Fat replacement in chicken sausages manufactured with broiler and old laying hens by different vegetable oils

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ABSTRACT The effect of old laying hen (**OLH**) and commercial broiler (**CB**) meat on emulsion-type sausages produced with different lipid types (canola, olive, and sunflower oils) to replace pork backfat was studied. To determine the physicochemical, textural, and microstructural properties, the proximate composition, color, pH, emulsion stability, cooking yield, water holding capacity, collagen content, textural properties, and scanning electron microscopy images of sausage samples were analyzed. Although there were significant differences in pH and emulsion stability between breed types (OLH and CB, $P < 0.05$), no significant differences were found for cooking yield and water holding capacity. The utilization of OLH meat in sausages produced higher total and insoluble collagen content than that of the CB meat. The replacement of pork backfat with olive oil produced the most similar texture to that of pork backfat among the lipid types used. The results showed the applicability of OLH meat in emulsion-type sausages and the use of vegetable oils, especially olive oil, might also be feasible.

Key words: old laying hen, broiler, vegetable oil, pork backfat, sausage

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INTRODUCTION

The number of laying hens has been increasing worldwide with a steady increase in egg production, reaching 73,890 thousand metric tons globally in 2017 (Conway, 2018). However, as their productivity becomes very low after 70 wk of age, the old laying hen (**OLH**) is disposed of, resulting in an economic burden to farmers as well as environmental problems such as microbial and chemical contamination of burial sites (Kim and Kim, 2012). Therefore, many studies have been conducted to identify the potential use of OLH, which can be used as a good protein-based food resource as it contains high protein and low fat, cholesterol, and calories compared with pork (Jeon et al., 2015). However, its tough texture compared with broilers has limited the utility of OLH meat in the industry. Therefore, it has been recommended to be used in a comminuted form, especially in emulsion-type sausages, where the processing shortens the structure of the connective tissue, which is responsible for the tough texture of the OLH meat with highly developed collagen crosslinking in its muscle that can be disintegrated (Souza et al., 2011).

Pork backfat is used for the manufacture of sausages owing to its great functionality. However, it contains cholesterol and saturated fatty acids, which increase health risk concerns in humans (Kim et al., 2016). Several studies have attempted to determine a method for reducing the pork backfat content in sausages by replacing pork backfat with vegetable oils such as canola oil and olive oil or a mixture of functional ingredients including collagen and dietary fiber (Youssef and Barbut, 2011; Choe and Kim, 2019).

Considering the quality of emulsion-type meat products, emulsifying is one of the most important processes, and it can be affected by the types of proteins and lipids used (Youssef and Barbut, 2009). Recently, Baek et al. (2016) compared the interaction of OLH meat and canola or flaxseed oil in sausages and found the potential of these oils as substitutes for pork backfat.

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However, to the best of our knowledge, the difference between commercial broiler (**CB**) and OLH meat on their emulsification with different vegetable oils has not yet been elucidated. Thus, the present study was undertaken to compare CB and OLH meat emulsification with 3 different vegetable oils (canola, olive, and sunflower oils) to use OLH meat in producing meat products with reduced pork backfat content.

MATERIALS AND METHODS

Raw Materials

At 12 h postmortem, CB (Ross, 5-weeks-old) and OLH (Hy-Line, 92-weeks-old) were purchased from 2 slaughterhouses (Jayeonilga, Paju, Korea and Maniker, Namyangju, Korea, respectively) and frozen immediately at −40°C. The frozen chicken carcasses were thawed at 4 ± 1°C for 16 h, and then, the breast meat was manually deboned and used to manufacture the meat products. Pork backfat was supplied from a local butchery (Seoul, Korea), and the vegetable oils (canola, sunflower, and olive oils) were purchased from a local market (©Oleificio Sabo, Romania, Italy; 100% purity).

