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Effect of Kimchi Powder Levels and Pork Skin on the Quality Characteristics of Liver Sausages

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Abstract

The aim of this study was to evaluate the effect of kimchi powder levels (0, 1, 2, and 3%) and pork skin (5%) on the quality characteristics of liver sausages. The additions of the kimchi powder and pork skin improved the color, cooking yield, and sensory properties of the sausages. The addition of the pork skin and increasing concentrations of the kimchi powder significantly increased cooking yields. The moisture and protein contents of the sausages made with kimchi powder and pork skin were higher than those of the control ($p<0.05$). Due to the low pH of the kimchi powder, the pH values of the batter and sausages with added kimchi powder were lower than those of the treatment without kimchi powder ($p<0.05$). The control had the lowest hardness, gumminess, and chewiness values ($p<0.05$). For the sensory attributes of the samples, color, flavor, juiciness, and overall acceptability were higher in the treatments made with kimchi powder than in the treatments without kimchi powder, in which the treatment with 2% kimchi powder had the highest overall acceptability ($p<0.05$). In conclusion, the additions of kimchi powder and pork skin improved the quality characteristics of liver sausages.

Key words : liver sausage, pork skin, dietary fiber, kimchi, quality characteristics

Introduction

Liver sausage is one of the most commonly consumed sausage types in Europe due to European preference for its specific flavor and the various levels of liver eliminated gall with which it is made. A considerable number of studies have been conducted on the manufacturing process of liver sausage (Hammer, 1998; Moon, 1987; Wiegner, 1981). Pork liver contains high levels of nutrients such as protein, lipids, vitamins A, D, E, B, and iron. Therefore, due to its abundant nutritional value, pork liver sausage is an ideal food for growing children, eyesight protection, and anemia protection and treatment (Lee and Cho, 1999). On the other hand, liver sausage is high-calorie (around 300-400 kcal/100 g) with a relatively high percentage of lipids (30-40%) (McCance and Widdowson, 1992; Mataix, 1994; Senser and Scherz, 1999; Moreiras *et al.*, 2001), and due to interests in health and reduced fat intake, individual may avoid its consumption. Liver sausage, in particular, is one of the most heat-sensitive meat products (Wirth *et al.*, 1971); even sausages heated at low temperature can have a bitter and burnt taste. In 1995, 7.6% of tested liver sausages had a negative burnt, high-temperature-heated flavor (Stiebing, 1996). Lee *et al.* (1997) reported on lipid rancidity, and Hong *et al.* (2003) reported on the physicochemical properties of liver sausages. Although liver sausage has abundant nutrients, in Korea, applications for liver are limited due to the negative burnt, high-temperature-heated flavor of the sausage as well as the dark brown color caused by the Maillard reaction between the liver amino acids and sugars (Hilmes and Fischer, 1997).

Pork skin, a by-product of slaughter, may potentially improve quality and reduce production cost when used as a replacement for raw meat. Pork skin contains 44.24% moisture, 28.29% fat, and 26.27% protein. Moreover, pork skin mainly contains collagen protein (269.67 mg/g) (Osburn, 1996) that is converted to soluble gelatin, forming a membrane of fat globules, breaking hydrogen bonds and covalent bonds (Bell, 1989). Furthermore, collagen may have use in certain fabricated meat items (Zhang *et al.*, 2009). Some proteins perform functional characteristics such as water holding capacity, gel forming, stability, and solubility (Hammonds and Call, 1972). Satterlee and

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Zachariah (1973) reported that the water- and fat-holding capacity of sausage were improved by adding enzyme-hydrolyzed pork skin collagen as a binder.

Kimchi, a traditional Korean fermented food, is a recognized dish all over the world, and has high nutritional value including vitamins, minerals, and dietary fiber since it contains different vegetables (radish, onion, green onion, etc.) and spices (garlic, ginger, hot pepper, etc.) (Lee and Kunz, 2005). The dietary fiber in kimchi can prevent diseases such as cancer, constipation, obesity, arteriosclerosis, diabetes, hypertension, and gallstone formation (Park *et al.*, 1996). Furthermore, dietary fiber is desirable not only for its nutritional properties but also for increasing cooking yield due to its water and fat binding properties, improving the texture properties of cooked meat products (Thebaudin *et al.*, 1997). Finally, the addition of kimchi powder in meat products can reduce burnt flavor and improve color (Lee *et al.*, 2008).

