm$ 0.99 ^A	7.00 $\pm$ 0.53 ^A	6.88 $\pm$ 0.99
	2	6.63 $\pm$ 0.52 ^A	6.75 $\pm$ 0.46 ^{AB}	7.25 $\pm$ 0.46 ^A	7.25 $\pm$ 1.28
	4	5.71 $\pm$ 0.76 ^B	6.29 $\pm$ 0.49 ^B	6.29 $\pm$ 0.49 ^B	6.14 $\pm$ 1.07
Tenderness	0	6.13 $\pm$ 0.64 ^{Bb}	6.38 $\pm$ 0.92 ^b	7.50 $\pm$ 0.53 ^{Aa}	8.25 $\pm$ 0.89 ^{Aa}
	2	7.00 $\pm$ 0.76 ^A	7.25 $\pm$ 0.71	7.38 $\pm$ 0.74 ^A	7.13 $\pm$ 0.83 ^B
	4	6.14 $\pm$ 0.90 ^B	6.57 $\pm$ 0.98	6.43 $\pm$ 0.53 ^B	6.71 $\pm$ 0.95 ^B
Overall acceptability	0	6.88 $\pm$ 0.35 ^{AB}	7.00 $\pm$ 0.76	7.25 $\pm$ 0.46 ^{AB}	7.50 $\pm$ 0.76 ^A
	2	7.13 $\pm$ 0.35 ^A	7.25 $\pm$ 0.46	7.38 $\pm$ 0.52 ^A	7.50 $\pm$ 1.07 ^A
	4	6.43 $\pm$ 0.79 ^B	6.86 $\pm$ 0.90	6.71 $\pm$ 0.76 ^B	6.57 $\pm$ 0.53 ^B

^{A,B}Means $\pm$ SD with different superscripts in the same column significantly differ at $P < 0.05$.

^{a,b}Means $\pm$ SD with different superscripts in the same row significantly differ at $P < 0.05$. $n = 15$.

¹C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi.

²Aroma (9 = very intense and 1 = very weak), flavor (9 = very good and 1 = very bad), color (9 = very good and 1 = very bad), juiciness (9 = very juiciness and 1 = very dry), tenderness (9 = very tender and 1 = very tough), overall acceptability (9 = very good and 1 = very bad).

hens, although WHC was not influenced by pH increase. However, hardness was significantly lower in sausage containing spent laying hen surimi samples. This may be due to the amount of spent laying hen breast surimi additive, and pH should be less affected.

Meat Color

In meat color, L^* decreased with storage periods in all sausage samples, and sausage containing spent laying hen surimi samples [sausage containing 20% spent laying hen surimi (T1), T2, and T3] was significantly higher in L^* compared with control. Redness was higher in control and T1 at 2 and 4 wk of storage. However, whiteness was shown to be significantly higher in T2 and T3 during storage. Fernandez-Lopez et al. (2003) reported that the meat color is thought to be due to 3 factors, the concentration of heme pigments, chemical state of these pigments, and the physical light-scattering properties of the meat structure. This high L^* could be expected because chicken muscle generally has a lower myoglobin content than pork. Meat color is closely related to its pH. The state of the pigment is affected by the meat pH and the reaction of the heme with other reactants such as O_2 on their effect on the state of the heme iron (Fernandez-Lopez et al., 2003). Washing is also a very important step to remove undesirable fat, heme pigment, connective tissues, and other water-soluble components in surimi manufacturing. Our results agree with Nowasad et al. (2000), who reported that spent hen mince had increased L^* and decreased a^* and suggested that this phenomenon may be related to

the loss of pigments. In this study, the water washing step should reduce the myoglobin of surimi. Thus, water washing could influence colors in sausage containing spent laying hen surimi samples.