Formulation and Processing of Sausages

In the present study, 3 batches of emulsion-type sausages were manufactured using CB and OLH meat and 4 different lipids (pork backfat, and canola, sunflower, and olive oils). The formulation of sausages was as follows: 60% ground chicken breast meat, 20% lipid, and 20% iced water with additives (1.2% salt and 0.2% sodium triphosphate). The meat was ground through a 5-mm plate and was then emulsified with each lipid, iced water, and additives in a silent cutter for 2 min (C4W, Sirman, Padova, Italy). During the procedure, the temperature of the mixture was maintained below 8°C and monitored using a digital thermometer (TM-747DU, Tenmars Electronics Co., Ltd., Taipei, Taiwan). After emulsification, each meat batter was stuffed in collagen casing (25-mm diameter; NDX, Viscofan, Ceske Budejovice, Czech Republic). These were cooked in a water bath (WB-22, Daihan Scientific, Wanju, Korea) at 80 ± 1°C until the core temperature reached 75 ± 1°C. The core temperature was monitored using a thermometer (TM-747DU, Tenmars Electronics Co., Ltd.).

Proximate Composition

The moisture, protein, and ash contents of the sausage samples were determined using the official methods of the AOAC international (Horwitz and Latimer, 2006). The moisture content was measured based on the weight loss of the sample after drying at 105°C for 12 h in a drying oven (DS-520L, Daewon Science, Bucheon, Korea). The protein content was obtained by the Kjeldahl method using an automatic Kjeldahl nitrogen analyzer (Kjeltec 2200 Analyzer Unit, Foss Analytical AB, Höganäs, Sweden). The lipid content was determined by the method of Folch (1957) using a 2:1 ratio of chloroform and methanol. The ash content was evaluated according to the AOAC method (Horwitz and Latimer, 2006).

Color Analysis

The surface color of the sausages was measured using a colorimeter (CM-5, Konica Minolta Co., Ltd., Osaka, Japan) with an 8-mm measuring area, calibrated with standard black and white calibration plates (CM-A210, Konica Minolta Co., Ltd., Osaka, Japan). The color values were recorded and expressed as L* (+brightness, − darkness), a* (+redness, − greenness), and b* (+yellowness, − blueness).

pH Value

The pH values of the sausages were measured using a pH meter (SevenGo, Mettler-Toledo International Inc., Schwerzenbach, Switzerland). Briefly, 5 g of sample and 20 mL of distilled water were homogenized for 30 s (T10 basic, Ika Works, Staufen, Germany), and the pH value of the homogenate was measured.

Emulsion Stability

The emulsion stability of each meat batter was measured according to the methods described by Lee et al. (2019). At the middle of the 15 mL glass tubes (Pyrex Chojalab Co., Seoul, Korea), a 4 × 4 cm, 25 mesh sieve was set. The batter was filled on the mesh which was placed in the glass tube. The glass tubes were closed and heated in an 80 ± 1°C water bath (WB-22, Daihan Scientific) to a core temperature of 75 ± 1°C. After cooling at room temperature (20–25°C) for 12 h to facilitate fat and water layer separation, the volume (mL) of the water and lipid separated at the bottom of the glass tube were measured and calculated as a percentage:

$$\textit{Water loss}\ (\%) = \frac{\textit{Separated water after heating}\ (mL)}{\textit{Weight before heating}\ (g)} \times 100$$

$$\textit{Lipid loss}\ (\%) = \frac{\textit{Separated lipid after heating}\ (mL)}{\textit{Weight before heating}\ (g)} \times 100$$

Cooking Yield

All sausages were cooked in a water bath (WB-22, Daihan Scientific) at 80 ± 1°C until the core temperature reached 75 ± 1°C. The core temperature was monitored using a real-time mode thermometer with a probe-type thermocouple (TM-747DU, Tenmars Electronics Co., Ltd.). The cooking yields were then

determined from the weight of the sausages before and after cooking:

$$Cooking\ yield\ (\%) = \frac{Weight\ of\ cooked\ sample\ (g)}{Weight\ of\ raw\ sample\ (g)} \times 100$$

Water Holding Capacity

The moisture content of sausages was determined according to the AOAC method (Horwitz and Latimer, 2006). The sausage sample (5 g) was chopped and placed on a filter paper and was then centrifuged at 252 × *g* for 10 min (Continent 512R, Hanil Co., Ltd., Incheon, Korea). The water holding capacity (**WHC**) percentage was calculated using the following formula:

$$Released\ water\ (\%) = Weight\ before\ centrifuging\ (g) - Weight\ after\ centrifuging\ (g)$$

$$Water\ holding\ capacity\ (\%) = \frac{Moisture\ content\ (g) - Released\ water\ (g)}{Moisture\ content\ (g)} \times 100$$

