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Research Article

Effects of Partial Replacement of Pork Meat with Chicken or Duck Meat on the Texture, Flavor, and Consumer Acceptance of Sausage

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This study investigated the textural and sensory characteristics of sausage, where pork meat was partially replaced with chicken or duck meat (5–30% replacement). Nine treatments including the control (100% pork) were used in this study. TPA showed hardness to be decreasing as larger proportions of chicken or duck meat were substituted for pork meat. Descriptive analysis revealed that greater amounts of chicken or duck meat produced lower intensities of hardness, springiness, and chewiness and tended to increase juiciness. The control was least liked by consumers, while the overall liking (OL) tended to increase as the chicken content rose. The OL for the duck-substituted sausage was highest in samples containing 5% duck meat and tended to decrease as more duck meat was added. The substitution of chicken or duck meat made the sausage more acceptable by adding softness and juiciness. Based on consumers' OL, 30% of chicken or 5% of duck meat is recommended to replace pork meat in sausage.

1. Introduction

Between 2006 and 2011, the market for processed meat in Korea increased by 7.1% per year, with sausage accounting for more than 22% of these sales [1]. Since 2011, the demand for healthier and premium quality sausage has been rising in the Korean sausage industry. Today, higher-priced sausages made with 100% pork but free of color-fixing agents, *L*-sodium glutamate, artificial preservatives, artificial flavoring agents, and sodium erythorbate are stretching the market share in Korea because they are considered to offer greater health benefits than traditionally processed sausages that contain chemical additives.

Although pork is the main ingredient, other meats, such as beef, chicken, turkey, and duck, are also used in sausage processing [2]. Chicken, the most widely raised poultry in the world, is being promoted in sausage making for health and economic reasons, and the demand for chicken in the meat and processed meat industry has been steadily increasing [3]. According to the National Chicken Council [4], unit prices of chicken meat on a wholesale and retail weight basis are estimated to be 2~3 times less than beef or pork meat. In Korea, chicken is considered healthier than pork because of its lower fat content [5]. Therefore, adding chicken to sausage products is likely to be a positive change from a health standpoint.

Duck is another type of poultry that is commonly used in processed meat products for similar reasons to chicken. In 2012, more than 90% of ducks in the world were being raised in Asia [6]. Huda et al. [7] found that sausage with various ratios of duck and chicken meat demonstrated higher hardness and lower consumer acceptance when more duck meat was used for sausage mainly due to harder texture of duck sausage. Other nonmeat ingredients of duck sausage included various types of flour, such as rice, wheat, tapioca, sago, and potato, in the product [8, 9]. Tapioca and wheat flour had a negative influence on consumer acceptability, while sago and wheat flour in duck sausage generated relatively higher consumer acceptance ratings. The unit price of duck is much higher than that of chicken in Korea, which produces

complaints from consumers even though many Koreans believe that duck is a healthier meat than pork [5].

The partial replacement of pork meat with chicken or duck meat in sausage has two advantages; it adds versatile texture characteristics and is perceived by consumers as a premium product that is healthier than traditional pork sausage. Although some studies regarding the quality of poultry-substituted sausage have been conducted, no comprehensive study has examined the mechanical textural quality, sensory profiles, and consumer acceptability of poultry-substituted sausage. Therefore, the objectives of this study were to investigate the effects of partial replacement of pork meat with chicken or duck meat in different proportions on the mechanical texture attributes, sensory characteristics, and consumer acceptability of sausage.

2. Materials and Methods

2.1. Sausage Preparation. Chicken meat and duck meat were used at different ratios as a substitute for the pork meat in sausage. The control in this study was sausage consisting of 70% pork meat, 10% pork fat (lard), and 20% other ingredients, including salt, sodium nitrite, soy protein isolates, phosphate, potassium sorbate, and seasonings. Due to the company's request for confidentiality, the exact proportions and manufacturers for each ingredient were not disclosed. A total of nine treatments including the control were used in this study. Differing amounts of pork meat (5, 10, 20, and 30%) were replaced with the same portion of chicken (C05, C10, C20, and C30) or duck meat (D05, D10, D20, and D30), while the other ingredients remained the same. Since a preliminary test revealed that replacing with more than 30% poultry meat did not seem to be appropriate for maintaining a processed meat texture, the substitution level of poultry meat did not exceed 30%. Pork shank portions (SK Livestock Co., Ltd., Republic of Korea), lean meat from chicken thighs (Harim Co., Ltd., Republic of Korea), and duck thighs (the Big Retail Co., Ltd., Republic of Korea) were used in the sausage. The sausage was processed using a standard commercial procedure by a sausage-producing company (Alpsfood, Co., Ltd., Republic of Korea). A processing procedure is shown in Figure 1 and this procedure was replicated twice in a batch type. The average weight, length, and diameter of each sample were 300 g, 100 mm, and 26 mm, respectively. The test samples were sealed and stored in a freezer at −18°C prior to the analyses as prepared in Huda et al. [7]. The frozen samples were transferred to a refrigerator to thaw for 48 h (4 ± 1°C). All the experiments were completed within two weeks once the samples were frozen. Color of the samples was not taken into consideration in this study, although we understood the color was as important as the texture of sausage because the color of all the samples was adjusted to be equivalent by the manufacturer to prevent potential biases occurring from the color of samples so that we could focus on comparing texture and flavor of the samples.