Amino Acid

Most amino acid content significantly increased with storage period in control group, whereas sausage containing spent laying hen surimi samples was not significantly different in amino acid content in all amino acids during storage. Total amino acid content and essential amino acids were significantly higher in sausage containing spent laying hen surimi samples at 0 d of storage; however, total amino acid and essential amino acid of control group was significantly higher than other sausage samples at 4 wk of storage. Yano et al. (2001) also reported that total amino acid in pork was gradually increased with an increase in storage period within 20 d. In the present study, total amino acid amount may be influenced by the addition of sausage containing spent laying hen surimi samples after 4 wk of storage and may be due to muscle types. However, it is not exactly understood how much influence the muscle type has on amino acid amount; thus, more research is needed to determine effect of chicken breast surimi on total amino acid amount in sausage.

Fatty Acid

Fatty acid composition results are presented in Table 6. The saturated fatty acid (SFA) was higher in controls than

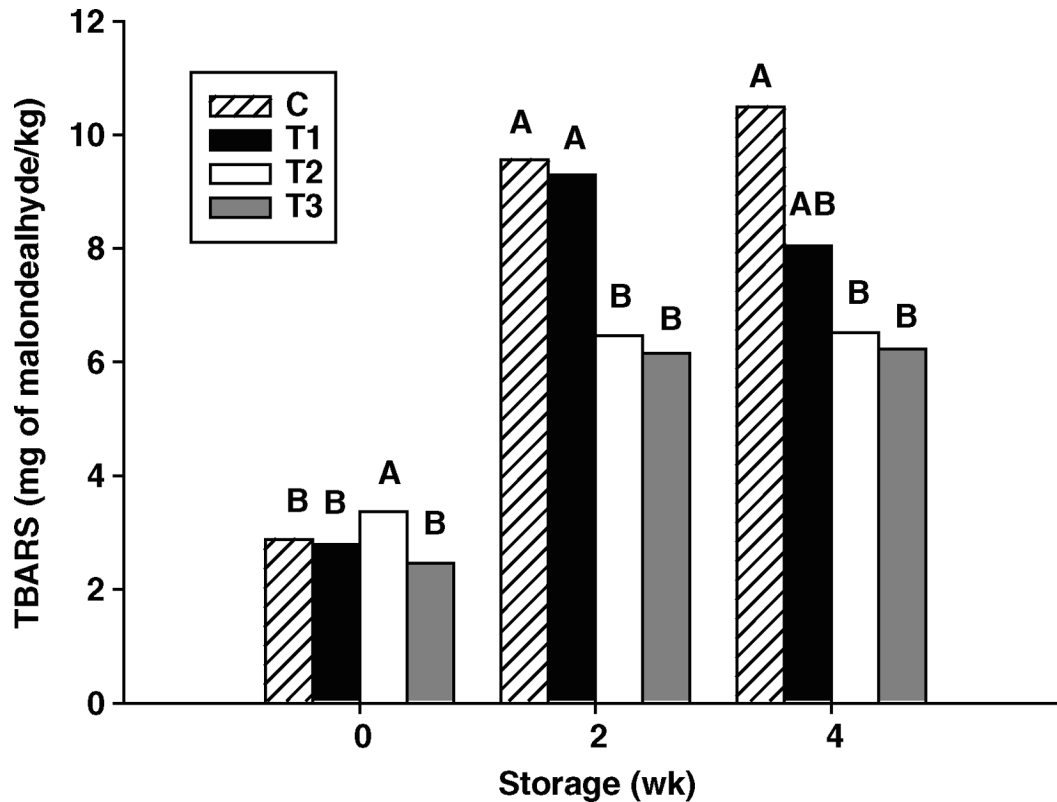


Figure 1. Thiobarbituric acid reactive substances (TBARS) in sausage made from spent laying hen surimi during storage at 0°C. C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi. $n = 5$. ^{A,B}Means with different letters are significantly different ($P < 0.05$).

sausage containing spent laying hen surimi samples. Especially, linoleic acid content was higher in the control than other sausage containing spent laying hen surimi samples. This change is the main reason for increased SFA and decreased unsaturated fatty acid (UFA). Wood et al. (2003) reported that the fatty acid composition can influence the fat tissue firmness because the effect of fatty acid on firmness is due to the different melting points of the fatty acid in meat. They suggested that the melting point is increased by saturation increase in meat. Usually, UFA contents are much higher in chicken compared with pork or beef. In this study, the UFA amount should be increased by spent laying hen breast surimi additive. Also, our results showed that mechanical hardness was higher in the control sausage group than the sausage made from spent laying hen breast surimi. This may be due to the lower SFA in the spent hen surimi.