Collagen Content

The content of total and insoluble collagen was determined according to the methodology described by Palka (1999) with some modifications. Briefly, total collagen content was determined by hydrolyzing 1 g of sausage sample with 6 N hydrogen chloride at 110°C for 16 h. Hydrolysates were neutralized with 6 N sodium hydroxide and diluted using distilled water to 500 mL. After clarifying by filtration with Whatman No. 1 filter paper, 4 mL of the filtrate was mixed with 2 mL of chloramine T (1.41 g chloramine T, 10 mL distilled water, 10 mL *n*-propanol, and 80 mL citric buffer at pH 6) and was then allowed to react for 20 min at 20°C. Next, 2 mL of 4-dimethyl-aminobenzaldehyde solution (10%, in 35 mL 60% perchloric acid and 65 mL isopropanol) was added. The mixture was shaken and heated in a water bath (WB-22, Daihan Scientific) at 60°C for 1 h. The sample was cooled with tap water, and its absorbance analyzed at 558 nm using a spectrophotometer (X-ma 3100, Human Co. Ltd., Seoul, Korea). The hydroxyproline content of the sample was determined using hydroxyproline standard curves and was calculated as collagen using a coefficient of 0.99.

Insoluble collagen was determined using 5 g of homogenized sample with 24 mL of Ringer's reagent (3-fold dilution of sodium chloride 8.6 g + potassium chloride 0.3 g + calcium chloride dihydrate 0.33 g in 1 L distilled water). The homogenate was heated in a 77°C water bath (WB-22, Daihan Scientific) for 70 min. After centrifugation at 1,331 × *g* for 30 min, the supernatant was discarded. Using the same volume of Ringer's reagent, the pellet was washed and centrifuged again. Then, the insoluble collagen content of the pellet was determined following Palka's (1999) method above.

Texture Profile Analysis

Sausage samples (Ø 2.5 cm) were cut into 2 cm height and were then analyzed using a TA1 texture analyzer (AMETEK Lloyd Instruments Ltd., Fareham, UK). A compression plate of Ø 70 mm was attached to the analyzer that compressed the samples twice to 60% of their original height (test speed of 2.0 mm/s, trigger force of 0.1 N). The data were analyzed using the NexygenPlus software program (AMETEK Lloyd instruments Ltd.). The hardness (Newton, **N**), cohesiveness, springiness, chewiness (N), and gumminess (N) were recorded.

Scanning Electron Microscopy

Scanning electron microscopy was performed according to the methods described in the study by Andres et al. (2006). Small rod-shaped pieces of sausages of approximately 0.5 cm long and 0.3 cm thick were prepared. The samples were fixed using Carnoy fluid (60% ethyl alcohol, 30% chloroform, and glacial 10% acetic acid, v/v) at 4°C for 24 h, and they were then dehydrated at 4°C using ethyl alcohol: 70% (12 h), 95% (2 h), and 100% (2 h). The samples were then immersed twice in hexamethyldisilazane for 10 min each and dried in a fume hood. The dried samples were carefully mounted on carbon taped aluminum stubs and were coated with a layer of platinum under vacuum (EM ACE600, Leica Microsystem, North Ryde, NSW, Australia), facilitating surficial visualization. Micrographs of the samples were obtained with a Zeiss Sigma field emission scanning electron microscope (AURIGA, Carl Zeiss Microscopy, Thornwood, NY).

Statistical Analysis

All experiments were performed in triplicate with 3 batches of sausages on different days. Statistical analysis for each single effect (type of chicken breed [n = 6] and lipid [n = 12], 5 observation numbers for each replication) was performed using one-way analysis of variance, and significant differences were identified using Student–Newman–Keuls multiple range test in the SAS statistical software program (SAS, Release 9.4; SAS Institute Inc., Cary, NC) with a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Proximate Composition

The proximate composition of emulsion-type sausages prepared from different chicken breeds and lipid types revealed that the moisture content of the CB sausages was higher than that of the OLH sausages (Table 1, $P < 0.01$), whereas the different vegetable oils did not

Table 1. Effect of breed and lipid type on proximate composition (%) of chicken sausages with various vegetable oils.

