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Replacement of Pork Meat with Pork Head Meat for Frankfurters

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Abstract

The effect of reducing pork meat concentrations from 50% to 30% and replacing it with up to 20% pork head meat on chemical composition, cooking characteristics, physicochemical and textural properties, apparent viscosity, and sensory characteristics of frankfurters was determined. The highest moisture content in frankfurters was found in the control and T1 (frankfurter with 45% pork meat + 5% pork head). Protein and fat contents in frankfurters with pork head meat added were significantly ($p<0.05$) higher than those in the control. When the concentration of pork head meat was increased from 0% to 20%, cooking loss, total expressible fluid separation, fat separation, and pH of frankfurters were increased, while the lightness, redness, yellowness, and apparent viscosity of frankfurters were decreased. Ash contents, cohesiveness, color, and tenderness of sensory characteristics of frankfurters added with different amounts of pork meat or pork head meat were not significantly ($p>0.05$) different from those of the control or there treatments. Frankfurters in T4 (frankfurter with 30% pork meat + 20% pork head) had the lowest ($p<0.05$) hardness and gumminess. The hardness and gumminess of frankfurters in other treatments were not significantly different ($p>0.05$) from that in the control. Frankfurters with higher pork head meat concentrations had lower flavor, juiciness, and overall acceptability scores. Therefore, replacing pork meat with pork head meat in the formulation could successfully produce results similar to those of control frankfurters. The best results were obtained when 10% pork head meat was used to replace pork meat.

Keywords: pork meat, pork head, frankfurter, optimization, sensory characteristics

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Introduction

The meat processing industry is increasing 10% annually (Choi *et al*., 2015; Yun *et al*., 2013). Consumption patterns of meat products tend to be advanced, diversified, and convenient (Seo *et al*., 2014). Although the domestic meat processing industry is increasing in quantity every year, the quality of meat products is still insufficient (Kim and Lee, 2010). The quality of meat products can be affected by the prices of raw pork. Thus, the meat processing industry needs to improve its international competitiveness and sustainable development. Quality products at affordable prices can help the production and supply by replacing pork with by-products (Park, 2004).

Pork by-products include blood, bone, skin, feet, tail, red internal organs (liver, lung, heart, and kidney), white internal organs (large and small intestine), and head. By-product can provide energy, proteins, minerals, and vitamins required for human health (Kang *et al*., 2014; Seong *et al*., 2014). However, by-products are underutilized with low price because they are regarded as inferior protein source (Kim *et al*., 1999). Utilization of by-products in commercial products has so far been limited to the production of animal feed (Choi *et al*., 2009; Choi, 2013; Koh *et al*., 1984) due to their less desirable sensory quality and lower biological value of proteins with higher possibility of microbial contamination (Nuckles *et al*., 1990). However, food products will not be enough for people without using by-products (Choi *et al*., 2016; Hong *et al*., 2003). Thus, by-products should be used as food materials. Most studies on pork by-products have focused on the physicochemical properties of manufactured meat products containing by-products such as blood and skin (Choi *et al*., 2009; Choe *et al*., 2013). Utilizing pork head

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meat as food material has not been reported yet.

Pork head meat contains 21% tongue and 79% boneless meat. It provides collagen required for functional properties (Gonulalan et al., 2003; Park, 2004). The pork head meat has 57.0% moisture content, 20% protein content, 21.5% fat content, and high content of essential amino acids such as lysine, leucine, isoleucine, threonine, and phenylalanine (Ryu and Kim, 1984; Skarpeid et al., 2001). The head meat has been considered as an haute cuisine and served in great party of families with long history (Kim and Lee, 1998; Park, 2004). However, the consumption of pork head meat is being gradually reduced recently.

Therefore, the objective of this study was to determine the effect of reducing pork meat concentrations from 50% to 30% and replacing it with up to 20% pork head meat on chemical composition, cooking characteristics, physicochemical and textural properties, apparent viscosity, and sensory characteristics of frankfurters.

