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Effect of *Hanwoo* Crust on the Physicochemical Properties of Emulsion-Type Sausages

Abstract

This study aimed to investigate the effects of *Hanwoo* crust on the physicochemical properties of emulsion-type sausages. Sausage samples were prepared with various amounts of *Hanwoo* crust—0% (i.e., control), 1%, 2%, and 3%. The physicochemical properties studied included the proximate composition, pH, color, water holding capacity, cooking yield, and viscosity. Texture profile analysis and sensory evaluation were also carried out. Protein, fat, and ash contents of the *Hanwoo* crust-treated samples were found to be significantly higher than those of the control ($p<0.05$). Moreover, the CIE b^* value of cooked sausage with *Hanwoo* crust treatments was significantly lower than that of the control ($p<0.05$). The CIE L^* value of uncooked and cooked samples with 3% *Hanwoo* crust was significantly lower than that of the control ($p<0.05$). In contrast, the CIE a^* value of uncooked and cooked samples with 3% *Hanwoo* crust was significantly higher than that of the control ($p<0.05$). The viscosity of the uncooked samples increased with increasing *Hanwoo* crust content. Samples containing 3% *Hanwoo* crust exhibited significantly higher water holding capacity and cooking yield than the control ($p<0.05$). In the texture profile analysis, samples containing 2% and 3% *Hanwoo* crust showed significantly higher hardness, gumminess, and chewiness than the control ($p<0.05$). Overall, the sensory properties of *Hanwoo* crust treatments were significantly better than those of the control ($p<0.05$). In conclusion, adding 3% *Hanwoo* crust to emulsion-type sausage leads to optimal physicochemical properties.

Keywords: ***Hanwoo*** **crust, Sausages, Physicochemical properties, Pork**

Introduction

Currently, the main trend pertaining to food consumption is a health-oriented diet. With an increasing number of people following a low-carb, high-fat (LCHF) diet and a calorie deficit to achieve weight loss, the importance of protein has come to the foreground (Epstein et al., 1990; MARFA and aT, 2019; Paoli et al., 2012).

Processed meat products are among the most easily available sources of protein. Of them, sausage is a meat product made from ground meat (pork, beef, etc.) along with fat, crushed ice or ice-cold water, spices, and various flavorings (Nicli et al., 1990). Sausage sales in Korea increased by 49.3%, from 52,813 tons in 2008 to 78,849 tons in 2018 (KMIA, 2018). In line with the current dietary trend of high protein intake, premium sausages with improved functional and organoleptic properties are being developed and upgraded with protein additives, in addition to the main ingredient (meat). For example, legumes (Amadi, 2020), soy protein isolate (Lee et al., 2017), and edible insects (Kim and Lee, 2019).

The crust is the inedible surface layer formed during the aging process of dry-aged meat, and its use as meat is infrequent because moisture loss through evaporation causes the surface to become dry and hard (Dashdorj et al., 2016). According to a recent study, however, the crust of dry-aged meat has higher protein and fat contents and a higher concentration of flavor compounds than meat. Moreover, it was also found to exhibit additional effects, such as antioxidant and antihypertensive activities (Choe et al., 2020). Other related studies found that adding the crust to stocks as a flavor enhancer with health benefits increased the mineral content and free amino acid fraction in the stock (Kang et al., 2020). Furthermore, adding it to sauces enhanced the flavors and improved the organoleptic properties of the sauce (Park et al., 2020). While these studies have demonstrated that crust used as an additive has excellent benefits and functions, they used the crust extracted from dry-aged meat of the *Holstein* variety. Therefore, there is a need to investigate the utility of the crust extracted from various varieties of dry-aged meat.

Hanwoo is a native Korean cattle breed. Compared to *Holstein*, it has a higher muscle fat content and superior organoleptic properties such as succulence and flavor (Jayasena et al., 2015; Frank et al., 2016). However, *Hanwoo* consumption is popular when it comes to high-grade products, viz. grades 1^{++} and 1^{+} (49.3%), while the consumption of grades 2 and 3 meat and low-fat parts is exceedingly low. This extremely skewed *Hanwoo* consumption pattern is attributable to Koreans' preference for grilled meat, for which tenderness is the decisive attribute of meat quality and taste. Low-grade *Hanwoo* is less tender due to lower muscle fat content, which it is compensated for by dry-aging it (Jung et al., 2016). Dry-aged *Hanwoo* enjoys high popularity among consumers for its excellent flavor, and its production in Korea is higher than that of *Holstein*. In the process of dry-aging, Hanwoo also yields more crust than Holstein because high production of dry aged meat from hanwoo (Cho et al., 2018), but no research has yet been conducted to investigate its use.