Therefore, the objective of this study was to improve acceptability of liver sausage, in terms of nutritional value and Korean taste preference, by the addition of kimchi powder, and to evaluate the physicochemical and sensory properties of different formulations containing pork skin and various levels of kimchi powder.

Materials and Methods

Preparation of kimchi powder

Baechu kimchi (Chongga kimchi, Daesang FNF, Seoul, Korea) was obtained from a local market. The kimchi was removed of its water and juice after fermentation in a refrigerator (4°C). The kimchi was dried by a hot air dryer (Enex-Co-600, Enex, Koyang, Korea) at 60°C for 12 h. The dried kimchi was pulverized by a blender (KA-2610, Jworld Tech, Ansan, Korea) for 30 s and screened through a 35 mesh sieve. The kimchi powder contained 32.5% dietary fiber (7.40% soluble dietary fiber and 25.09% insoluble dietary fiber).

Formulation and processing of liver sausages

Fresh pork hams, weighing 6.5-7.0 kg each, were purchased from a pilot plant at Konkuk University, Korea, at 48 h postmortem. The pork back fat, pork liver, and defatted pork skin were also collected from the slaughter house. All subcutaneous and intramuscular fat and visible connective tissues were removed from the fresh ham muscles. The liver sausage formulation is presented in Table 1, and the manufacturing process is presented in Fig. 1.

The manufacturing process was divided into two parts involving cured and emulsified portions of lean pork meat. A silent cutter (Nr-963009, Scharfen, Witten, Germany) was used for emulsification. Then, the emulsion was mixed with the pork liver in the cutter for 2 min. The cured and emulsified portions were mixed, and the pork liver chopped using the 3 mm plate was added. Two percent isolated soy protein, 0.44% nitrite pickle salt (NPS), and kimchi powder were added to this mixture, and then blended for 15 min and stuffed into fibrous casings (approximate diameter of 72 mm) using a stuffer (IS-8, Sirman, Marsango, Italy). The hot-air-dried kimchi powder was added at levels of 0, 1, 2, and 3%. These percentages were based on the control formula weight. Then, the liver sausages were dried in a smoker (ES-1, ETL testing laboratories INC., Newyork, USA) at 55°C for 30 min, smoked at 65°C for 60 min, and cooked at 75°C for 2 h. The cooked liver sausages were cooled by cold water for 3 min and stored at 4°C until testing.

Proximate composition

The compositional properties of the samples were determined using standard AOAC (1995) methods. The moisture contents were determined by weight loss after 12 hr of drying at 105°C in a drying oven (SW-90D, Sang Woo Scienctific Co., Bucheon, South Korea). The fat contents were determined by the Sohxlet method with a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Höganas, Sweden). The protein contents were determined by the Kjeldahl method

Table 1. Formulations of liver sausages with/without pork skin and added various levels of kimchi powder

Ingredient (%)	Treatments				
	Control	SK0	SK1	SK2	SK3
Lean pork meat	45	45	45	45	45
Pork back fat	20	20	20	20	20
Pork liver	10	10	10	10	10
Pork skin	-	5	5	5	5
Meat stock	5	5	5	5	5
ISP[1)]	2	2	2	2	2
NPS[2)]	1.5	1.5	1.5	1.5	1.5
MSG[3)]	0.5	0.5	0.5	0.5	0.5
Sugar	0.5	0.5	0.5	0.5	0.5
Sodium tripolyphosphate	0.25	0.25	0.25	0.25	0.25
Ascorbic acid	0.02	0.02	0.02	0.02	0.02
Frank-seasoning	0.1	0.1	0.1	0.1	0.1
Kimchi powder	-	-	1	2	3

[1)] ISP, isolated soy protein.
[2)] NPS, nitrite pickle salt (NPS; salt:nitrite=99.4:0.6).
[3)] MSG, monosodium L-glutamate.