Materials and Methods

Frankfurters processing

Fresh pork ham, pork head, and pork back fat were purchased from a local processor at 48 h postmortem. All subcutaneous and intramuscular fat as well as visible connective tissues were removed from the muscle. Pork ham (moisture 55.24%, protein 17.85%, fat 18.54%, pH 5.75, L*-value 60.12, a*-value 14.24, b*-value 9.14), pork head (moisture 57.12%, protein 15.71%, fat 18.74%, collagen 5.62%, pH 5.87, L*-value 56.24, a*-value 17.02, b*-value 8.32), and pork fat (moisture 12.61%, fat 85.64%) were ground through an 8-mm plate. Each part of the pork head meat ratio was 78% meat and 22% tongue. Ground tissues were then placed in polyethylene bags, vacuum sealed using a vacuum packaging system, and stored at 0°C until use. Five different groups of frankfurters were produced.

The experimental compositions of frankfurters are shown in Table 1. The first frankfurters served as controls were prepared with 50% pork meat without any pork head meat. The remaining four groups were prepared with the following combinations of pork meat and pork head meat: T1, 45% pork meat + 5% pork head; T2, 40% pork meat + 10% pork head; T3, 35% pork meat + 15% pork head; T4, 30% pork meat + 20% pork head. Pork meat and pork head meat were homogenized and ground for 1 min 30 s in a silent cutter (Nr-963009; Hermann Scharfen GmbH & Co., Germany). Pork back fat, NaCl, and sodium tripolyphosphate were added to the meat and mixed for 1 min 30 s. Meat batters were homogenized for 3 min. The temperature was maintained below 10°C throughout batter preparation. The meat batter was stuffed into collagen casings (#240; NIPPI Inc., Japan; approximate diameter, 25 mm) using a stuffer (IS-8; Sirman, Italy). Meat batters were heated at 80°C for 60 min in a chamber (MAXi3501; Kerres, Germany) followed by cooling down at 21°C for 3 h (Choi et al., 2014).

Proximate composition

Compositional properties of the frankfurters were performed using AOAC (2000). Moisture content, fat content, protein content, and ash content were determined by oven drying method (950.46B), Soxhlet method (960.69), Kjeldahl method (981.10), and muffle furnace method (920.153).

Cooking loss

The meat batters were analyzed for cooking loss using the method of Choi et al. (2007) with the following.

Cooking loss (g/100g) = [(weight of raw meat batter (g) − weight of cooked meat batter (g)) / weight of raw meat batter (g)] × 100

Table 1. Frankfurters formulations with different pork head meat levels (units: g/100 g)

Ingredients	Treatments				
	Control	T1	T2	T3	T4
Pork ham	50	45	40	35	30
Pork head	-	5	10	15	20
Back fat	25	25	25	25	25
Ice	25	25	25	25	25
Total	100	100	100	100	100
Salt (NaCl)	1.5	1.5	1.5	1.5	1.5
Sodium tripolyphosphate	0.15	0.15	0.15	0.15	0.15
Sodium nitrite	0.01	0.01	0.01	0.01	0.01
Sorbitol	0.5	0.5	0.5	0.5	0.5

Emulsion stability

The meat batters were analyzed for emulsion stability using the method of Blouka and Honikel (1992) with the following.

Total expressible fluid separation (mL/g) = [(the water layer (mL) + the fat layer (mL)) / weight of raw meat batter (g)] × 100

Fat separation (mL/g) = [the fat layer (mL) / weight of raw meat batter (g)] × 100

pH

The pH values of samples were measured in a homogenate prepared with 5 g of sample and distilled water (20 mL) using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland).

Color measurements

The color of each samples was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta Ltd., Japan; illuminate C, calibrated with a white plate, L^*= +97.83, a^*=-0.43, b^*=+1.98). CIE L^*-value (lightness), CIE a^*-value (redness), and CIE b^*-value (yellowness) values were recorded.

Texture profile analysis

Texture profile analysis (TPA) was performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., England). The hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described by Bourne (1978). The frankfurters samples were taken from the central portion of each sample. The calculation of TPA values was obtained by graphing a curve using force and time plots (pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g).