TBARS

The TBARS values were increased with storage periods in all sausage samples. At 0 d of storage, T2 had a significantly higher TBARS value compared with other samples. However, TBARS value was significantly lower in sausage containing spent laying hen surimi samples than control at 2 and 4 wk of storage. Lipid oxidation induces formation of an array of products, which decrease directly or indirectly the sensory quality of the meat products. Ahn et al.

(1993) reported that the differences in fat content, fatty acid composition, and the classes of lipids have significant effects on lipid oxidation only when oxygen has free access to the stored meat products. Usually, UFA is more prone to

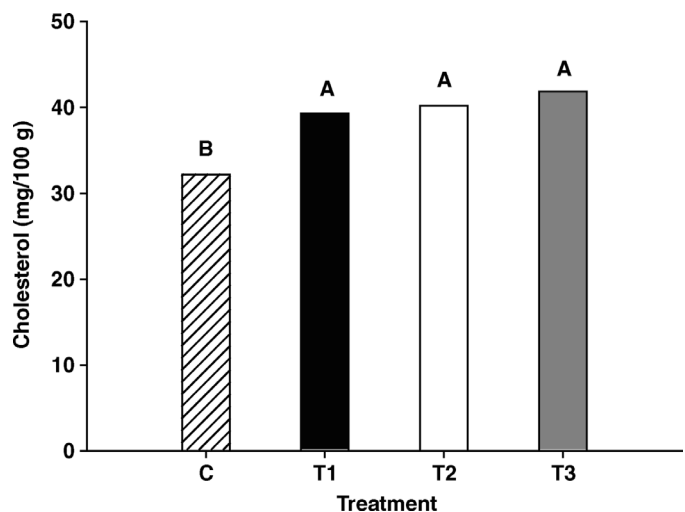


Figure 2. Cholesterol contents in sausage made from spent laying hen surimi during storage at 0°C. C = sausage made with 0% spent laying hen breast surimi; T1 = sausage made with 20% spent laying hen breast surimi; T2 = sausage made with 40% spent laying hen breast surimi; and T3 = sausage made with 60% spent laying hen breast surimi. $n = 5$. ^{A,B}Means with different letters are significantly different ($P < 0.05$).

oxidation than SFA. However, results show lower TBARS value in sausage containing spent laying hen surimi samples even though UFA amount was much higher in sausage containing spent laying hen surimi sample than the control. This mechanism is still not well understood, but we assume that it may be due to some lipid losses occurred during the washing to make the surimi and may have influenced lipid oxidation. Thus, more research is needed to determine the effect of fatty acid composition on lipid oxidation in sausage containing spent laying hen surimi. As a result of this study, the oxidation stability of sausage containing spent laying hen surimi should be higher than pork sausage. This result can influence sausage quality during storage.

Cholesterol

Cholesterol content results are presented in Figures 1 and 2. Cholesterol content was significantly lower in control than sausage containing spent laying hen surimi samples. However, there was no significant difference in cholesterol content among the sausage containing spent laying hen surimi samples. In general, cholesterol content is slightly higher in chicken than fresh pork (USDA, 2001). Therefore, in this study, cholesterol content should be higher in sausage containing spent laying hen surimi. However, it is not exactly sure that how much influence the muscle type has on cholesterol content; thus, more research is needed to determine effect of chicken breast surimi on cholesterol content.

Sensory Evaluation

The sensory evaluation results are presented in Table 7. Aroma and flavor were not significantly different among the sausage samples during storage. Color, juiciness, tenderness, and overall acceptability were significantly decreased with storage periods in all sausage samples. However, most test items were not significantly different among the sausage samples, although T2 and T3 were more tender than other samples at 0 d of storage. These results indicate that the taste of sausage containing spent laying hen surimi by panels was not much different compared with original pork sausage. In conclusion, we suggested that sausage can be made with spent laying hen breast surimi. This sausage may improve spent laying hen consumption.

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