2.2. Proximate Analysis. A proximate analysis based on the AOAC methods [10–12] was conducted. The sausage for analyses was ground using a mixer. Approximately 3 g of the ground sausage was placed into a dish and kept in a dry oven at 105°C overnight and then cooled in a desiccator for 30 min to measure the moisture content of the sausage. The amount of total protein in the sausage was analyzed using a micro Kjeldahl method. Soxhlet extraction was used to measure the total fat content of the sausage. All measurements were replicated in triplicate.

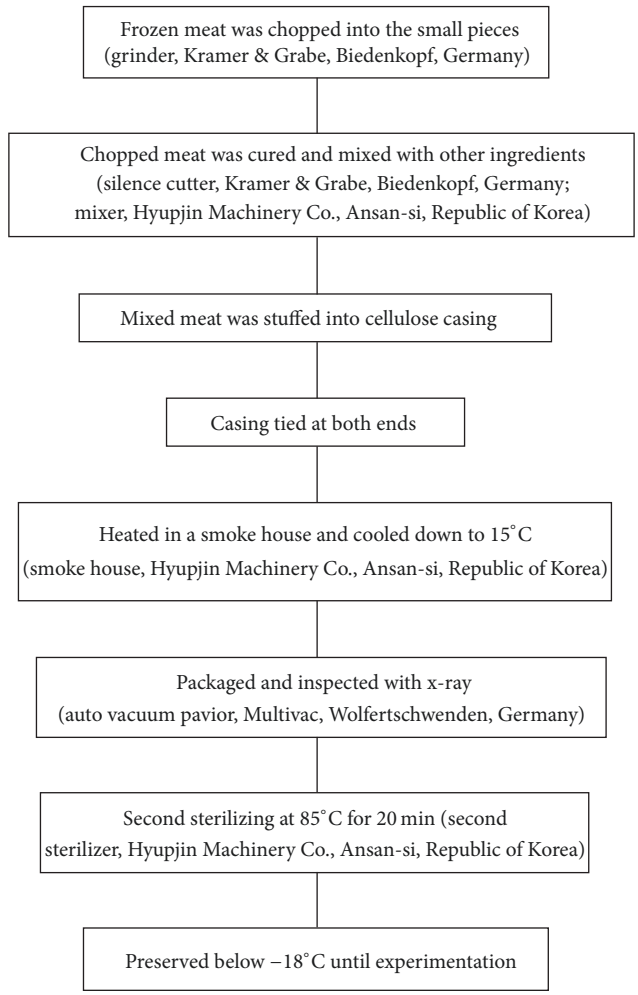

Figure 1: Flow chart for sausage processing.

2.3. Texture Profile Analysis. A Texture Analyzer (TA.XT2/Plus Upgrade, Stable Micro Systems, Surrey, UK) with a two-bite compression setup was used to assess the textural characteristics of the sausage for hardness, springiness, cohesiveness, and chewiness. The Texture Analyzer was equipped with a cylindrical probe of 36 mm. The mechanical test conditions included a 50% compression rate, 5 mm/s of crosshead speed for the pretest, test, and posttest speeds, and 5 g of automatic trigger load. The samples were cut into slices which were 12.5 mm thick and 26 mm in diameter, and the measurements were carried out 16 times for each treatment. The parameters extracted were as follows: hardness (maximum force of the first compression), springiness (distance of the detected height during the second compression divided by

the original compression distance; distance 2/distance 1), cohesiveness (area of work during the second compression divided by the area of work during the first compression; area 2/area 1), chewiness (hardness × cohesiveness × springiness), and resilience (calculated by dividing the upstroke energy of the first compression by the downstroke energy of the first compression; area 4/area 3).