In this context, this study aimed to develop high-protein sausage with excellent taste and quality by investigating emulsion-type sausages with crust derived from dry-aged *Hanwoo*, which has exhibited excellent health benefits and flavor-enhancement properties.

Materials and Methods

Preparation of *Hanwoo* crust and sausage samples

In total, six pieces of beef loin (M. *longissimus dorsi*) were obtained from six carcasses (*Hanwoo*, Korea quality grade 2) two days postmortem and were divided into three sections of equal length and width. The *Hanwoo* loins (M. *longissimus dorsi*, Dawoo hanwoo, Korea) were refrigerated for 24 h and dry aged under the following conditions: refrigeration at 4 ℃, 60–70% relative humidity, and air velocity of 5 ± 3 m/s for 4 weeks. After aging, to obtain dry aged *Hanwoo* loin crust (*Hanwoo* crust), dry aged *Hanwoo* loins were trimmed off the surface by 30–70 mm from the outside. Subsequently, the obtained Hanwoo crust was stored at −18 ℃ for 24 h (CA-H17DZ, LG, Korea) for freeze-drying, and lyophilization was performed at −80 ℃ for 15 h using a freeze dryer (FDU-1110, Eyela, Japan). Following this, the Hanwoo crust was pulverized to a size of 15 mesh using a hand blender (MQ5135, Braun, Germany) and stored at 4 ℃. The crust was measured moisture 1.20%, protein 44.06%, fat 49.33%, ash 1.95, pH 5.67, CIE L^* 37.82, CIE a^*

12.87 and CIE b^* 2.08

The formulations of pork emulsion sausages with various *Hanwoo* crust contents is presented in Table 1. To prepare the pork emulsion sample, the pork hind leg and back fat from pork were first purchased from a local market (Hongju meat Co., Chungnam, Korea). All subcutaneous and intermuscular fat and visible connective tissues were removed from the pork muscle and then ground using 3-mm-plate grinder (PA-82, Mainca, Spain). Following this, the ground meat (60%) was mixed with back fat (20%), ice water (20%), nitrite pickling salt (1.2%; nitrite content: 6,000 ppm), phosphate (0.3%), sugar (1%), mixed spice (0.6%; Bockworst, Raps GmbH & Co., Germany), and various amounts of Hanwoo crust—0% (control), 1%, 2%, and 3%. The prepared sausage emulsion of the samples was filled into a collagen casing (#240, NIPPI Inc., Japan; approximately 25-mm diameter) using a stuffer (EM-12, Manica, Spain) and cooked using a chamber (10.10ESI/SK, Alto Shaam, Menomonee Falls, USA) at 80 ± 1 ℃ until the internal temperature of the samples reached 75 ℃. The cooked samples were subsequently cooled at room temperature (20 ℃) for 30 min and stored at 4 ℃. All processing was performed in triplicate.

Proximate composition

The proximate composition was determined following the methods in compliance with the AOAC official method 932.06 (AOAC, 2012). Moisture content was measured using 1 g of sample in a drying oven at 105 ℃ for 24 h., while the crude protein content was measured by the Kjeldahl method. Additionally, the crude fat content was measured by the Soxhlet method and ash content was measured by the dry ashing method.

pH

The pH of mixtures of the sausage samples and distilled water were in a ratio of 1:4, as determined using a pH meter (Model 340, Mettler-Toledo GmbH Analytical, Switzerland).

Color

The color of the samples was examined using a colorimeter (CR-10, Minolta, Japan; illuminant C, calibrated with a white standard plate $L^* = 97.83$, $a^* = -0.43$, and $b^* = +1.98$), which had a measuring area with a diameter of 8 mm and an illumination area of 50 mm diameter. Color values (CIE L^*, a^*, and b^*) were measured on the surface of samples with results taken in triplicate for each sample.