Treatment	Moisture	Protein	Lipid	Ash
Breed type				
Commercial broiler	61.66 ± 1.53^{A}	14.23 ± 1.25^{B}	17.03 ± 1.60^{B}	2.32 ± 0.16^{A}
Old laying hen	59.33 ± 2.64^{B}	15.86 ± 0.88^{A}	19.58 ± 3.79^{A}	2.06 ± 0.18^{B}
Lipid type				
Pork backfat	61.05 ± 2.12	15.17 ± 1.83	16.17 ± 2.64	2.21 ± 0.20
Canola oil	61.16 ± 1.89	14.66 ± 1.13	16.71 ± 1.95	2.16 ± 0.18
Olive oil	60.43 ± 2.96	15.72 ± 1.11	20.05 ± 1.25	2.22 ± 0.35
Sunflower oil	60.37 ± 3.07	14.96 ± 1.13	19.43 ± 2.92	2.17 ± 0.17
P-value				
Breed type	0.0003	<0.0001	0.0259	<0.0001
Lipid type	0.2410	0.3143	0.0310	0.9316

^{A,B}Means with different letters between breed type are significantly different ($P < 0.05$).
All values are mean ± SD (breed type; n = 6, lipid type; n = 12).

cause any significant differences. The differences in moisture content between the CB and OLH sausages might be related to the different WHC of each raw meat material. Jeon et al. (2015) reported that CB meat had a higher WHC than that of OLH meat ($P < 0.05$). Additionally, owing to the lower moisture content of OLH sausages, the amount of protein, and lipid, these sausages contained was significantly higher than those in the CB sausages. Thus, the retained water in the CB sausages produced proportional differences in the protein and lipid contents. These trends regarding the proportion of moisture, lipid, and protein contents of CB and OLH sausages are similar to those found by Biswas et al. (2006) who compared the qualities of patties prepared from CB and OLH meat. Meanwhile, the difference in ash content might be caused by the influence of significantly higher ash content in CB meat (Jung et al., 2013).

Color

OLH meat (L* = 63.48 ± 4.67, a* = 5.58 ± 1.56, b* = 21.49 ± 1.71) had a brighter and yellower color than CB meat (L* = 58.61 ± 1.06, a* = 5.97 ± 0.41, b* = 19.08 ± 2.12). The use of OLH meat resulted in a higher L* value of the sausages compared with those prepared from CB meat owing to their original meat color ($P < 0.05$, Table 2). In contrast, the b* value of the sausages did not show any significant difference. The a* value of the chicken sausages was lower when OLH meat was used. Regarding lipid type, canola oil had a higher L* value than that of the others, whereas the pork backfat and olive oil had the significantly highest a* and b*values, respectively ($P < 0.001$). These differences in color are attributed to each lipid type. Canola oil had the highest L*value among the oils used (80.97 ± 0.85, $P < 0.05$), and olive oil had an indigenous yellow-gold color, resulting in the highest b* value among all the oils used (18.44 ± 0.88, $P < 0.05$). These results are consistent with those of previous studies that attempted to replace the pork backfat totally (Baek et al., 2016) or partially (Choi et al., 2009) in meat products with various vegetable oils. Baek et al. (2016) reported that the OLH sausages prepared with canola oil exhibited a higher L*value than those prepared with pork backfat or flaxseed oil ($P < 0.05$). Choi et al. (2009) reported that among the tested lipid types (pork backfat and olive, grape, corn, canola, and soybean oils), the treatments with pork backfat had the highest a* value, whereas their b* value was lower than those prepared with olive oil on cooked pork emulsion.

pH Value

The pH values of the emulsion-type sausages were significantly affected by both breed and lipid types (Table 3, $P < 0.0001$). The higher pH values (CB, pH 5.90 ± 0.01; OLH, pH 5.85 ± 0.01, $P < 0.05$) of the CB meat itself led to significantly higher pH values of sausages containing CB meat compared with sausages containing OLH meat. Considering the lipid type, pork backfat increased ($P < 0.05$) the pH value of sausages, whereas olive oil decreased ($P < 0.05$) the pH value. In a previous study (Bloukas and Paneras, 1993), a similar result was obtained to that of the present study where the addition of pork backfat led to higher pH values than that for olive oil in a low-fat frankfurter.