Apparent viscosity

The meat batter viscosity was measured in a rotational viscometer (HAKKE Viscotester® 550, Thermo Electron Corporation, Germany) set at 10 rpm. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with meat batter and allowed to rotate under a constant share rate (s^{-1}) for 30 s (Shand, 2000).

Sensory evaluation

A trained 12-member panel consisting of researchers of the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea was used to evaluate the frankfurters at the time. This analysis was conducted using the Hedonic test described by Choi *et al.* (2008). The 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) of the cooked samples were evaluated using a 10-point descriptive scale.

Statistical analysis

Experimental design was a completely randomized design with total of three independent batches. One-way ANOVA was performed on all the variables using the general linear model (GLM) procedure of the SAS (Statistical Analysis Systems Institute, 2008) statistical package. Duncan's multiple range test ($p<0.05$) was used to determine the differences between treatment means.

Results and Discussion

Proximate composition

Proximate compositions of frankfurter with different amounts of pork meat and pork head meat are summarized in Table 2. The highest moisture content was found in the control and T1 frankfurters. When pork head meat level was increased from 0% to 20%, the moisture content of frankfurters was decreased. According to Choi *et al.* (2016), the head meat containing connective tissue was low water holding capacity and water binding capacity. The protein and fat contents in frankfurters added with pork head meat were significantly ($p<0.05$) higher than those in the control frankfurters. However, the ash contents in the frankfurters added with different amounts of pork meat and pork head meat were not significantly ($p> 0.05$) different from those in the control frankfurters. Park (2004) reported that the moisture, protein, and fat contents of sausage was not significantly different among treatments with different pork ham or pork head meat concentrations. In addition, there is no nutritional difference when pork meat is replaced with pork head meat (Park, 2004), similar to our results.

Cooking loss and emulsion stability

The cooking loss of frankfurters formulated with different amounts of pork meat and pork head meat is shown in Table 3. The cooking loss of frankfurters with pork head meat added was significantly ($p<0.05$) higher than that of

Table 2. Effect of various combinations of pork meat and pork head levels on proximate composition of frankfurters

Treatments[1]	Moisture content (%)	Protein content (%)	Fat content (%)	Ash content (%)
Control	61.37±0.14[a]	18.27±0.31[b]	16.08±0.26[b]	1.51±0.09
T1	61.20±0.47[a]	20.16±0.96[a]	17.86±0.95[a]	1.48±0.09
T2	59.96±0.73[b]	20.50±0.33[a]	17.99±1.15[a]	1.55±0.05
T3	59.73±0.33[b]	20.92±2.94[a]	18.43±0.95[a]	1.48±0.05
T4	59.05±0.74[b]	21.87±0.50[a]	18.72±0.34[a]	1.45±0.15

All values are mean±standard deviation of three replicates (n=9).
[a,b]Means within a column with different letters are significantly different ($p < 0.05$).
[1]Control, frankfurter with 50% pork meat; T1, frankfurter with 45% pork meat + 5% pork head; T2, frankfurter with 40% pork meat + 10% pork head; T3, frankfurter with 35% pork meat + 15% pork head; T4, frankfurter with 30% pork meat + 20% pork head.

Table 3. Cooking loss and emulsion stability of frankfurters with various pork meat and pork head meat levels

Treatments[1]	Cooking loss (%)	Emulsion stability	
		Total expressible fluid separation (%)	Fat separation (%)
Control	7.01±0.68[c]	5.71±0.61[d]	0.59±0.28[cd]
T1	8.76±0.56[b]	5.86±0.51[cd]	0.39±0.05[d]
T2	8.94±0.34[b]	7.08±1.06[bc]	0.78±0.15[bc]
T3	9.41±0.62[a]	8.28±1.08[ab]	0.98±0.23[b]
T4	9.45±0.82[a]	8.95±0.62[a]	2.53±0.25[a]