Water holding capacity (WHC)

The WHC determined was by a slightly modified Cabling et al. (2015) method. Each cooked sample of 5 g was placed in a conical tube covered with cotton, which was sheathed with filter paper, before the lid was closed. Centrifugation of the prepared sample was undertaken using a centrifuge (Supra R22, Hanil, Korea) at 1,092×g and 4 ℃ for 10 min. After centrifugation, the WHC was calculated using the following formula by measuring the weight of the water-drained sample:

$$\text{WHC (\%)} = \frac{A - B}{B} \times 100$$

A: (Weight of before centrifugation (g) × Water content (%))/100

B: Weight of sample before centrifugation (g) – Weight of sample after centrifugation (g)

Cooking yield (CY)

The cooking yield of each group was determined by weighing the meat batters before and after cooking and expressing in the form of percentages.

Viscosity

The flow behavior and time dependence of the batters were investigated at 20 ± 1 ℃ using a parallel plate rotational viscometer (HAKKE Viscotester 500 R®, Thermo Electron Corporation, Germany). The batter was allowed to equilibrate for 5 min at room temperature (23 ± 3 ℃) and was tested using a standard cylinder sensor (SV-2). Time dependence of the batter viscosity was determined by measuring the apparent viscosity under a constant shear rate of 10/s for 60 s.

Texture profile analysis (TPA)

Cooked samples cut into sections with a height of 25 mm and φ 16 mm diameter were used in this study. A cylinder probe (φ 20 mm diameter) set attached to a texture analyzer (TA-XT2i, Stable Micro System Ltd., UK) was used to examine the textural properties for each sample. The test conditions used in the study were as follows: stroke, 2 kg; test speed, 2.0 mm/s; and distance, 8 mm. The texture profile analysis (TPA) parameters, hardness (gf), springiness, gumminess (gf), chewiness (gf), and cohesiveness were collected.

Sensory evaluation

Ten panelists were selected using basic taste identification tests. Each sample was evaluated in terms of color, flavor, juiciness, tenderness, and overall acceptability. The samples were served to 10 experienced panel members. The panelists were presented with randomly coded samples. The color, flavor, tenderness, juiciness, and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the samples were evaluated using a 10-point descriptive scale. The panelists were also required to cleanse their palates with water between tasting the samples.

Statistical analysis

Statistical analysis was performed with a general linear model (one-way analysis of variance), using SAS software (SAS, Release 9.3 for window, SAS Institute Inc., USA). The significant differences ($p<0.05$) were verified using Duncan's multiple range tests. The data was shown as mean±standard deviation (SD).

Results and discussion

Proximate composition

Table 2 presents the analytical results of the proximate composition of emulsion-type pork sausage samples with added *Hanwoo* crust. The 2% and 3% treatment samples showed significantly lower moisture contents than the control and the 1% treatment samples ($p<0.05$). In contrast, the protein, fat, and ash contents of the former groups were significantly higher than those of the latter groups ($p<0.05$). These findings are consistent with those of a study in which the protein, fat, and ash contents of beef patties increased proportionally when okara, a protein additive, was added to them (Turhan et al., 2007). The changes in the proximate composition of sausage may be due to the proximate composition of the freeze-dried *Hanwoo* crust (water: 1.2%; protein: 44.06%; fat; 49.33%; ash: 1.95%) added in the process of sausage production, resulting in different proximate compositions for the *Hanwoo* crust treatments (Lee and Kim, 2020). As noted above, crust is known to have high protein and ash contents due to surface moisture loss through evaporation during dry aging (Campbell et al., 2001). From this, it can be inferred that the protein, fat, and ash contents of the emulsion-type sausage increased with increase in the amount of *Hanwoo* crust added to it.

pH and color

The pH of meat products varies according to the mixing ratio of raw meat and additives. It is an important factor affecting meat quality traits such as its water holding capacity, color, and texture (Miller et al., 1980). The color of meat products is an important factor that significantly influences consumer preferences (Osburn and Keeton, 1994). Table 3 presents the pH and color values of the emulsion-type pork sausage samples with added *Hanwoo* crust at different concentrations (0–3%), which were investigated to determine the effects of *Hanwoo* crust on the pH and color of sausage. The pH of cooked sausage samples was inversely related to the content of *Hanwoo* crust, and the pH of uncooked samples was significantly lower in the 3% treatment compared to the control ($p<0.05$). In a study conducted by Lee et al. (2015), the pH of dry-aged *Hanwoo* sirloin samples decreased as the aging period increased, presumably due to the influence of the lower pH (5.67) of the crust from dry-aged *Hanwoo* used in this study compared to the control.

