Physicochemical characteristics of breast and thigh meats from old broiler breeder hen and old laying hen and their effects on quality properties of pressed ham

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ABSTRACT The consumption of meat products from old broiler breeder hen (**OBH**) and old laying hen (**OLH**) is limited by their poor organoleptic properties. In this study, the physicochemical properties of breast and thigh meat from OBH and OLH and their application to the development of pressed ham with better quality properties were examined. To manufacture pressed ham, 3 different chicken meat mixtures (mixture A, 50% breast and 50% thigh from OBH; mixture B, 50% breast and 50% thigh meat from OLH; mixture C, 25% breast and 25% thigh from OBH and OLH, respectively) were used. Breast meat from OBH showed a higher water holding capacity (**WHC**; $P < 0.001$), a^* values ($P < 0.05$), and tenderness ($P < 0.001$) and lower cooking loss ($P < 0.001$) and b^* values ($P < 0.01$) than those of other samples. No significant differences in physicochemical properties of thigh meat were detected between OBH and OLH. Regardless of chicken breed, the thigh samples showed significantly higher pH values, cooking loss, and a^* and significantly lower WHC, L^*, and b^* than those of breast samples. The quality properties of pressed ham were affected by the physicochemical characteristics of meat ingredients, including pH, WHC, and textural properties. The pressed ham samples with mixtures A and B showed the lowest ($P < 0.05$) and highest ($P < 0.05$) values, respectively, for cooking loss, L^*, b^*, hardness, gumminess, and chewiness. The highest ($P < 0.05$) overall acceptability scores were obtained for samples made with mixture A. Thus, breast and thigh meat from OBH could be used for pressed ham with favorable WHC, tenderness, and overall acceptability.

Key words: old broiler breeder hens, old laying hens, processed ham, physicochemical characteristics

2020 Poultry Science 99:2230–2235
https://doi.org/10.1016/j.psj.2019.10.076

INTRODUCTION

In 2017, 10.4 million broiler breeder hens (for meat production) and 51.6 million laying hens (for egg production) were raised in Korea (Korea Poultry Association, 2017). Worldwide, approximately 2.6 billion laying hens are not used for human consumption; they are mostly used for animal feed (Navid et al., 2011). The number of slaughtered hens also increases with animal age owing to the deterioration in the egg production rate. Old broiler breeder hen (**OBH**) and old laying hen (**OLH**) usually outlive their productive lives at about 60–72 wk (Bramwell et al., 1996; Wang et al., 2013). The phenomenon leads to economic burden to the farmers as well as environmental problems such as microbial and chemical contamination of burial sites (Kim and Kim, 2012).

Old broiler breeder hen has a high edible meat yield (high amounts of protein) and strong flavor but has a tough texture due to cross-linking between connective tissues (Giri et al., 2018). Old laying hen contains high myofibrillar protein and omega-3 fatty acid contents but a low edible meat yield and poor sensory traits (including toughness) (Hur et al., 2011). Thus, the poor organoleptic properties of both OBL and OLH explain their low market value, despite their potential as protein sources. Hence, comparative analyses of the physicochemical characteristics and applications of OBHs and OLHs have been narrowly performed (Reddy et al., 2016).

Therefore, the aims of this study were to determine (1) the physicochemical characteristics of chicken breast and thigh meats from OBHs and OLHs and (2) the

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Received July 4, 2019.
Accepted October 29, 2019.

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quality properties of pressed ham made with chicken breast and thigh meats from OBHs and OLHs with different formulas.

MATERIALS AND METHODS

Preparation of Chicken Breast and Thigh Meats From OBH and OLH

At 24-h postmortem, chicken OBHs (75 ± 2 wk; n = 50) and OLHs (77 ± 3 wk; n = 50) breasts (*pectoralis major*) and thighs (*biceps femoris*) were provided by a slaughterhouse (Jung Food, Gyeonggi, Korea). Subcutaneous fat and visible connective tissues were removed from the chicken muscles. Each chicken breast or thigh sample was cut into 2 portions and randomly divided into 2 sections. One section was used for analyses of physicochemical properties, including pH, color, sarcomere length, water holding capacity (**WHC**), cooking loss, and shear force. The other section was used to manufacture pressed ham. Processing was repeated for 2 batches on different days.