Cooking Yield, WHC, and Emulsion Stability

In general, the cooking yield, WHC, and emulsion stability are highly affected by the pH value of meat products (Kuo and Chu, 2003). In the present study, the

Table 2. Effect of breed and lipid type on the color of chicken sausages with various vegetable oils.

Treatment	L* value	a* value	b* value
Breed type			
Commercial broiler	80.90 ± 1.39^{B}	1.24 ± 0.50^{A}	15.16 ± 1.49
Old laying hen	81.58 ± 1.07^{A}	0.68 ± 0.16^{B}	15.24 ± 1.49
Lipid type			
Pork backfat	80.36 ± 0.40^{b}	1.56 ± 0.61^{a}	14.55 ± 0.50^{b}
Canola oil	82.02 ± 1.18^{a}	0.75 ± 0.24^{b}	14.30 ± 0.46^{b}
Olive oil	80.89 ± 1.14^{b}	0.97 ± 0.45^{b}	16.52 ± 1.61^{a}
Sunflower oil	81.08 ± 1.54^{b}	0.95 ± 0.38^{b}	15.14 ± 1.50^{b}
P-value			
Breed type	0.0184	<0.0001	0.8261
Lipid type	0.0006	<0.0001	<0.0001

^{A,B}Means with different letters between breed type are significantly different ($P < 0.05$).
^{a,b}Means with different letters between lipid type are significantly different ($P < 0.05$).
All values are mean ± SD (breed type; n = 6, lipid type; n = 12).

Table 3. Effect of breed and lipid type on pH, cooking yield, water holding capacity, and emulsion stability of chicken sausages with various vegetable oils.

Treatment	pH	Cooking yield (%)	Water holding capacity (%)	Emulsion stability (%)	
				Water loss	Oil loss
Breed type					
Commercial broiler	6.25 ± 0.03^{A}	95.41 ± 2.48	75.22 ± 9.06	6.83 ± 2.81^{B}	0.40 ± 0.76
Old laying hen	6.14 ± 0.05^{B}	95.13 ± 2.61	70.69 ± 10.02	14.43 ± 2.23^{A}	0.11 ± 0.29
Lipid type					
Pork backfat	6.26 ± 0.02^{a}	95.05 ± 2.80	80.69 ± 3.59	9.33 ± 1.84	0.10 ± 0.22
Canola oil	6.21 ± 0.06^{ab}	95.18 ± 2.53	72.50 ± 10.59	7.59 ± 5.22	0.06 ± 0.17
Olive oil	6.18 ± 0.03^{b}	95.38 ± 2.58	71.21 ± 10.38	11.67 ± 4.32	0.55 ± 0.87
Sunflower oil	6.20 ± 0.08^{ab}	95.23 ± 2.59	72.16 ± 10.48	10.70 ± 4.75	0.3 ± 0.67
P-value					
Breed type	<0.0001	0.6298	0.1370	<0.0001	0.2050
Lipid type	0.0614	0.9849	0.2320	0.2488	0.3465

^{A,B}Means with different letters between breed type are significantly different ($P < 0.05$).
^{a,b}Means with different letters between lipid type are significantly different ($P < 0.05$).
All values are mean ± SD (breed type; n = 6, lipid type; n = 12).

lower pH value of the OLH sausages might have led to the lower emulsion stability with higher water loss than that of the CB sausages (Table 3, $P < 0.0001$). A lower pH value induces a negative charge of the myofibrillar protein and results in a reduced interfilament spacing that can retain moisture (Jo et al., 2018). Additionally, the different characteristics of their proteins may affect water loss. In our previous study, we found that the myofibrillar protein of CB meat had a more intense band on the 200 kDa myosin heavy chain than that of OLH meat (Shin et al., 2017). Because the myosin heavy chain acts as a protein unit that participates in the formation of the oil–water interface (Galluzzo and Regenstein, 1978), during the emulsification, the higher myosin heavy chain content of the CB meat might induce better emulsion stability.