2.4. Descriptive Analysis. Six trained panelists (1 female and 5 males, ages 21–31) participated in the descriptive analysis of the sausage samples using a quantitative descriptive analysis and Spectrum method with slight modifications [13]. The panelists had more than one year of experience conducting descriptive analyses of several food products. Ten 2-hour training sessions were held prior to the actual evaluations. In the first session, the panelists were told the purpose of the study, and descriptive sensory attributes for the sausage evaluations were generated. During the second session, the panelists discussed definitions, evaluated the sausage, and compared reference products. The final attributes were determined at the end of the session. Similar attributes were merged, and any attributes perceived by less than 50% of the panelists were discarded. The final 15 descriptive attributes (4 for taste, 3 for flavor, 6 for texture and oral sensations, and 2 for appearance) and their definitions, reference preparations, reference products, and reference intensities are presented in Table 1. During the third and fourth sessions, the panelists evaluated the reference products and determined their intensities. The panelists also compared the intensities of each attribute for nine sausage samples with the references during the fifth through the eighth sessions. In the ninth session, the panelists performed a practice evaluation following the same procedure that would be later used for the actual evaluation. The intensity ratings from the practice evaluation were discussed, and the products were retasted during the final (tenth) training session to minimize variations among panelists. The panelists participated in two final evaluations. The sample presentation was completely balanced to minimize carry-over effects [14]. Crackers (IVY, Haitai Co., Seoul, Republic of Korea) and a cup of filtered spring water (HiteJinro Co., Ltd., Seoul, Republic of Korea) were used as palate cleansers to rinse between the samples. The samples which were 12.5 mm thick and 26 mm in diameter were cut in half and served to subjects. A 16-point category scale (0–15) was used in comparison with the standard intensities. A side-by-side scale presentation method was applied for the evaluation of each descriptive attribute to allow intensity comparisons within the samples [15].

2.5. Consumer Acceptance Test. The consumer acceptance test was conducted with 104 consumers (85 females and 19 males, ages 19–37) who were students or staffs at a university campus. They reported consuming sausage at least once a week, and their participation in the test was voluntary. These participants were served two slices of sausage (12.5 mm thick and 26 mm in diameter) in a 189 ml paper cup labeled with random three-digit numbers. The samples were completely balanced to minimize first-order carry-over effects [14]. The consumers evaluated seven samples in the first session and, after a two- to three-hour interval, six samples in the second session. The panelists were asked to follow the tasting order written on a paper ballot and to rinse their mouths prior to tasting and also between samples for palate cleansing. Using a nine-point hedonic scale (Peryam and Pilgrim, 1957), the participants rated their overall liking (OL) as well as the acceptance of saltiness, meat flavor, chewiness, juiciness, and oiliness for each sausage sample. Those who completed the full consumer acceptance test received monetary compensation.

2.6. Data Analysis. XLSTAT (version 2016, Addinsoft, Paris, France) was used for all statistical analyses. One-way analysis of variance (ANOVA) and Tukey's test were applied to the results regarding physicochemical characteristics, texture, and consumer acceptance to determine significant differences across the samples at $P < 0.05$. The results of the descriptive analysis were analyzed by two-way ANOVA treating products as a fixed effect and panelists as a random effect. Tukey's test was used to identify any significant difference across the samples for each descriptive attribute at $P < 0.05$. A principal component analysis (PCA) was carried out to characterize the samples with regard to the descriptive attributes and consumer acceptance test results to determine the directions of consumer preference toward the samples. An agglomerative hierarchical clustering (AHC) analysis was conducted to divide the consumers into small numbers of groups based on their OL ratings with an automatic truncation option.

3. Results and Discussion

3.1. Proximate Analyses. The results of the proximate analyses for moisture, crude protein, and crude fat content of the samples are shown in Table 2. The moisture content did not differ significantly across the samples containing chicken meat ($P > 0.05$) compared to the control. However, significant difference in moisture content was observed for the duck samples ($P < 0.05$), showing the control to be least, while D30 to be highest, although the difference was minimal between the samples. It is generally known that the moisture content of pork shank is lower than that of duck lean meat [16]. The crude protein content of all the samples also did not differ significantly from that of the control ($P > 0.05$). In addition, there were significant differences in the crude fat content across the samples containing either chicken or duck meat ($P < 0.05$). The highest fat content was observed for the control as the shank used in the pork sausage contained more fat than the lean meat from the thighs for chicken or duck sausage [16].

3.2. Texture Profile Analysis. The results of the texture profile analysis (TPA) of the sausage are presented in Table 3. The control had the highest values for hardness, chewiness, and resilience compared to other samples, while little difference was observed for springiness among the treatments. Higher values for cohesiveness were observed for the control, C05, and C20, although the absolute values seemed to be slightly

Table 1: Attributes, definitions, reference preparations, reference products, and reference intensities for sausage descriptive analysis.