Physicochemical Analysis of Different Chicken Meats From OBH and OLH

pH Measurement The pH value of each chicken meat sample in distilled water (1:4) was determined using a pH meter (Model 340; Mettler-Toledo GmbH Analytical, Schwerzenbach, Switzerland).

Color Evaluation Color measurements were obtained after 25-min bloom time using a colorimeter (Chroma meter CR-210; Minolta, Tokyo, Japan; Illuminate C, calibrated with a white standard plate, L^* = 97.83, a^* = -0.43, b^* = +1.98), with diameters of 8 mm for the measuring area and 50 mm for the illumination area. Color values (CIE L^*, a^*, and b^*) were measured on the surface of meat samples in triplicate.

Sarcomere Length Samples for sarcomere length measurements (300 mg) were placed in a fixative (2% glutaraldehyde) for 30 min, and measurements were obtained by optical diffraction using a helium–neon laser (Model NO. 212-2; Spectra-Physics, Santa Clara, CA) according to Voyle (1971).

Shear Force For the determination of shear force, each sample was cooked individually with polyethylene bags immersed in a 80°C water bath (Model 10-101; Daehan Co., Seoul, Korea) for 30 min until the internal temperature reached 72°C. After cooking, the samples were cooled in ice water for 1 h and 6 cores (diameter, 1.27 cm) were taken in the longitudinal direction of muscle fibers. Shear force values were determined using a Warner–Bratzler shear attachment on a texture analyzer (TA-XT2*i*; Stable Micro Systems Ltd., Godalming, UK). Test speeds were set at 5 mm/s. Data were collected and shear force values (N) were used to obtain the maximum force required to shear each sample.

Water Holding Capacity The WHC was determined in triplicate by the filter paper press method (Choe and Kim, 2019a). Samples of 0.3 g were weighed on Whatman No. 2 filter paper and pressed between 2 Plexiglass plates for 3 min. The areas of pressed water and sample were measured using a planimeter (Type KP-21; Koizumi, Tokyo, Japan). Water holding capacity was calculated as follows: WHC (%) = area of pressed sample/area of pressed water × 100.

Cooking Loss The cooking loss for each treatment was determined by weighing meat or meat batters before and after cooking as follows: cooking loss (%) = [(weight of uncooked sample (g) – weight of cooked sample (g))/ weight of uncooked sample (g)] × 100. The cooking was conducted as described in the section Shear force.

Pressed Ham Manufacturing

Chicken breast and thigh meat samples from OBHs and OLHs were cut into cubes and cured at 4°C for 24 h with 1.2% nitrite pickled salt (salt: nitrite = 99.4:0.6). The cured chicken meat was grounded through a 6-mm plate using a meat grinder. Three meat mixtures (mixture A, 50% breast and 50% thigh from OBHs; mixture B, 50% breast and 50% thigh meat from OLHs; mixture C, 25% breast and 25% thigh from OBHs and OLHs, respectively) were prepared.

The pressed ham was produced (total 4.5 kg/batch) according to the following formulation: 80% chicken meat (meat mixture A, B, and C, respectively), 10% pork backfat, 10% ice water, 1% sugar, 0.3% sodium tripolyphosphate, 0.03% ascorbic acid, 0.6% mixed spice, and 0.1% monosodium glutamate, based on the total weight of the meat batter. All ingredients and additives were mixed using a mixer (RM-20; Mainca Co., Barcelona, Spain) at 4°C for 1 h. The meat batter was stuffed into a pressed ham retainer (5 × 2.5 × 17 cm, width × length × height; 350 ± 3 g) with cellophane film (thickness, 0.036 mm; oxygen permeability, 80 CC/m^2) using a stuffer (IS-8; Sirman, Marsango, Italy). The stuffed meat batter was dried at 60°C for 30 min and smoked at 65°C for 30 min and then cooked using a combination chamber (10.10ESI/SK; Alto Shaam, Menomonee Falls, WI) until the core temperature reached 72°C, as monitored using a temperature logger (Thermo TP 20 Thermometer; i-Tronics, Reno, NV). The cooked samples were immediately placed in ice water and at 4°C to cool, vacuum-packed, and stored at 4°C until analyses.