Although there were significant differences in pH values and protein characteristics between OLH and CB sausages, no significant differences were observed for cooking yield and WHC among the breed types. This phenomenon was not expected as Jeon et al. (2015) evaluated physicochemical characteristics of OLH and CB and reported that OLH had lower WHC and higher cooking loss than that of CB ($P < 0.05$). The results in the present study could be attributed to the use of the collagen casing diminishing the changes in cooking yield and WHC. Ustunol (2009) reported that wrapping meat products with collagen films reduced shrink loss and increased the juiciness of meat products compared with the unwrapped treatment. In addition, Warner (2017) referred that the sausage casing could decrease the water loss or sample weight during cooking. These reports are implying an intervention by the collagen casing on the cooking yield or WHC of sausages. Warner (2017) added the possibility of reabsorption of outflowed water during cooling. This appears reasonable because free waters are bound in a heated meat emulsion system by capillary force in the interwoven gel structure (Gordon and Barbut, 1992). Owing to this structure, some of the outflowed water might be reabsorbed by capillary action; therefore, the difference in emulsion stability between treatments would not be reflected in the cooking yield and WHC of the sausages. Concurrently, there was no difference in emulsion stability, cooking yield, and WHC among sausages prepared with different lipid types.

Collagen Content

Considering the various aspects of collagen, the amount of divalent crosslinking that is insoluble is highly correlated to tenderness. Collagen crosslinking is developed based on the maturity of the animal (Purslow, 2005). Therefore, both the total and insoluble (which is crosslinked) collagen content of sausages from different chicken breeds were considered in the current study in which 5-week-old CB and 92-week-old OLH were compared in an emulsion system. The results presented a higher content of total/insoluble collagen in sausages containing OLH meat than that containing CB meat (Table 4, $P < 0.01$), possibly owing to breed type because the total collagen content in muscle has a low correlation with age (Nakamura et al., 1975; Lepetit, 2008). Additionally, CB meat has a lower total collagen content than that of OLH meat (Nowsad et al., 2000). However, the higher insoluble collagen contents of sausages produced with OLH meat did not cause any significant difference in

Table 4. Effect of breed and lipid type on the texture profiles of chicken sausages with various vegetable oils.

Treatment	Total collagen (% of muscle)	Insoluble collagen (% of muscle)
Breed type		
Commercial broiler	0.23 ± 0.15^{B}	0.11 ± 0.06^{B}
Old laying hen	0.42 ± 0.08^{A}	0.31 ± 0.04^{A}
Lipid type		
Pork backfat	0.47 ± 0.06	0.22 ± 0.02
Canola oil	0.24 ± 0.10	0.17 ± 0.10
Olive oil	0.31 ± 0.02	0.17 ± 0.13
Sunflower oil	0.36 ± 0.19	0.21 ± 0.15
P value		
Breed type	0.0024	<0.0001
Lipid type	0.2381	0.8465

^{A,B}Means with different letters between breed type are significantly different ($P < 0.05$).
All values are mean ± SD (breed type; n = 6, lipid type; n = 12).

Table 5. Effect of breed and lipid type on the texture profiles of chicken sausages with various vegetable oils.

Treatment	Hardness (N)	Cohesiveness	Springiness	Gumminess (N)	Chewiness (N)
Breed type					
Commercial broiler	30.87 ± 8.00	0.24 ± 0.02	0.46 ± 0.07	7.53 ± 1.15	3.19 ± 0.76
Old laying hen	29.12 ± 7.24	0.24 ± 0.02	0.48 ± 0.02	7.13 ± 2.08	3.31 ± 1.00
Lipid type					
Pork backfat	42.60 ± 3.71[a]	0.25 ± 0.02	0.44 ± 0.04	8.93 ± 0.48[a]	3.88 ± 0.34
Canola oil	26.73 ± 3.31[b]	0.24 ± 0.02	0.48 ± 0.08	6.43 ± 1.11[b]	3.03 ± 0.61
Olive oil	31.35 ± 7.81[b]	0.24 ± 0.03	0.47 ± 0.02	8.14 ± 2.23[a]	3.66 ± 1.20
Sunflower oil	27.98 ± 7.34[b]	0.23 ± 0.02	0.47 ± 0.02	7.12 ± 1.06[b]	2.91 ± 0.70
P-value					
Breed type	0.4065	0.6818	0.3901	0.4012	0.6508
Lipid type	<0.0001	0.4801	0.3172	0.0023	0.0263

[a,b]Means with different letters between lipid type are significantly different ($P < 0.05$).
All values are mean ± SD (breed type; n = 6, lipid type; n = 12).
Abbreviation: N, Newton.

textural properties in the present study. This could be because the effect of collagen was reduced owing to the comminution process of the meats (Souza et al., 2011)

Among the different lipid types, sausages with pork backfat tended to have a higher total/insoluble collagen content than the other vegetable oils. This phenomenon may be caused because pork backfat is an aggregation of the adipose tissues itself containing cell structures including collagen (Youssef and Barbut, 2010). There were more or less differences created by the different oils. However, as there are no studies that consider the effect of vegetable oils on collagen, this phenomenon was difficult to interpret.