All values are mean±standard deviation of three replicates (n=9).
[a-d]Means within a column with different letters are significantly different ($p < 0.05$).
[1]Control, frankfurter with 50% pork meat; T1, frankfurter with 45% pork meat + 5% pork head; T2, frankfurter with 40% pork meat + 10% pork head; T3, frankfurter with 35% pork meat + 15% pork head; T4, frankfurter with 30% pork meat + 20% pork head.

control frankfurters. When the pork head meat level was increased from 0% to 20%, the cooking loss of frankfurters was also increased, in agreement with results of Park (2004) that cooking loss of sausages with increasing pork head meat level was increased. These results might be due to the composition of head meat. According to Lee et al. (2008), cooking loss of meat products can be affected by cooking method, additives, fat type, and raw meat type. The cooking loss of frankfurter in this study might be affected by proximate composition of pork head meat containing connective tissue.

Differences in emulsion stability of frankfurters formulated with different amounts of pork meat and pork head meat are shown in Table 3. The total expressible fluid separation and fat separation of frankfurters was significantly ($p < 0.05$) increased in frankfurters when the pork head level was increased from 0% to 20% due to the composition of head meat. The emulsion stability exhibited a similar trend to cooking loss. For these reason, the head meat with collagen is poor emulsion stability of meat batters (Choi et al., 2016). Lee et al. (2008) have reported that improving emulsion stability can result in high water binding and high water absorption. Therefore, emulsion stability is valuable quality criteria in meat processing. According to Choi et al. (2007), water holding capacity is dependent on both moisture and fat contents.

To maintain the appropriate juiciness of emulsion meat product, controlling the emulsion stability is very important. Some researchers have recommended that emulsion stability is an index of quality characteristics in emulsion meat products (Choi et al., 2008; Choi et al., 2015).

pH and color

The pH and color of meat batters and frankfurters formulated with different combinations of pork meat and pork head meat are shown in Table 4. Control meat batters and frankfurters had the lower ($p < 0.05$) pH values. The pH values of meat batters and frankfurters were significantly ($p < 0.05$) increased when pork head concentration was increased. This was due to the higher pH of pork head meat at 5.87. Similarly, Park (2004) has reported that the pH of emulsion sausages formulated with pork head meat was higher than that of the control. Kim et al. (1999) have indicated that the pH values of *pyunyuk* products added with pork head meat are significantly higher than those of the control *pyunyuk* products without any by-product added.

The differences in the lightness (CIE L^*- value), redness (CIE a^*- value), and yellowness (CIE b^*- value) values of meat batters and frankfurters with different combinations of pork meat and pork head meat are shown in Table 4. The lightness, redness, and yellowness values of

Table 4. Effect of various combinations of pork meat and pork head levels on pH and color of frankfurters

Treatments[1]	Batter				Frankfurter			
	pH	CIE L*-value	CIE a*-value	CIE b*-value	pH	CIE L*-value	CIE a*-value	CIE b*-value
Control	6.19±0.03[e]	76.73±0.41[a]	7.34±0.74[a]	13.86±0.54[a]	6.28±0.03[e]	76.75±0.84[a]	6.40±0.33[a]	10.84±0.60[a]
T1	6.23±0.02[d]	76.37±1.48[ab]	5.40±0.45[b]	13.40±0.58[ab]	6.32±0.02[d]	76.66±1.52[a]	5.87±0.50[b]	10.50±0.24[ab]
T2	6.27±0.02[c]	75.77±1.05[b]	5.31±0.65[b]	13.09±0.28[b]	6.36±0.03[c]	76.27±1.67[ab]	5.11±0.43[c]	10.47±0.39[ab]
T3	6.29±0.03[b]	74.90±0.60[b]	4.82±0.35[b]	13.00±0.61[b]	6.38±0.03[b]	75.79±1.80[ab]	4.93±0.23[c]	10.18±0.68[bc]
T4	6.32±0.02[a]	73.09±1.99[c]	4.81±0.52[b]	12.83±0.33[b]	6.44±0.02[a]	74.63±1.31[b]	4.91±0.49[c]	9.83±0.50[c]

All values are mean±standard deviation of three replicates (n=9).
[a-e]Means within a column with different letters are significantly different ($p<0.05$).
[1]Control, frankfurter with 50% pork meat; T1, frankfurter with 45% pork meat + 5% pork head; T2, frankfurter with 40% pork meat + 10% pork head; T3, frankfurter with 35% pork meat + 15% pork head; T4, frankfurter with 30% pork meat + 20% pork head.