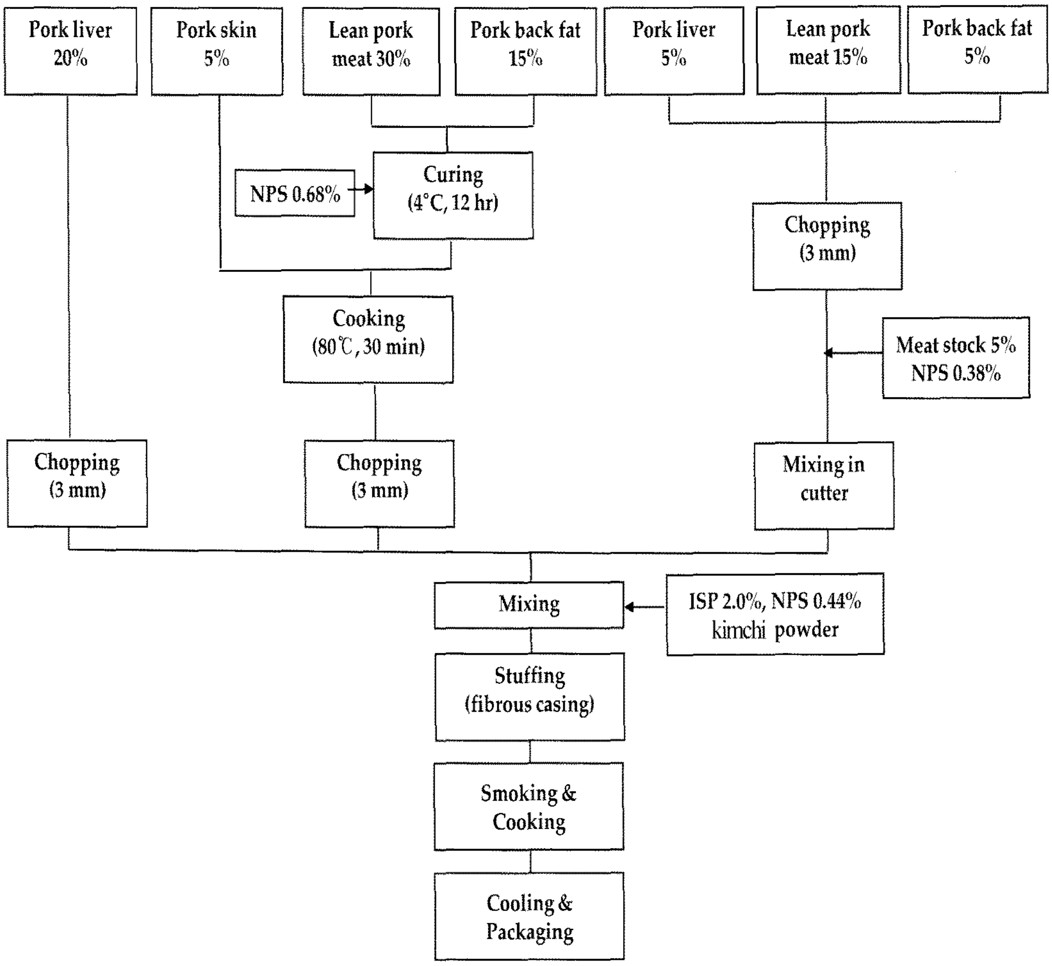

Fig. 1. The diagram of liver sausage manufacturing.

with an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Analytical AB, Höganäs, Sweden). Finally, the ash contents were determined according to AOAC method 923. 03.

pH

The pH values of samples were determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). The pH of the liver sausage was measured after blending 5 g of sample with 20 mL of distilled water for 60 s in a homogenizer (Ultra-Turrax SK15, Janke & Kunkel, Staufen, Germany).

Instrumental color evaluations

The instrumental color analyses of the liver sausage samples were conducted as follows. The raw liver sausage was weighed (80 g) into a Petri dish and cooked at 75±1°C for 30 min. After cooling, the cooked liver sausages were evaluated. The color measurements were taken with a colorimeter (Chroma meter CR-210, Minolta, Japan; illuminate C, calibrated with a white standard plate CIE L* = 97.83, CIE a* = -0.43, CIE b* = +1.98), consisting of an 8 mm diameter measuring area and a 50 mm diameter illumination area. The color values (CIE L*, a*, and b*) were measured on the sample surfaces and data were taken in triplicate for each sample.

Cooking yield

The meat batter was weighed (80 g) and stuffed into fibrous casings and then heat processed at 75±1°C for 30 min. After cooling 30 min, the cooked liver sausages were weighed and the percentage cooking yields were calculated from the weights.

$$\text{Cooking yield (\%)} = \frac{\text{weight of sausage after cooking}}{\text{weight of sausage before cooking}} \times 100$$

Emulsion stability

The meat batters were analyzed for emulsion stability using the method of Bloukas and Honikel (1992) with the following modifications. At the middle of a 15 mesh sieve (50 mm diameter), pre-weighed graduated glass tubes (Pyrex Chojalab Co., Seoul, South Korea, Volume: 15 mL, Graduated units: 0.2 mL) were filled with batter. The glass tubes were closed and heated for 30 min in a boiling water bath to a core temperature of 75±1°C. They were then cooled to approximately 4°C to facilitate the separation of the fat and water layers. The fluid water and fat, which separated well in the bottom of the graduated glass tube, were measured in milliliters and calculated as percentages of the original weight of the batter.