Textural Properties

There were no significant differences in texture profile (e.g., hardness, cohesiveness, springiness, chewiness, and gumminess) for the sausages prepared from the different chicken breeds (Table 5). Because sausage texture is formed from the interaction among the charged polymers, which are fragments of muscle fibers, the pH can alter the interactions between muscle proteins. This can lead to a change in WHC and then in the textural characteristics of the sausages (Xiong and Moody, 1999). However, in the present study, differences in pH as well as the different quality properties such as WHC and the proximate composition between CB and OLH meat did not affect any texture profiles ($P > 0.05$). The difference in the lipid–protein interaction depending characteristics of meat protein (protein crosslinking, and hydrophobicity; Shin et al., 2017) and used lipids (fatty-acid chain length and locations of double bonds in the fatty acid chains; Youssef and Barbut, 2009; Miao et al., 2014) could offset the differences arising because of breed type, statistically with markedly high deviation. This could be partly interpreted by the effect of the collagen casing, as discussed previously. Gennadios et al. (1997) reviewed the effect of casing and coatings and showed that they could prevent the evaporation of moisture. Presumably, some of the vapor pressurized the meat batter inside the casing, and thus, the moisture that might have evaporated without the casing could be bound in the protein structures of the sausage. The bound water could influence the textural profiles of the sausages (Xiong and Moody, 1999) so that the differences in meat characteristics could be equalized, resulting in an insignificant difference in texture parameters.

Meanwhile, depending on the different lipid types, significantly different properties in hardness and gumminess were found in chicken sausages. In hardness, sausages with pork backfat exhibited a higher value than those with vegetable oils ($P < 0.0001$). Similar to this result, Alvarez et al. (2012) reported that the total replacement of pork backfat with canola oil in pork frankfurters resulted in significantly lower hardness than that of pork backfat. However, the opposite trend has been reported where the replacement of animal fat with canola oil (pork backfat, Baek et al., 2016; beef fat, Youssef and Barbut, 2011) increased the hardness of sausage. This could be explained by the higher amounts of saturated fatty acids that pork fat has influencing the hardness (Choe and Kim, 2019). Compared with vegetable oils, pork fat is solid at room temperature.

Scanning Electron Microscopy

The results from the scanning electron microscopy exhibited characteristics of a gel-like compact structure of usual heated meat-emulsion systems (Marchetti et al., 2015). In the present study, numerous cavities shaping a sponge-like structure were observed in all treatments (Figure 1). The cavities are responsible for the capillary action, which helps water to be held inside the heated meat emulsion (Liu et al., 2016). The CB sausage with pork backfat had the smoothest surface and finest cavities; therefore, it was well emulsified (Figure 1A). In the OLH sausage with pork backfat, an intact adipocyte was observed, which might be responsible for the higher hardness of the pork backfat sausage than that of the other treatments (Figure 1E). In other treatments, fat globules that were immobilized were shown; however, it was difficult to discriminate the differences in microstructure properties among the different oil treatments.