Table 5. Effect of various combinations of pork meat and pork head levels on textural attributes of frankfurters

Treatments[1]	Hardness (kg)	Springiness	Cohesiveness	Gumminess (kg)	Chewiness (kg)
Control	0.26±0.03[a]	0.87±0.03[b]	0.42±0.02	0.11±0.02[a]	0.09±0.03[b]
T1	0.26±0.02[a]	0.88±0.06[b]	0.43±0.02	0.11±0.03[a]	0.10±0.03[ab]
T2	0.26±0.06[a]	0.95±0.06[a]	0.43±0.03	0.11±0.04[a]	0.11±0.03[a]
T3	0.25±0.03[a]	0.87±0.05[b]	0.43±0.01	0.11±0.02[a]	0.09±0.02[b]
T4	0.21±0.02[b]	0.88±0.02[b]	0.43±0.02	0.09±0.02[b]	0.08±0.02[c]

All values are mean±standard deviation of three replicates (n=9).
[a-c]Means within a column with different letters are significantly different ($p<0.05$).
[1]Control, frankfurter with 50% pork meat; T1, frankfurter with 45% pork meat + 5% pork head; T2, frankfurter with 40% pork meat + 10% pork head; T3, frankfurter with 35% pork meat + 15% pork head; T4, frankfurter with 30% pork meat + 20% pork head.

meat batters and frankfurters with pork meat and pork head meat were significantly ($p<0.05$) decreased when pork head meat concentration was increased. Similar trends in color of emulsion sausages were previously reported by Park (2004) when pork head meat is added to emulsion sausages. Kim and Lee (1998) reported that the color values of pork head meat products can be affected by proximate compositions of meat products, protein denaturation, and fat denaturation due to heating. These effects observed in this study could also be due to the color of pork head which is darker than pork lean meat.

Texture profile analysis

The textural properties of frankfurters formulated with different combinations of pork meat and pork head meat are shown in Table 5. Frankfurters in T4 had the lowest ($p<0.05$) hardness and gumminess. However, the hardness and gumminess of frankfurters in other treatments were not significantly ($p>0.05$) different from those of the control. Frankfurters in T2 had the highest ($p<0.05$) springiness. However, the cohesiveness of frankfurters in other treatments is not significantly ($p>0.05$) different from that of the control frankfurters. These results were in agreement with those of Park (2004) that the hardness of sausages added with pork head meat was not significantly different from that of the control sausage without any

pork head meat. Kim et al. (1999) have reported that all treatments added with pork by-products have significantly lower shear force than the control. Thus, emulsion sausages manufacturing may be able to replace pork meat with head meat to achieve the texture similar to that of the control frankfurter without any pork head meat.