Attribute	Definition	Reference preparation	Reference product	Intensity
Appearance				
Amount of fat globule	Amount of fat in sausage section	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	The healthy ham (CJ CheilJedang Co., Seoul, Republic of Korea)	10
Taste and flavor				
Sweet	Fundamental taste sensation of which sugar is typical	3% sugar solution (w/v)	White sugar (Samyang Co., Seoul, Republic of Korea)	3
Salty	Fundamental taste sensation of which salt is typical	0.47% sodium chloride solution (w/v)	Hanju salts (Hanju Salt Co., Ulsan, Republic of Korea)	8
Sour	Fundamental taste sensation of which citric acid is typical	0.06% citric acid solution (w/v)	Citric acid (Sigma-Aldrich, LLC, St. Louis, MO, USA)	3
Umami	Fundamental taste sensation of which monosodium glutamate or other nucleotides are typical	0.22% MSG solution (w/v)	Mono sodium glutamate (ES Food, Gunpo, Republic of Korea)	5
Meat flavor	Aromatics associated with meat	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Roast ham (Nonghyup Moguchon, Seoul, Republic of Korea)	9
Sausage spice	Aromatics associated with sausage spice	5% sausage spice solution (w/v)	Sausage spice (HS Newtech, Daegu, Republic of Korea)	15
Rancidity	Aromatics associated with rancid oil	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	The healthy ham (CJ CheilJedang Co., Seoul, Republic of Korea)	2
Texture				
Hardness	Resistance strain when force is applied	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Delicatessen (CJ CheilJedang Co., Seoul, Republic of Korea)	7
			Real delicious sausage (CJ CheilJedang Co., Seoul, Republic of Korea)	3
Springiness	Returns to original shape, stretchiness, tendency to act like a rubber band after manipulation	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Delicatessen (CJ CheilJedang Co., Seoul, Republic of Korea)	8
			Real delicious sausage (CJ CheilJedang Co., Seoul, Republic of Korea)	2.5
Cohesiveness	Slightly gelled feeling, maintains form	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Roast ham (Nonghyup Moguchon, Seoul, Republic of Korea)	5
			88 fruitful sausage (CJ CheilJedang Co., Seoul, Republic of Korea)	9
Chewiness	Chewing times before swallowing	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Delicatessen (CJ CheilJedang Co., Seoul, Republic of Korea)	7
			Real delicious sausage (CJ CheilJedang Co., Seoul, Republic of Korea)	2
Juiciness	Tendency to release product moisture in mouth	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Roast ham (Nonghyup Moguchon, Seoul, Republic of Korea)	9
			Real delicious sausage (CJ CheilJedang Co., Seoul, Republic of Korea)	2
Oiliness	Tendency to release product oil in mouth	Cutting (thickness: 12.5 mm, diameter: 26 mm, globular shape)	Roast ham (Nonghyup Moguchon, Seoul, Republic of Korea)	8
			Spam (CJ CheilJedang Co., Seoul, Republic of Korea)	12

Table 2: Moisture, crude ash, crude protein, and crude fat contents of sausages partially substituted with chicken and duck.

Sample[(1)]	Moisture content (%)	Crude protein content (%)	Crude fat content (%)
Control	65.0 ± 0.4 bc[(2)]	14.6 ± 4.2 a	13.8 ± 2.7 a
C05	64.8 ± 0.2 bc	14.3 ± 2.6 a	11.4 ± 0.6 ab
C10	64.5 ± 0.2 c	18.4 ± 3.0 a	9.8 ± 1.0 ab
C20	64.4 ± 0.5 c	15.2 ± 0.4 a	13.9 ± 1.2 a
C30	64.4 ± 0.7 c	17.1 ± 1.1 a	8.7 ± 0.4 b
D05	66.3 ± 0.2 ab	16.5 ± 0.2 a	9.7 ± 0.9 ab
D10	66.2 ± 0.1 ab	16.4 ± 0.6 a	8.6 ± 0.8 b
D20	65.8 ± 0.6 abc	15.4 ± 0.2 a	10.4 ± 0.4 ab
D30	66.8 ± 0.1 a	15.0 ± 0.1 a	11.7 ± 1.7 ab

[(1)]C05, C10, C20, and C30 meant the substitution ratio (%) of chicken, respectively, and D05, D10, D20, and D30 meant the substitution ratio. [(2)]Different characters within a column for chicken or duck mean significant difference at $P < 0.05$ by Tukey's test.

highest for the control. Substituting chicken or duck meat for pork meat generated textural differences compared with the control. In the chicken samples, hardness values decreased from 30,682 g (C05) to 20,773 (C30) as more chicken meat was substituted for pork meat.