The color of meat products is determined by the types of additives added in the production process and the heat-induced generation of caramel pigments (Jung et al., 1994). The CIE color values measured revealed that the lightness (CIE L^*) of both uncooked and cooked sausage samples tended to decrease with increase in the level of *Hanwoo* crust, and the lightness was significantly lower in the 3% treatment compared to the control ($p<0.05$). The redness (CIE a^*) of both uncooked and cooked sausage samples increased proportionally with the *Hanwoo* crust content, and the redness of the cooked samples was significantly higher in the treated samples than in the control ($p<0.05$). The yellowness (CIE b^*) of the uncooked sausage samples was inversely proportional to the *Hanwoo* crust content, whereas the redness of the cooked samples significantly decreased with increase in *Hanwoo* crust content ($p<0.05$). In a study conducted by Choi et al. (2019), the lightness and yellowness of the patties were due to the added freeze-dried edible *Tenebrio molitor* mealworm powder, a protein additive, and it decreased proportionally with the quantity of the powder added to the patties in both uncooked and cooked conditions, which is consistent with the results of this study. These differences in the CIE color values in the sausage samples may be due to the effect of the CIE values, viz. lightness (L^*: 37.82), redness (a^*: 12.87), and yellowness (b^*: 2.08), of the *Hanwoo* crust added to the emulsion-type pork sausage, resulting in decrease in lightness and yellowness and increase in redness with increase in the *Hanwoo* crust content.

WHC and cooking yield

The water holding capacity (WHC) refers to the ability of meat protein to absorb and retain moisture according to the binding strength between protein and water molecules, and cooking loss occurs due to evaporation of moisture and elution of fat during heat process (Park, 2011). The proportion of cooked meat remaining after cooking loss is referred to as cooking yield (CY). These properties are determined by the quantity, structure, physical properties, and composition of the protein in meat products (Mittal and Usborne, 1985). Fig. 1 illustrates the measured values of the WHC and CY of the emulsion-type pork sausage samples added with *Hanwoo* crust at different concentrations (0–3%). Both WHC and CY tended to increase as the amount of *Hanwoo* crust increased, and the 3% treatment showed significantly higher HWC and CY compared to the control (0% *Hanwoo* crust) and the 1% treatment ($p<0.05$). Kim et al. (2009) reported that cooking loss was reduced by adding soy protein isolate, i.e., a vegetable protein, to Frankfurt sausage, and Cofrades et al. (2000) observed that adding plasma proteins to Bologna sausage reduced the amount of cooking loss. These findings are consistent with those of this study. Xue et al., (2021) found that when crust derived from dry-aging beef was added to patties, the cook loss was significantly decreased compare to control. In sausage production, meat protein forms a three-dimensional matrix structure that suppresses the elution of fat and water while being cooked (Wismer-Petersen, 1979; Parés 1998). It may thus be assumed that the increase in protein is advantageous for the formation of a stable matrix structure, which enhances WHC and CY by suppressing the elution of water and fat.

Viscosity

In emulsion-type sausages, the viscosity of the emulsion before cooking is an important quality criterion for estimating the bonding force between main ingredients and sub-ingredients constituting the emulsion (Uzlaşır et al., 2020). Fig. 2 plots the measured values of the viscosity of the emulsion-type sausage samples added with *Hanwoo* crust at different concentrations (0–3%). It is shown therein that the viscosity increased with increase in the amount of *Hanwoo* crust added, whereby the values of apparent viscosity of all *Hanwoo* crust treatments were higher than that of the control. Similarly, it has been reported that the added soy protein isolate as a protein additive suppresses water and fat loss of the emulsion, thus increasing the emulsion stability and the viscosity (Joseph, 1987; Raokosky, 1970). Lee and Kim (2020) compared the emulsifying power of the crusts derived from dry-aged sirloin samples of *Hanwoo* and *Holstein*, and found that *Hanwoo* considerably outperformed *Holstein*, proving that it is an efficient emulsion binder. In this study as well, the emulsifying power of sausage emulsion was enhanced by the addition of *Hanwoo* crust with excellent emulsifying properties, which in turn enhanced its viscosity.