Quality Analysis of Chicken Pressed Ham Made With Different Chicken Breeds

pH, Color, and Cooking Loss The pH, color, and cooking loss were evaluated using the aforementioned methods (see Physicochemical Analysis of Different Chicken Meats From OBH and OLH).

Texture Profile Analysis of Pressed Ham A texture profile analysis of each sample was performed in quadruplicate. Samples were cut to equal sizes (25 mm height × 25 mm width × 25 mm depth). The textural properties of each sample were measured using a cylindrical probe (φ 20 mm diameter) attached to a Texture

Table 1. pH and instrumental color of chicken breast and thigh meats from old broiler breeder hen and old laying hen.

Traits	Breast			Thigh			Effect of muscle location (*P*-value[1])
	OBH	OLH	*P*-value[1]	OBH	OLH	*P*-value[1]	
pH							
Uncooked	5.73 ± 0.05	5.77 ± 0.06	NS	6.30 ± 0.02	6.21 ± 0.04	**	***
Cooked	5.90 ± 0.04	5.91 ± 0.03	NS	6.57 ± 0.08	6.44 ± 0.04	**	**
CIE L*	55.34 ± 1.35	57.17 ± 1.19	NS	47.45 ± 1.50	49.65 ± 0.96	**	***
CIE a*	12.49 ± 0.66	10.75 ± 0.53	*	14.89 ± 1.28	14.67 ± 1.43	NS	***
CIE b*	6.78 ± 0.49	7.73 ± 1.33	**	3.87 ± 0.76	4.80 ± 0.79	**	***

Mean ± standard deviation.
Abbreviations: OBH, old broiler breeder hen; OLH, old laying hen.
[1]NS: nonsignificance; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Analyzer (TA-XT2*i*; Stable Micro Systems Ltd., Surrey, UK). The test conditions were as follows: stroke, 19.6 N; test speed, 2.0 mm/s; distance, 15 mm. The texture profile analysis parameters, that is, hardness [peak force on first compression (N)], springiness [ratio of the sample recovered after the first compression], cohesiveness [ratio of active work done under the second force-displacement curve to that done under the first compression curve], gumminess [hardness × cohesiveness (N)], and chewiness [hardness × cohesiveness × springiness (N)], were computed.

Sensory Evaluation of Pressed Ham Sixteen panelists with experience in the sensory evaluation of meat products (age: 20–35 years) were recruited. Before the test, panelists were trained using commercial pressed ham 4 times during a 2-week period as described by Kim (1997). Each precooked sample was reheated to a 70°C internal temperature in an oven and sliced to a thickness of 10 mm, coded randomly, and served to panelists (2 pieces/treatment). A 10-point descriptive scale was used to evaluate attributes, such as color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable). Panelists cleansed their palate with water between samples.

Statistical Analysis

Data were collected for 3 batches (n = 3) on 2 different days. Chicken meat samples were analyzed and 3 treatments (mixtures A, B, and C) were used to manufacture each batch. In each batch, 2 measurements were performed. The data obtained from breast and thigh meats from OBHs and OLHs were analyzed using the independent-samples *t*-test implemented in SPSS version 18.0 (SPSS Inc., Chicago, IL) with significance levels of 0.05 (*), 0.01 (**), or 0.001 (***). For data from pressed ham, analyses of variance were performed for all measured variables using the general linear model procedure within the SAS statistical package. Duncan's multiple range test ($P < 0.05$) was used to determine statistical differences among treatment means. The linear regression equation, significance of the slope, and correlation coefficient (R^2) were calculated using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Chicken Breast and Thigh Meats From OBH and OLH