It has been reported that the texture of meat depends upon the structures and composition of skeletal muscle, including myofibrils and intramuscular connective tissue [17]. Connective tissue is an inherent factor that influences meat texture, while myofibrils are usually referred to as a processing factor and are affected mainly by the aging of meat [18, 19]. The amount and composition of connective tissue significantly vary depending on the species of meat. The overall connective tissue content is a major factor that affects meat texture and is greater in pork than in poultry. In addition, muscle fibers in poultry are generally finer and softer than those found in pork [17]. Therefore, it seems likely that these differences between pork and poultry meat structures may account for the decreased hardness values for the sausage in which chicken or duck meat was substituted for pork, as compared with the control. Another possible explanation regarding this is that higher fat contents in pork sausage than in chicken or duck sausage might contribute to the increased hardness in pork sausage. As more fat is present in sausage, the amount of water acting as a plasticizer is eventually decreased and results in harder texture of sausage. This finding was in line with the works by Hensley and Hand [20], Sutton et al. [21], Chang and Carpenter [22], Candogan and Kolsarici [23], and Andrés et al. [24]. Textural properties of sausage have been also affected by moisture content, with a lower moisture content producing a harder and chewier product [7]. However, this is not the case in this study because no significant difference between the 100% pork sausage and chicken or duck sausage was observed (Table 2). We believe that the structural differences in muscle between pork and poultry meat played a more important role in differentiating textural characteristics.

There was no significant difference in springiness across the control and chicken samples ($P > 0.05$). The values for cohesiveness, chewiness, and resilience also tended to decrease as the proportion of chicken meat increased with the exception of C20 possibly due to the sample variations. Although the hardness of the duck sausage decreased in a pattern similar to that seen with the chicken-containing sausage, the decrease from D10 to D30 was smaller than that of the chicken-containing sausage. The degree of chewiness decreased significantly from 0 to 5%, but this decrease was diminished for the 30% duck meat sample. The decreasing values of hardness and chewiness as the proportions of chicken or duck increased were due to differences in structure between the pork and poultry meat, as previously mentioned [17].

3.3. Descriptive Analysis. The mean intensity ratings of the 14 descriptive attributes for the sausage samples containing various proportions of chicken or duck meat are shown in Table 4. There was no significant difference across two replications (P values = 0.069–0.948, results not shown), which suggested that the panelists' evaluations of the descriptive attributes were reproducible [25]. The panelists contributed to significant variations in the descriptive attributes, which are typically observed in descriptive analyses (Stone and Sidel, 2004). Among the 14 descriptive attributes, significant differences were seen for 5 attributes ($P < 0.05$). With regard to taste and flavor attributes, umami demonstrated significant differences across the sausage ($P = 0.034$). Substituting chicken meat for pork meat seemed to be somewhat effective in increasing the umami intensity, showing the increased umami intensity for the chicken samples (7.3~7.8) compared to the control (7.0), although no significant differences were observed for all the treatments. The insignificant differences might be due to a small number of replications (replication was 2 in this study) or panelists participated (six panelists in this study). Contents of glutamic acid and nucleotides naturally found in meat are two major components in affecting umami taste of meat [26]. Durations of meat aging also influence the amount of glutamic acid of meat [27]. Based on the work by Maga and Yamaguchi [28], the free glutamate content of cooked meat was larger in chicken than in pork. Kato and Nishimura [29] examined the effect of meat storage on IMP levels and found that chicken meat showed the highest IMP level in a very short period of aging (2 days) compared to pork meat. Therefore, we hypothesized that above two factors might contribute to the increased umami taste in chicken sausage although the exact duration of aging for the meat used in the current study was unknown. Taste and flavor characteristics of the chicken or duck samples (C05 to C30 and D05 to D30) were not affected by the meat substitution, and the trained panelists did not discern significant differences across the sausage except for the umami attribute. Four out of six texture attributes differed significantly across the samples ($P < 0.05$) owing to the difference in meat structure between pork and poultry (chicken and duck meat) [30]. These sensory results were comparable to the TPA results, which showed significant differences across the samples ($P < 0.05$) (Table 3). Hardness,

Table 3: Texture profile analysis of sausages partially substituted with chicken and duck.