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

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

Viscosity

The flow behavior and time dependency of the batters were measured in triplicate with a rotational viscometer (HAKKE Viscoteste® 550, Thermo Electron Corporation, Karlsruhe, Germany) set at 10 rpm. The tests were performed by a standard cylinder sensor (SV-2) at 20±1°C. The time dependency of the meat batter was evaluated by measuring the viscosity under a constant share rate of 10 s^{-1} for 60 s.

Texture profile analysis (TPA)

Texture profile analyses were performed in duplicate on each sausage. The samples were cooked as previously described. The cooked sausages were cooled at room temperature for 1 h to determine the texture properties. The textural properties of each sausage were measured by a spherical probe (5 diameter), attached to a Texture Analyzer (TA-XSK1*i*, Stable Micro System Ltd., Surrey, U.K.). The test conditions were as follow: stroke, 20 g; test speed, 2.0 mm/s; and distance, 10.0 mm. The data were collected and analyzed in terms of hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) values.

Sensory evaluations

The liver sausages were evaluated for color, flavor, juiciness, tenderness, kimchi flavor, and overall acceptability. The cooked samples as previously described were cooled to room temperature at 25±1°C and cut and served to the panelists in random order. The sensory evaluations were performed by the panelists under fluorescent lighting. The panelists were instructed to cleanse their palates between samples using water. The color, flavor, kimchi flavor, and overall acceptability (1 = extremely undesirable, 10 = extremely desirable); tenderness (1 = extremely tough, 10 = extremely tender); and juiciness (1 = extremely dry, 10 = extremely juicy) of the cooked samples were evaluated using a 10-point descriptive scale. The panel consisted of 10 members from the Department of Food Science and Biotechnology of Animal Resources at Konkuk University, Korea.

Statistical analysis

Analysis of variance was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Institute, Inc., 1999). Duncan's multiple range test ($p<0.05$) was used to determine the differences between treatment means.

Results and Discussion

Proximate composition

The proximate compositions of the liver sausages made with kimchi powder and pork skin are presented in Table 2. For moisture, protein, fat, and ash contents, significant differences were found between the control and treatments. The fat content of SK0 was lower than that of the control ($p<0.05$) because of addition of defatted pork skin. The moisture and fat contents were increased by the addition of the kimchi powder. This may be due to the fact that the kimchi powder increased the water and fat binding properties of the meat during cooking. The kimchi powder possessed a high water holding capacity due to its high insoluble fiber content. Moreover, in meat, moisture and fat content are very closely related (Fernández-Gins *et al.*, 2004), and fiber improves the water and fat-binding properties of cooked meat products (Cofrades *et al.*, 2000). According to Jiménez Colmenero *et al.* (2003), fat content increased by the addition of walnuts in restructured beef steak. The protein content of SK3 was highest among all the treatments ($p>0.05$). Due to the pork skin, the protein content of the pork skin treatment was higher than that of the treatment without pork skin ($p<0.05$). The ash contents of the treatments increased by the addition of the kimchi powder and decreased with the addition of the pork skin. Yilmaz (2005) observed that the ash contents of treatments increased by the addition of wheat bran.

pH and color

The pH and color parameters of the liver sausages made with pork skin and kimchi powder are shown in Table 3.

Table 2. Proximate analysis of liver sausages[1)] formulated with/without pork skin and added various levels of kimchi powder

Properties	Treatments[1)]				
	Control	SK0	SK1	SK2	SK3
Moisture (%)	52.95±0.45[c2)]	53.83±0.90[bc]	54.23±0.93[b]	57.02±0.92[a]	57.29±0.72[a]
Protein (%)	15.13±0.65[c]	17.34±0.22[ab]	17.45±0.18[ab]	16.77±0.29[b]	17.58±0.06[a]
Fat (%)	25.50±0.34[a]	19.30±0.92[c]	21.80±0.37[b]	21.53±0.41[b]	22.23±0.15[b]
Ash (%)	1.89±0.07[bc]	1.73±0.02[d]	1.82±0.06[c]	1.91±0.05[b]	2.11±0.02[a]

[1)] For treatments denomination see Table 1.
[2)]Mean±SD of three replicates.
[a-d] Means within the same row with different letters are significantly different ($p<0.05$).