The pH values of meat samples were dependent on the chicken breed and muscle location (Table 1). The pH values of breast meat were not affected ($P > 0.05$) by the chicken breed. However, for thigh meat, OBH had higher ($P < 0.01$) pH values than those of OLH. Regardless of chicken breed, thigh samples had significantly higher pH values than breast samples, consistent with Sampaio et al. (2012), who reported that breast and thigh meats exhibit pH values of 5.7–6.4 and 6.3–6.9 during storage, respectively. The pH values of meat can influence physicochemical characteristics, including color, WHC, and tenderness (Honikel, 1987).

The chicken breed or muscle location generally influenced the color of meat samples. Old laying hen showed higher L^* and b^* values ($P < 0.01$) and lower a^* values ($P < 0.01$) for both breast and thigh samples than those of OBH, except for a^* values of thigh meat. Similarly, Kim and Kim (2016) observed higher b^* values ($P < 0.05$) and lower a^* values ($P < 0.05$) in breast ham manufactured with OLH compared to that manufactured with OBH. In this study, pH values for meat samples would relate to L^* and b^* values. According to Fernandez-Lopez et al. (2004) and Hui (2006), meat color is mainly associated with the (1) heme pigment content, (2) chemical state of pigments, and (3) light scattering and absorption properties. In this study, as expected, there was a significant difference in a^* values between breast (type IIB white fiber) and thigh (type I and IIA red fibers) muscles (Suzuki et al., 1985) due to the level of myoglobin. Furthermore, the difference in color between chicken breeds or muscle locations might be explained by differences in the light scattering properties of sarcoplasmic proteins (Fernandez-Lopez et al., 2004). Swatland (2004) reported that the lightness of meat is closely linked to the pH value and sarcomere length. Low pH and short sarcomere lengths lead to an increase in light scattering and high L^* values. In this study, high