TPA

Table 4 shows an overview of the texture profile analysis (TPA) results of the emulsion-type pork sausage samples added with *Hanwoo* crust at different concentrations (0–3%). The measured values of various TPA parameters led to the following findings. The hardness increased significantly with increase in the amount of *Hanwoo* crust ($p<0.05$) and gumminess and chewiness were significantly lower in the control and 1% treatment compared to the 3% treatment ($p<0.05$). In a similar study conducted by Lee and Chin (2013) with low-salt sausage mixed with freeze-dried mungo bean powder with added plant-based protein, the protein additive was observed to have a positive effect on the hardness and chewiness of the sausage samples. A similar result was also obtained in a study with low-fat sausage with added pea protein isolate, in which hardness, gumminess, and chewiness of the sausage also improved by the addition of protein (Choi and Chin, 2020), which is consistent with the results of this study. Similarly, soy protein isolate was also found to increase the hardness of the sausage, and the 2% treatment, in particular, was found to considerably improve the texture profile (Claus and Hunt, 1991). These consistent results are attributable to the improvement in the physical properties due to the enhanced binding capacity and hence enhanced binding strength between meat and fat (Lu and Chen, 1999). As has been found previously, the texture of meat products may have different properties depending on the state of raw meat, type of additives, fat, and moisture content (Song et al., 2000). In this study, reduction of the moisture content and increase in the binding capacity of sausage due to the addition of freeze-dried *Hanwoo* crust are assumed to be the factors that improved the hardness, gumminess, and chewiness of the sausage.

Sensory evaluation

Table 5 presents the results of sensory evaluation of emulsion-type pork sausage samples with 0–3% added *Hanwoo* crust. The sensory evaluation resulted in the following findings. There were no significant differences between control and treatments in color, tenderness, and juiciness. In terms of flavor, the 2% and 3% treatments led to significantly higher scores than the control ($p< 0.05$). As for overall acceptability, the 2% and 3% treatments provided significantly higher scores than the control ($p< 0.05$). In a previous study with brown sauce added with crust derived from dry-aged meat, the flavor and overall acceptability increased significantly with increase in the crust content (Park et al., 2020), which is consistent with the findings of this study. As noted previously, the flavor profile is enhanced on the addition of the crust derived from dry-aged meat is attributable to moisture loss due to evaporation during heat processing, thus increasing the concentrations of the substances related to taste and flavor such as the concentration of free amino acids obtained through proteolytic enzyme reactions. For example, the Maillard reaction during heat processing is a chemical reaction that occurs between a free amino group and amino acids:

it enhances the flavor profile, which is known to have a positive effect on flavor expression in foods rich in free amino acids (Ryu et al., 2018). Furthermore, flavor-related substances are generated from the unsaturated fat contained in the crust during heat processing, and this change positively affects the flavor of the food with added crust (Aaslyng and Meinert, 2017). This mechanism is believed to be the cause of the positive effect that the addition of *Hanwoo* crust used as an additive has on the flavor profile of the emulsion-type sausage.

Conclusion

This study analyzed the quality traits of emulsion-type sausage samples added with *Hanwoo* crust powder to determine the suitability of crust derived from dry-aged *Hanwoo* sirloin as an additive for processed meat products. The analysis results revealed that a 3% *Hanwoo* crust content (i.e., the highest weight ratio of *Hanwoo* crust to the emulsion-type sausage) outperformed traits such as the water holding capacity, cooking yield, viscosity, and textural properties. In sensory evaluation, the 3% treatment scored high in flavor and overall acceptability. Conclusively, it might be assumed that emulsion-type sausages with improved quality traits and enhanced flavor can be produced by adding *Hanwoo* crust at 3% concentration.

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Author Contributions

Conceptualization: Kim HY. Data curation: Kim HY. Formal analysis: Lee JA. Methodology: Kim HY. Software: Lee JA. Validation: Lee JA, Kim HY. Investigation: Lee JA. Writing - original draft: Lee JA. Writing - review & editing: Lee JA, Kim HY.