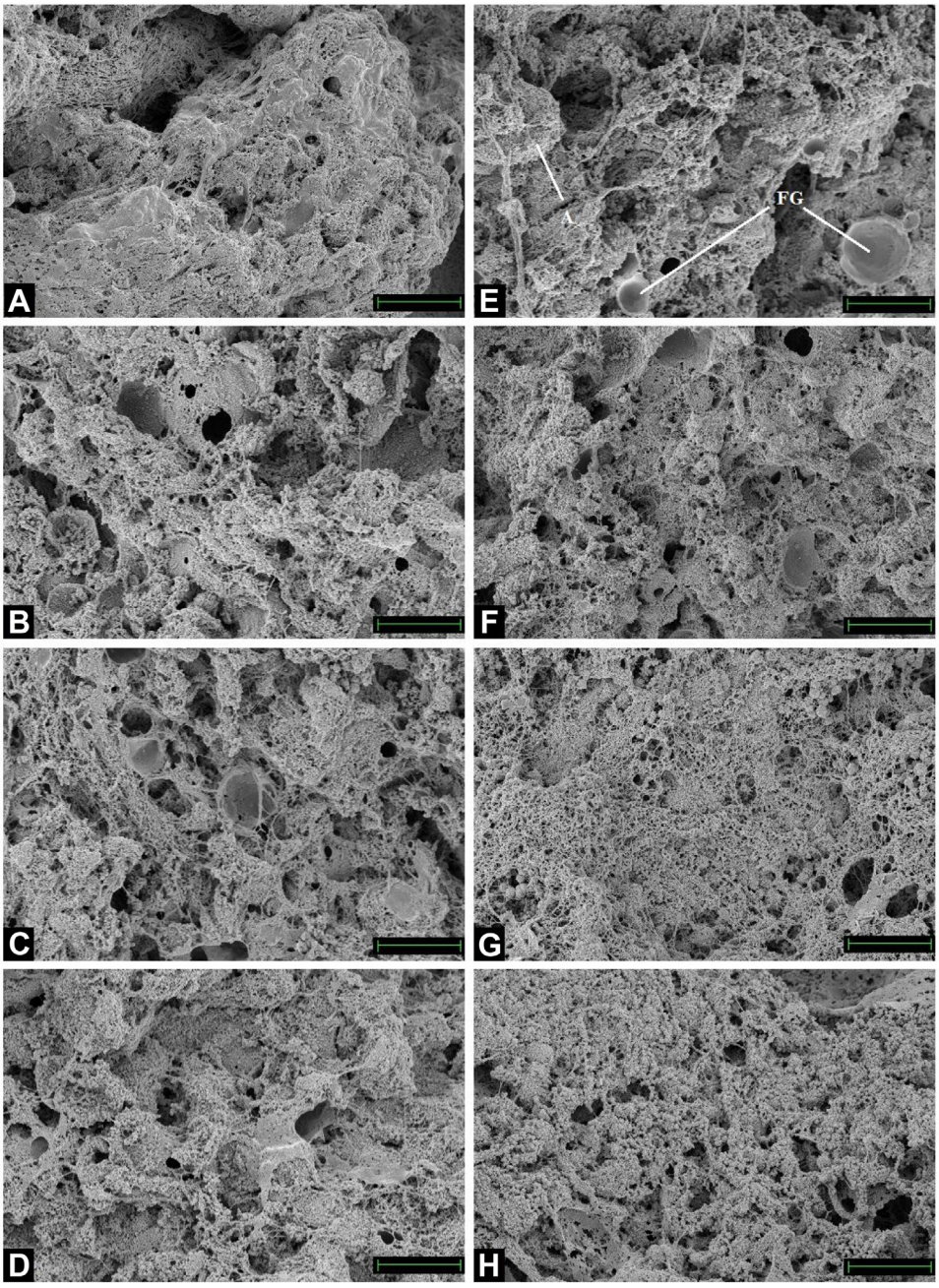

Figure 1. Scanning electron microscopy images of cooked chicken sausage with various vegetable oils: (A) Commercial broiler (CB) sausage with pork backfat, (B) CB sausage with canola oil, (C) CB sausage with olive oil, (D) CB sausage with sunflower oil, (E) Old laying hen (OLH) sausage with pork backfat, (F) OLH sausage with canola oil, (G) OLH sausage with olive oil, and (H) OLH sausage with sunflower oil. A, adipocyte; FG, Fat globule. Bar, 5 μm.

CONCLUSION

Based on the results of the present study, no adverse effects were found by using the different breed types as these could be compensated in a system of emulsion-type sausage manufacture. When considering different lipid types, OLH meat could be effectively used in emulsion-type sausages with vegetable oils, especially olive oil, as it resulted in texture profile most similar to the pork backfat-used sausages. In future studies, the characteristics of OLH meat and each vegetable oil will be investigated to elucidate their linkages in the emulsion system.

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