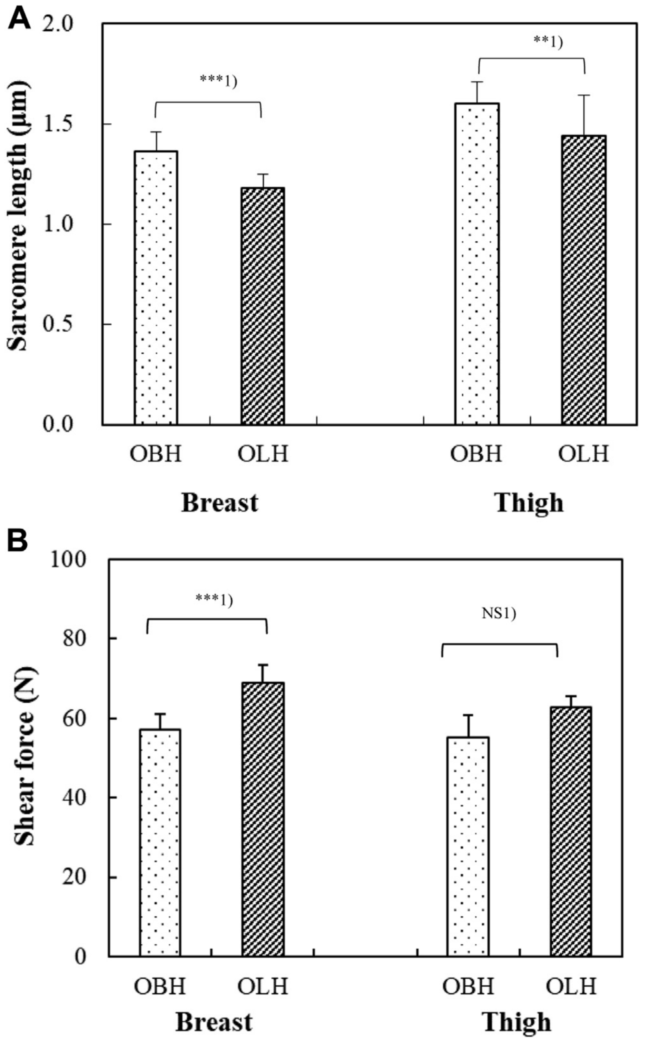

Figure 1. Sarcomere length and shear force of chicken breast and thigh meats from old broiler breeder hen (OBH) and old laying hen (OLH). $^{**}P < 0.01$; $^{***}P < 0.001$; NS, not significant.

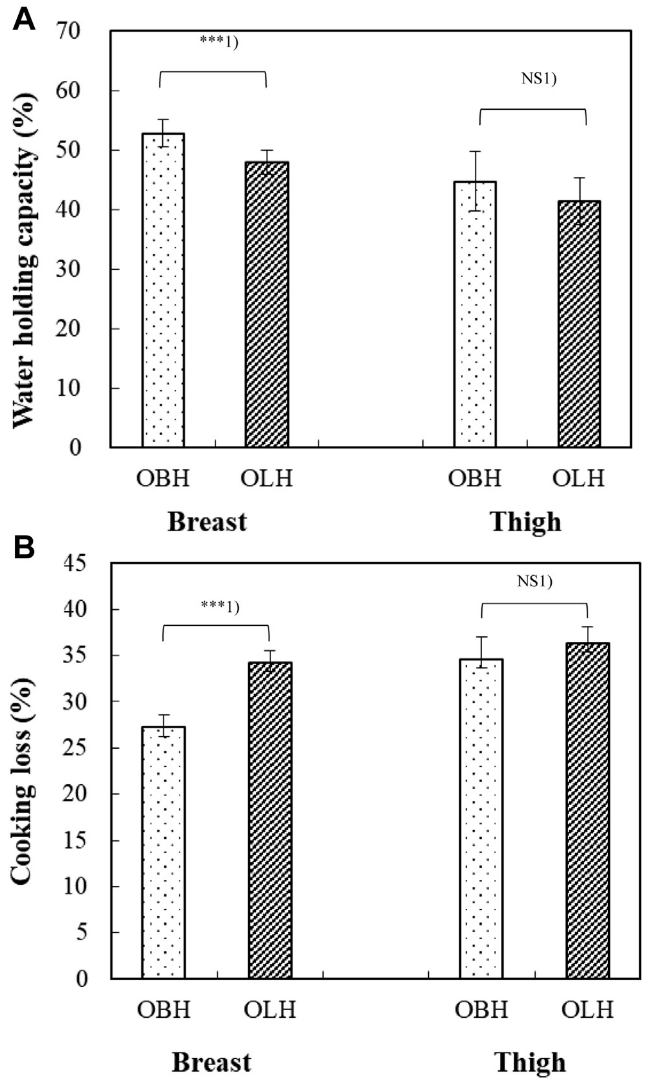

Figure 2. Water holding capacity and cooking loss of chicken breast and thigh meat samples from old broiler breeder hen (OBH) and old laying hen (OLH). $^{***}P < 0.001$; NS, not significant.

L^* values for OLH thigh meat might be explained by the relatively low pH and short sarcomere length compared to those of OBH meat (Figure 1).