Ethics approval

The sensory evaluation was approved by the Kongju National University's Ethics Committee (Authority No: KNU 2020-15).

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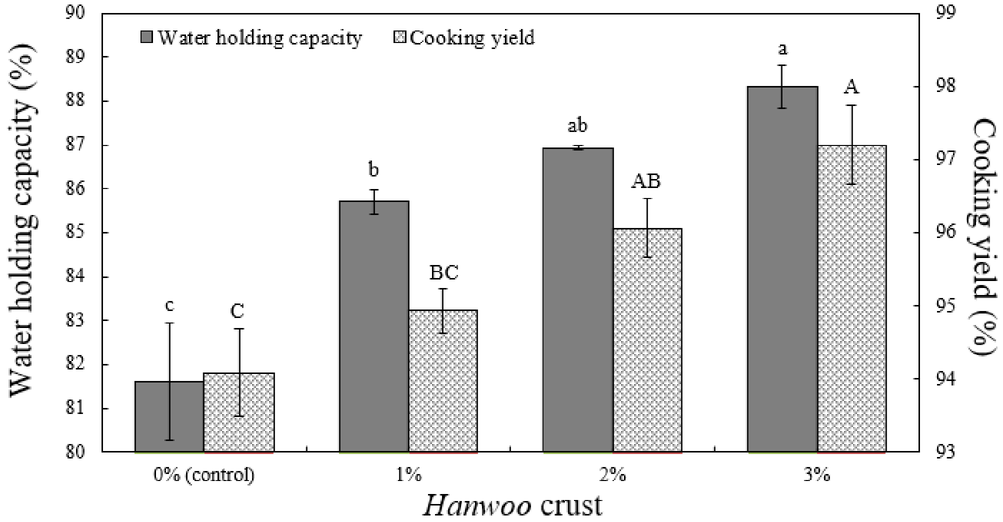

Fig. 1. Water holding capacity and cooking yield of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust. [a-c, A-C] Means with different letters differ significantly at the same color graph bar ($p<0.05$).

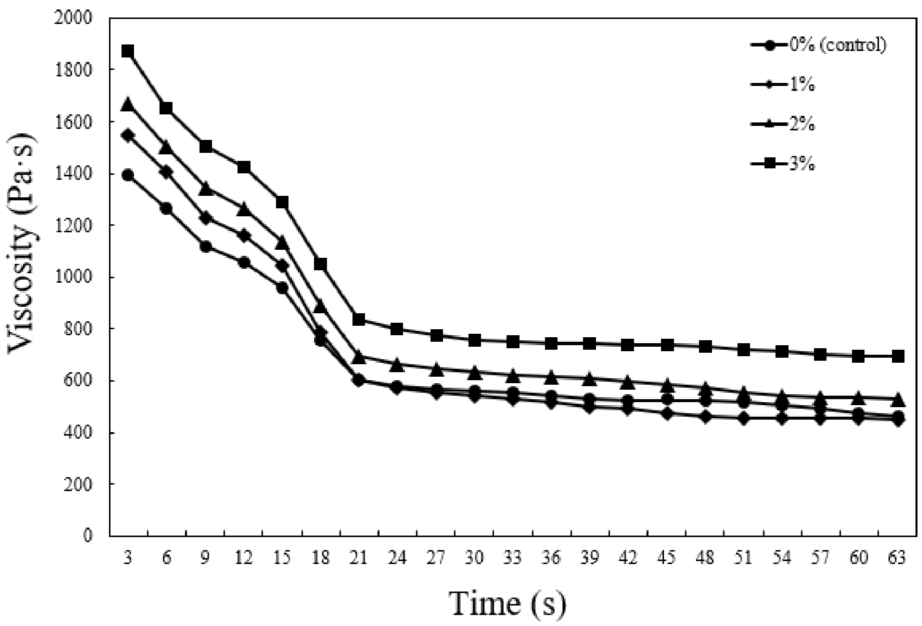

Fig. 2. Apparent viscosity of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust.