	Hardness (g)	Springiness	Cohesiveness	Chewiness (J)	Resilience
Control	35643 ± 4182 a[(1)]	0.92 ± 0.04 ab	0.35 ± 0.04 ab	12302 ± 4000 a	0.15 ± 0.03 a
C05	30682 ± 2471 bcd	0.91 ± 0.04 ab	0.34 ± 0.04 abc	11713 ± 4785 ab	0.13 ± 0.02 abcd
C10	28990 ± 1621 cde	0.92 ± 0.06 ab	0.32 ± 0.04 bcd	9304 ± 3349 abcde	0.11 ± 0.02 ef
C20	26851 ± 1545 efg	0.94 ± 0.04 a	0.33 ± 0.04 abcd	11234 ± 5673 abc	0.11 ± 0.01 def
C30	20773 ± 1860 i	0.86 ± 0.13 b	0.29 ± 0.03 d	5106 ± 1103 f	0.10 ± 0.01 f
D05	28087 ± 2527 def	0.95 ± 0.06 ab	0.32 ± 0.04 abcd	8505 ± 1418 bcdef	0.12 ± 0.02 bcde
D10	25436 ± 2052 fgh	0.89 ± 0.08 ab	0.31 ± 0.03 cd	6979 ± 1241 cdef	0.10 ± 0.01 f
D20	24872 ± 2062 gh	0.90 ± 0.09 b	0.32 ± 0.03 bcd	7173 ± 976 ef	0.12 ± 0.01 cdef
D30	22650 ± 1678 hi	0.90 ± 0.08 b	0.35 ± 0.04 ab	7043 ± 1177 def	0.13 ± 0.01 abc

[(1)]Different characters within a column for chicken or duck mean significant difference at $P < 0.05$ by Tukey's test.

Table 4: Mean intensities of 15 descriptive attributes for sausages substituted with chicken, duck, and beef.

	Sample								
	Control	C05	C10	C20	C30	D05	D10	D20	D30
Appearance									
AOFG[(1)]	2.9 ns[(2)]	3.1	2.6	2.5	2.8	2.8	2.5	2.6	2.8
Taste and flavor									
Sweetness	2.8 ns	3.0	2.7	2.8	3.1	2.8	2.8	2.8	2.5
Saltiness	8.9 ns	8.3	9.1	8.8	7.5	8.3	8.0	8.6	8.1
Sourness	1.8 ns	1.8	2.0	1.8	2.2	1.9	1.8	1.8	1.8
Umami	7.0 ns	7.7	7.8	7.3	7.6	6.8	8.2	6.9	6.9
Meat flavor	8.0 ns	8.0	8.1	7.9	7.6	7.8	7.8	7.4	7.8
Sausage spice	10.0 ns	9.8	9.5	9.5	9.4	9.3	9.2	9.0	9.1
Rancid flavor	1.8 ns	1.8	1.7	1.8	2.3	2.0	1.5	1.6	1.7
Texture and mouthfeel									
Hardness	10.0 a[(3)]	9.2 ab	8.6 abc	7.2 bc	6.4 c	8.1 abc	7.5 bc	6.8 bc	6.2 c
Springiness	9.2 a	8.7 ab	8.5 ab	7.3 abc	5.8 c	8.0 ab	6.9 bc	6.9 bc	5.9 c
Cohesiveness	6.1 ns	5.8	5.6	5.9	5.1	5.8	5.7	5.3	5.7
Chewiness	8.3 a	8.2 a	7.7 ab	6.9 ab	6.2 b	7.3 ab	6.7 ab	6.8 ab	6.3 b
Juiciness	9.7 ab	9.6 b	9.2 b	9.2 d	10.5 ab	10.0 ab	10.0 ab	10.9 ab	11.8 a
Oiliness	7.0 ns	6.5	6.7	7.0	7.3	6.9	7.3	7.1	6.7

[(1)]AOFG: amount of fat globule. [(2)]"ns" means nonsignificant. [(3)]Different characters within a row for chicken or duck mean significant difference at $P < 0.05$ by Tukey's test.

springiness, and chewiness tended to display decreasing intensities for the chicken samples (C05–C30) and the duck samples (D05–D30) in comparison with the control. In general, substituting chicken and duck meat for pork meat in sausage negatively influenced these attributes to a significant degree. Juiciness showed an increased trend as the proportion of chicken meat increased with an exception of C20, while this trend was not consistent for the duck sausage. The most significant differences in the descriptive analysis were observed for the texture characteristics, which have been the key parameters in meat substitution studies in sausage.

The PCA was performed using 14 descriptive attributes to visualize the relationships of all attributes across the sausage samples (Figure 2). The PCA biplot explained 67.15% ($F1$ = 45.90%; $F2$ = 21.25%) of the total variations for the descriptive attributes. The $F1$ dimension accounted for texture characteristics. Hardness, chewiness, springiness, and cohesiveness were loaded positively on the $F1$ dimension, while juiciness and oiliness were located negatively on $F1$. Most appearance, taste, and flavor attributes were loaded positively on $F2$, but saltiness was found on the negative side of $F2$. The control was on the positive $F1$-axis and characterized by chewiness, hardness, springiness, and cohesiveness. As more chicken or duck meat was substituted for the pork meat, the samples moved from the right to the left side of the $F1$-axis, owing to the significant decrease in texture characteristics, such as hardness, chewiness, and cohesiveness. In contrast, juiciness increased as more pork meat was replaced by chicken or duck meat. The sample loading patterns for chicken (C05–C30) and duck (D05–D30) meat went in different directions. The chicken samples were located positively on the $F1$-axis and $F2$-axis (C05) and moved to the lower left area of the plot as more chicken meat was used, while the duck samples were loaded at the bottom of the center and toward the location of the negative $F1$ and positive $F2$. The substitution of up to 30% chicken or duck meat produced increases in the juiciness