The sarcomere lengths, defined as the area between 2 Z-lines, for chicken meat samples were significantly influenced by the chicken breed and muscle location, ranging from 1.36 to 1.60 μm (Figure 1). The OBH samples showed longer ($P < 0.01$ or $P < 0.001$) sarcomere lengths, regardless of muscle location. Significantly longer sarcomeres were observed in thigh meat than in breast meat. The shear force was dependent on chicken breed and muscle location, which ranged from 55.3 to 69.0 N. A previous study has reported that chicken breast possesses a tougher texture than chicken thigh under the same pH conditions (Asghar et al., 1984). In this study, a lower shear force ($P < 0.001$) was observed in breast samples from OBH with longer sarcomeres than in OLH samples. However, for thigh meat samples, similar ($P > 0.05$) shear force values were observed for OBH and OLH. Many studies have shown that the sarcomere length is positively related to tenderness (Davis et al., 1979; Sorheim et al., 2001). Accordingly, there might be an inherent structural difference, including differences in sarcomere length, fiber diameter, or structure, depending on breed (OBH or OLH). Buzala and Janicki (2016) reported that greater size of muscle fiber was observed in broilers compared to laying hens.

The WHC of raw meat indicates the amount of water that is retained during processing, including heating, grinding, freezing, thawing, and cooking (Hamm, 1986; Pearce et al., 2011). The released water can be expressed as drip, purge, thawing, or cooking loss (Dikeman and Devine, 2014). In this study, the WHC against pressure and water loss by cooking was 44.7–52.7% and 27.2–36.3%, respectively (Figure 2). For breast meat, OBH showed a higher ($P < 0.001$) WHC and lower cooking loss than OLH. No significant differences in the WHC and cooking loss of thigh meat were observed between OBH and OLH. The WHC and cooking loss were influenced by the chicken muscle location, with a higher ($P < 0.05$) WHC and lower ($P < 0.05$) cooking loss in breast samples with lower pH values

Table 2. Quality properties of pressed ham with chicken breast and thigh meats from old broiler breeder hen and old laying hen.

Traits	Type of mixture A[1]	B	C
pH			
Uncooked	6.29 ± 0.02[a]	6.20 ± 0.01[b]	6.24 ± 0.02[a,b]
Cooked	6.42 ± 0.01[a]	6.33 ± 0.02[c]	6.36 ± 0.01[b]
Cooking loss (%)	7.35 ± 0.25[c]	8.23 ± 0.19[a]	7.66 ± 0.21[a,b]
Color			
CIE L*	64.98 ± 1.35[b]	66.13 ± 1.67[a]	65.70 ± 1.24[a,b]
CIE a*	10.83 ± 0.58	10.29 ± 0.73	10.52 ± 0.40
CIE b*	9.54 ± 0.53[b]	10.90 ± 0.78[a]	10.74 ± 0.82[a]
Texture			
Hardness (N)	74.52 ± 1.32[c]	89.06 ± 1.06[a]	80.58 ± 1.45[b]
Springiness	7.76 ± 0.06	7.71 ± 0.05	7.76 ± 0.07
Cohesiveness	4.88 ± 0.06	4.81 ± 0.10	4.33 ± 0.05
Gumminess (N)	35.94 ± 0.55[c]	50.36 ± 0.54[a]	43.83 ± 0.69[b]
Chewiness (N)	30.16 ± 0.69[c]	45.35 ± 0.60[a]	38.36 ± 0.57[b]

Mean ± standard deviation.
[a-c]The letters within the same row indicate significant difference ($P < 0.05$).
[1]Mixture A, 50% breast and 50% thigh from old broiler breeder hen; mixture B, 50% breast and 50% thigh meat from old laying hen; mixture C, 25% breast and 25% thigh from old broiler breeder hen and old laying hen.

than in thigh samples with higher pH values. By contrast, Kadıoğlu et al. (2019) found that thigh meat with relatively high pH values shows a higher WHC than that of breast meat with relatively low pH values. According to previous studies, greater water absorption ability of myofibrillar proteins was exhibited in the breast muscle compared to myofibrillar proteins from the thigh muscle (Asghar et al., 1984; Xiong and Brekke, 1989). The conflicting results might be explained by the difference in chicken breed with different chemical properties including extent of protein denaturation. The optimal ratio of meat from 2 breeds and muscle location should be established for processed meat manufacturing with favorable quality properties due to differences in functional properties.