Apparent viscosity

Replacing pork meat with pork head meat significantly affected the apparent viscosity of meat batters (Fig. 1). The apparent viscosity of meat batters with pork head was decreased when the pork head meat level was increased. Water holding capacity and water binding capacity of meat batters were weakened by the head meat with collagen (Choi et al., 2016), leading to the decreased the apparent viscosity. In addition, the viscosity values of both control and treatment samples were decreased when the rotation time was increased, thus, exhibiting a thixotropic behavior. These findings were in agreement with those of Park (2004) that the emulsion type sausages added with pork head meat had lower viscosity values compared to the control sausages without any pork head meat added. Choi et al. (2015) have reported that emulsion viscosity is correlated with emulsion stability in emulsion meat products. This study also revealed that higher apparent viscosity was correlated with higher emulsion stability of frank-
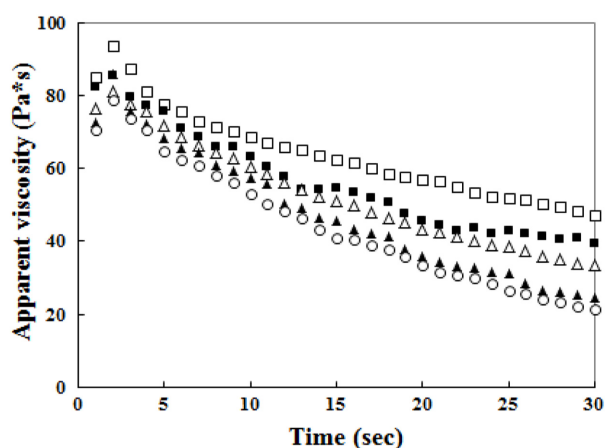
Fig. 1. Apparent viscosity of meat batters with various pork meat and pork head meat levels. (□) Control: frankfurter with 50% pork meat, (■) T1: frankfurter with 45% pork meat + 5% pork head, (△) T2: frankfurter with 40% pork meat + 10% pork head, (▲) T3: frankfurter with 35% pork meat + 15% pork head, (○) T4: frankfurter with 30% pork meat + 20% pork head.

furter meat batters. This might be due to the fact that pork head meat can lower the apparent viscosity value by diminishing water binding capacity and fat binding capacity (Choi *et al*., 2014).

Sensory characteristics

The sensory characteristics of the frankfurters formulated with different combinations of pork meat and pork head meat are shown in Table 6. The color and tenderness scores were not significantly ($p>0.05$) different between control and frankfurters added with pork head meat. The control frankfurters had the highest ($p<0.05$) scores in flavor, juiciness, and overall acceptability. Frankfurters with increasing pork head concentrations had lower scores in flavor, juiciness, and overall acceptability, due to pork head with connective tissue. Similar results in sensory evaluations of emulsion sausages were reported by Park (2004)

when pork head meat is added to emulsion sausages. They reported that the color, flavor, textural, juiciness, and overall acceptability of frankfurters with pork head did not significantly difference compared to control. Kim *et al*. (1999) have reported that the sensory evaluation appearance scores of all treatments with pork head meat added are significantly lower than those of the control. Thus, emulsion sausages manufacturing may be able to replace pork meat with up to 5% pork head meat to achieve an overall acceptability similar to that of regular or control frankfurters without any pork head meat added.

Conclusion

The replacement of pork meat with pork head meat was found to be able to affect the quality characteristics of frankfurters. Frankfurters formulated with a combination of 40% pork meat and 10% pork head meat maintained the similar sensory properties of control without head meat. Therefore, replacing pork meat with pork head meat in the formulation can successfully achieve qualities of control frankfurters. Replacing up to 10% pork meat with pork head meat in frankfurters is optimal for sensory characteristics.

Acknowledgements

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Table 6. Effect of various combinations of pork meat and pork head levels on sensory characteristics of frankfurters

Treatments[1]	Color	Flavor	Tenderness	Juiciness	Overall acceptability
Control	7.78±0.64	8.22±0.83[a]	8.89±0.78	8.17±0.79[a]	8.22±0.83[a]
T1	8.22±0.83	8.17±1.27[a]	8.56±0.73	8.16±0.78[a]	8.00±0.25[ab]
T2	8.33±0.71	8.00±0.50[ab]	8.48±0.71	8.14±0.79[a]	7.78±0.82[abc]
T3	7.67±0.52	7.33±0.52[b]	8.44±0.73	7.61±0.49[ab]	7.44±0.53[bc]
T4	7.72±0.44	7.28±0.44[b]	8.56±0.73	7.33±0.71[b]	7.24±0.46[c]

All values are mean±standard deviation of three replicates (n=9).
[a-c]Means within a column with different letters are significantly different ($p<0.05$).
[1]Control, frankfurter with 50% pork meat; T1, frankfurter with 45% pork meat + 5% pork head; T2, frankfurter with 40% pork meat + 10% pork head; T3, frankfurter with 35% pork meat + 15% pork head; T4, frankfurter with 30% pork meat + 20% pork head.

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