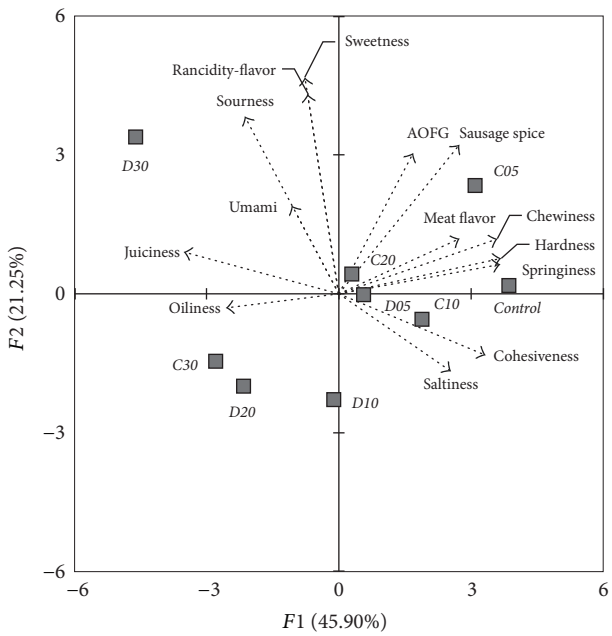

Figure 2: Principal component analysis of 14 attributes. Arrows meant the descriptive attributes. Squares are the sausage samples. Sample codes are described in the footnote of Table 2.

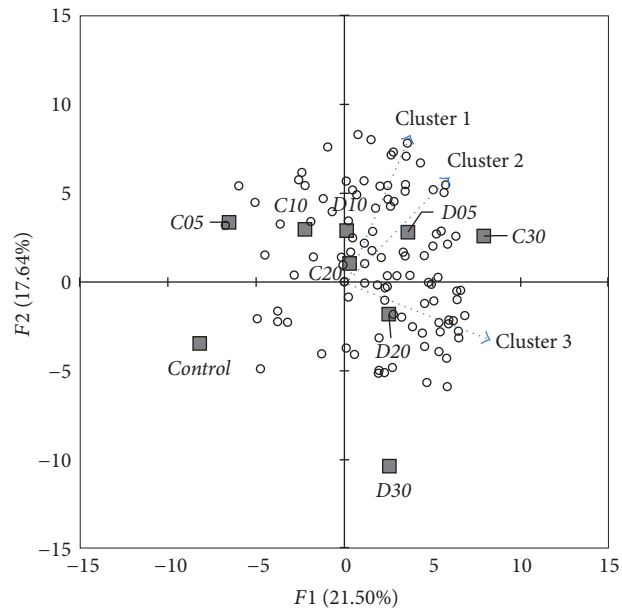

Figure 3: Principal component analysis of overall liking ratings of 104 consumers and the average overall liking ratings of consumer clusters from the agglomerative hierarchical clustering analysis. Squares are the sausage samples. Circles represented consumers. Arrows represented consumer clusters. Sample codes are described in the footnote of Table 2.

and oiliness characteristics but decreases in springiness and hardness. One caveat when substituting duck meat for pork meat was the rancid flavor that developed in the D30 sample, which may be related to duck's susceptibility to oxidative deterioration [31].

3.4. Consumer Acceptance Test. The mean consumer acceptance ratings for the sausage samples are presented in Table 5. The control had the lowest OL rating compared with other samples. For the chicken samples, OL increased as the proportion of chicken increased, showing C30 to be the highest OL among the samples. For the duck samples, D05 had the highest rating (5.6), while the least OL was observed for D30 (5.1). The control received the lowest scores for most of liking attributes, whereas C30 had the highest ratings. The increases in the acceptance of chewiness, juiciness, and oiliness depended on the substitution rates, which was not true for the taste- and flavor-related attributes for the chicken samples (Table 4). Variations in acceptance ratings for the duck samples were less than those for the chicken samples. D30 obtained slightly lower ratings with regard to specific attributes; however, these ratings did not differ significantly from those of the other samples ($P > 0.05$).