A close relationship between WHC and sarcomere length was reported by Ertbjerg and Puolanne (2017), who found that the WHC was lower when sarcomeres were shortened as a result of the stronger pull generated by a larger number of cross-bridges or a decrease in electrostatic repulsion due to the long distance between longitudinal filaments. However, a poor correlation between the WHC and sarcomere length has been reported by Xiong (2000). These contradictory results might be due to differences in intrinsic factors, including animal species, breed, and muscle fiber type.

Quality of Pressed Ham From Chicken Breast and Thigh Meats of OBH and OLH

Samples with mixtures A (made with OBH) and B (made with OLH) both before and after cooking showed the highest ($P < 0.05$) and lowest ($P < 0.05$) pH values, respectively, (Table 2). The result might be due to the higher pH value of thigh meat from OBH than the OLH counterpart. In general, the cooking loss, color, and textural properties of pressed ham samples (mixture A, B, or C) were consistent with the WHC, color, and tenderness of the chicken breed (OBH or OLH). A previous study has shown that the physicochemical properties of meat sources influence the quality characteristics of pressed ham, including the WHC and textural properties (Lee et al., 2007). Samples made from mixtures A and B showed the lowest and highest cooking loss, L^*, b^*, hardness, gumminess, and chewiness, respectively. No significant differences in a^*, springiness, and cohesiveness were detected among treatments.

Table 3. Sensory properties of pressed ham with chicken breast and thigh meats from old broiler breeder hen and old laying hen.

Traits	Type of mixture A[1]	B	C
Color[2]	8.90 ± 0.74[a]	8.20 ± 0.63[b]	8.10 ± 0.53[b]
Flavor	8.30 ± 0.67	8.10 ± 0.67	8.10 ± 0.74
Tenderness	8.10 ± 0.74	7.70 ± 0.82	7.50 ± 0.71
Juiciness	8.00 ± 0.67	7.90 ± 0.74	8.00 ± 0.67
Overall acceptability	8.40 ± 0.70[a]	7.70 ± 0.48[b]	7.70 ± 0.48[b]

[a,b]The letters within the same row indicate significant difference ($P < 0.05$).
[1]Mixture A, 50% breast and 50% thigh from old broiler breeder hen; mixture B, 50% breast and 50% thigh meat from old laying hen; mixture C, 25% breast and 25% thigh from old broiler breeder hen and old laying hen.
[2]Color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable).

Sensory Properties of Pressed Ham Made With Chicken Breast and Thigh Meats From OBH and OLH

The panel detected differences ($P < 0.05$) only in color and overall acceptability among the treatments (Table 3). In particular, mixture A scores for color and overall acceptability were significantly higher ($P < 0.05$) than those of mixtures B and C, as determined by the panel. The higher score for the color of mixture A might be related to the relatively lower L^* and b^* values determined by the instrumental color analysis compared to those of mixtures B and C. The panel did not detect a significant difference in tenderness among treatments, despite the difference in hardness of approximately 15 N ($P < 0.05$) between mixtures A and B. In a previous study (Choe and Kim, 2019b), a panel detected a significant difference in tenderness between sausage samples with a difference of 10 N based on instrumental hardness. This result might be due to the different types of meat product (pressed ham or sausage). In terms of overall acceptability, the combination of breast and thigh meat from OBH yielded pressed ham with more favorable sensorial properties compared to those of OLH or the combination of OBH and OLH.

CONCLUSION

In general, the physicochemical properties of chicken meat samples depended on the breed (OBH or OLH) and muscle location (breast or thigh). Based on the results of this study, breast and thigh meat from OBH could be used to obtain pressed ham with a better WHC, tenderness, and overall acceptability by instrument or panel analyses compared to those of OLH or the combination of OBH and OLH. The combination of OBH and OLH exhibited similar quality properties to those of ham samples with breast and thigh meat of OLH. For practical application, the acceptability of pressed ham made with breast and thigh meat from OBH should be further compared to one made with broiler meat.

ACKNOWLEDGMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2019R1I1A1A01059293).

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