Table 1. Formulation of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust

Ingredients		*Hanwoo* crust (%)			
		0 (control)	1	2	3
Main	Meat (%)	60	60	60	60
	Fat (%)	20	20	20	20
	Ice (%)	20	20	20	20
Additive	NPS[1)] (%)	1.2	1.2	1.2	1.2
	Phosphate (%)	0.3	0.3	0.3	0.3
	Sugar (%)	1	1	1	1
	Spice (%)	0.6	0.6	0.6	0.6
	Hanwoo crust (%)	0	1	2	3

[1)] NPS: nitrite pickling salt.

Table 2. Proximate composition of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust

Traits	*Hanwoo* crust (%)			
	0 (control)	1	2	3
Moisture (%)	63.50±0.91[a]	61.91±0.83[a]	59.61±0.55[b]	58.13±0.40[b]
Protein (%)	13.75±0.18[c]	14.24±0.15[b]	14.52±0.14[b]	14.99±0.20[a]
Fat (%)	17.33±2.89[b]	21.33±0.58[a]	22.00±1.00[a]	23.33±0.58[a]
Ash (%)	2.12±0.02[c]	2.22±0.02[b]	2.27±0.03[ab]	2.31±0.02[a]

All values are mean±SD.

[a-c] Mean in the same row with different letters are significantly different ($p<0.05$).

Table 3. pH, color of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust

Traits			*Hanwoo* crust (%)			
			0 (control)	1	2	3
pH		Uncooked	6.17±0.02[a]	6.16±0.01[a]	6.15±0.01[a]	6.11±0.01[b]
		Cooked	6.20±0.01[a]	6.19±0.01[a]	6.17±0.01[b]	6.16±0.01[c]
Color	Uncooked	CIE L*	74.75±0.50[a]	72.89±0.05[b]	72.21±0.03[b]	71.26±0.19[c]
		CIE a*	0.43±0.07[b]	0.70±0.21[ab]	0.83±0.21[ab]	0.89±0.07[a]
		CIE b*	19.25±0.18[a]	19.03±0.04[a]	18.72±0.01[b]	18.29±0.19[c]
	Cooked	CIE L*	70.82±0.35[a]	70.41±0.61[ab]	69.57±0.04[ab]	68.62±1.36[b]
		CIE a*	1.37±0.10[c]	1.80±0.06[b]	2.13±0.19[b]	2.68±0.28[a]
		CIE b*	17.36±0.17[a]	16.85±0.04[b]	16.25±0.12[c]	15.59±0.26[d]

All values are mean±SD.

[a-d] Mean in the same row with different letters are significantly different ($p<0.05$).

Table 4. Texture profile analysis of emulsion-type sausages formulated with various levels of *Hanwoo* crust

Traits	*Hanwoo* crust (%)			
	0 (control)	1	2	3
Hardness (gf)	2607.13±93.51^{d}	3016.13±308.82^{c}	3624.85±124.66^{b}	4035.22±123.80^{a}
Springiness	0.87±0.02	0.82±0.06	0.81±0.01	0.77±0.09
Gumminess (gf)	1433.36±142.18^{c}	1588.09±363.75^{c}	1931.72±60.06^{b}	2260.14±143.14^{a}
Chewiness (gf)	1257.12±116.04^{c}	1309.92±280.74^{bc}	1576.31±12.81^{ab}	1755.08±314.35^{a}
Cohesiveness	0.55±0.05	0.53±0.01	0.54±0.01	0.56±0.05

All values are mean±SD.

$^{a\text{-}d}$ Mean in the same row with different letters are significantly different ($p<0.05$).

Table 5. Sensory properties of pork emulsion-type sausages formulated with various levels of *Hanwoo* crust

Traits	*Hanwoo* crust (%)			
	0 (control)	1	2	3
Color	8.57±0.79	8.86±0.90	9.00±0.89	9.00±0.89
Flavor	8.00±0.58^{c}	8.43±0.79^{bc}	8.86±0.69^{ab}	9.29±0.49^{a}
Tenderness	8.57±0.98	8.86±0.90	8.86±0.69	8.86±0.69
Juiciness	8.43±0.53	8.86±0.69	8.86±0.38	8.83±0.41
Overall acceptability	7.86±0.38^{b}	8.57±0.79^{ab}	9.00±0.63^{a}	8.86±0.69^{a}

All values are mean±SD.

$^{a-c}$ Mean in the same row with different letters are significantly different ($p<0.05$).