The results of the AHC analysis are shown in Table 6. The consumers were divided into three clusters based on their OL ratings. Cluster 1 (44 consumers) preferred the C20, C30, and D05 samples. Cluster 2 (41 consumers) generally did not like the sausage samples, but they liked C30 the most, followed by D20, D05, and C10. The preference pattern for samples was similar to that seen with Cluster 1, but the ratings were lower than those from Cluster 1. Cluster 3 (19 consumers) showed OL rating patterns that differed from those of Clusters 1 and 2. D30 was the most acceptable, followed by C30, and the OL ratings for the duck samples were higher than those for the chicken samples. Thus, consumers in Cluster 3 preferred the duck-containing samples.

The OL ratings given by the 104 consumers with their mean OL ratings from the three clusters were analyzed by the PCA to identify consumer preference patterns regarding the sausage samples (Figure 3). The PCA biplot explained 39.14% of the total variation ($F1$ = 21.50% and $F2$ = 17.64%). The chicken sausage was loaded from the negative to positive side of the $F1$-axis as more chicken meat was used in the sausage. Duck sausages were located from the positive to negative direction of the $F2$-axis. Most consumers were loaded on the right side of the biplot, which was exactly opposite to the control results, owing to the lowest acceptance ratings for the control across the samples. Consumers clearly showed that their acceptance of the chicken sausage increased as more chicken meat was used. Clusters 1 and 2 were toward the positive $F1$-axis and $F2$-axis of the plot because these consumers rated C30 and D05 highly. Some panelists were loaded on the positive $F1$-axis and the negative $F2$-axis of the biplot, preferring the duck sausage similar to Cluster 3. The biplot clearly showed that consumers preferred sausages with added chicken or duck meat to those containing pork meat alone.

4. Conclusions

Substituting chicken or duck meat for pork meat in proportions up to 30% presented textural and consumer acceptance

Table 5: Mean acceptance intensities of overall liking, saltiness, meat flavor, chewiness, juiciness, and oiliness for sausage samples.

Sample	Overall liking	Saltiness	Meat flavor	Chewiness	Juiciness	Oiliness
Control	4.6 c[(1)]	4.0 d	5.1 ab	4.6 de	4.9 cd	4.7 c
C05	5.0 bc	4.6 bcd	5.1 b	5.0 cde	5.1 bc	5.2 abc
C10	5.3 bc	4.7 bcd	5.2 ab	5.3 bcd	5.3 bc	5.2 abc
C20	5.3 bc	4.4 cd	5.1 b	5.8 ab	5.5 abc	5.3 ab
C30	6.0 a	5.2 ab	5.7 a	6.0 a	6.0 a	5.6 a
D05	5.6 ab	5.1 ab	5.4 ab	5.5 abc	5.4 bc	5.3 ab
D10	5.4 ab	4.9 abc	5.5 ab	5.5 abc	5.4 bc	5.2 abc
D20	5.4 ab	5.0 abc	5.4 ab	5.5 abc	5.6 ab	5.3 ab
D30	5.1 bc	4.8 bc	5.4 ab	5.3 bc	5.3 bc	4.9 bc

[(1)]Different characters within a column mean significant difference at $P < 0.05$ by Tukey's test.

Table 6: Agglomerative hierarchical clustering analysis of OL ratings by 104 consumers and the mean separation of each cluster.

Sample	C1 (n = 44)	C2 (n = 41)	C3 (n = 19)
Control	5.5 cd[(1)]	4.1 d	3.8 g
C05	5.9 bc	4.4 bcd	4.4 fg
C10	6.0 bc	4.8 ab	4.6 ef
C20	6.0 abc	4.5 abcd	5.2 de
C30	6.6 a	5.0 a	6.6 ab
D05	6.1 ab	4.8 ab	6.2 bc
D10	5.9 bc	4.7 abc	5.9 cd
D20	5.8 bc	4.9 ab	5.9 cd
D30	5.1 d	4.2 cd	7.2 a

[(1)]Different characters within a column mean significant difference by Fisher's least significant difference test at $P < 0.05$.

changes of sausage. A texture profile analysis demonstrated that hardness and chewiness decreased as the substituted proportions of chicken or duck meat increased. A descriptive analysis showed a decreased tendency in hardness, springiness, and chewiness for the sausage containing chicken or duck meat. Consumer acceptability was positively influenced when sausage included chicken or duck meat instead of pork meat. This change was also connected to the OL of the sausage, with higher OL ratings for the chicken- or duck-containing sausage compared with the 100% pork samples (control), especially when more chicken meat was used. Decreasing the hardness of the sausage by substituting chicken and duck meat for some of the pork meat was the main reason for the increased OL. Texture characteristics also influenced the sensory profile and consumer acceptance of the sausage. The use of chicken or duck meat in sausage generated higher consumer acceptability among Korean consumers by delivering more softness and juiciness. Based on the consumer acceptance test, the pork meat in sausage should be replaced at a rate of 30% chicken or 5% duck meat.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Namrye Lee and Han Sub Kwak contributed equally to this study.

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