The pH values of SK0 were lower than the control due to the low pH (3.5-4.1) of the pork skin. Furthermore, the pH values of SK3, in both the uncooked and cooked forms, were lowest. The pH values of the samples significantly decreased by the addition of the kimchi powder due to its organic acid content. Similar results were obtained in other studies for a meat emulsion with added albedo (Sariçoban *et al.*, 2008), an emulsion-type sausage with added citron peel powder (Lee *et al.*, 2004), meat sausage with added chitosan (Youn *et al.*, 1999), and breakfast sausage with added kimchi (Lee *et al.*, 2008). On the contrary, additional studies have reported that added fiber resulted in increased pH values (Choi *et al.*, 2008; Yilmaz, 2005).

In our study, the pH values of the liver sausages with kimchi powder ranged from 6.28 to 6.42 in the raw sausages, and from 6.38 to 6.51 in the cooked sausages. The pH values of the cooked liver sausages were higher than those of the raw liver sausages in all treatments. This result is likely attributed to the protonation of the basic amino groups of the meat protein during processing (Choi *et al.*, 2008).

The CIE L-values of the uncooked and cooked sausages decreased when the kimchi powder content increased. A similar relationship between CIE L*-values and fiber content has been reported by several authors (Jiménez-Colmenero *et al.*, 2003; Turhan *et al.*, 2005; Fernández-López, 2004). However, the CIE a*- and b*-values of the uncooked and cooked treatments increased with an increase in kimchi powder content, respectively. This result was probably due to the a*- and b*-values of the kimchi powder. Moreover, increasing the kimchi powder content produced redder liver sausages, as was also found in a study carried out on a different meat product (Lee *et al.*, 2008). In addition, studies have reported the effects of added fiber on color in various meat products (Claus and Hunt, 1991; Grigelmo-Miguel *et al.*, 1999).

Cooking yield and emulsion stability

The additions of pork skin and kimchi powder (contributing fiber) affected the cooking yields of the liver sausages (Table 4). The cooking yield of SK0 was higher than that of the control ($p>0.05$). Increasing the kimchi powder concentration from 1 to 3% significantly increased the cooking yield ($p<0.05$). The cooking yields of

Table 3. Comparison on pH values and color parameter of liver sausages[1)] formulated with/without pork skin and added various levels of kimchi powder

Properties	Traits	Treatments[1)]				
		Control	SK0	SK1	SK2	SK3
Raw	pH	6.42±0.01[a2)]	6.34±0.01[c]	6.35±0.01[b]	6.31±0.01[d]	6.28±0.01[e]
	CIE L*	58.04±0.82[a]	57.25±0.72[b]	55.96±0.44[c]	54.99±0.70[d]	53.58±0.55[e]
	CIE a*	13.35±0.24[e]	13.85±0.21[d]	14.44±0.43[c]	15.05±0.30[b]	15.97±0.13[a]
	CIE b*	9.44±0.35[d]	9.74±0.58[d]	13.33±0.65[c]	14.34±0.76[b]	16.56±0.47[a]
Cooked	pH	6.51±0.01[a]	6.46±0.01[b]	6.44±0.01[c]	6.41±0.01[d]	6.38±0.01[e]
	CIE L*	62.11±0.36[a]	62.06±0.45[a]	60.28±0.42[b]	59.30±0.15[c]	58.77±0.50[d]
	CIE a*	12.28±0.31[c]	12.56±0.23[b]	12.99±0.26[a]	12.89±0.13[a]	13.09±0.21[a]
	CIE b*	10.35±0.30[d]	9.30±0.30[e]	11.07±0.26[c]	12.61±0.70[b]	14.85±0.86[a]

[1)] For treatments denomination see Table 1.
[2)]Mean±SD of three replicates.
[a-d] Means within the same row with different letters are significantly different ($p<0.05$).

Table 4. Cooking yield of liver sausages[1)] with/without pork skin and added various levels of kimchi powder

Properties	Treatments[1)]				
	Control	SK0	SK1	SK2	SK3
Cooking yield (%)	90.32±0.58[c2)]	91.96±0.94[b]	92.43±0.52[ab]	93.86±0.89[a]	92.90±0.93[a]

[1)] For treatments denomination see Table 1.
[2)] Mean±SD of three replicates.
[a-c] Means within the same row with different letters are significantly different ($p<0.05$).

SK2 and SK3 were highest among all the treatments. These results are in agreement with data reported by the following: Mansour and Khalil (1997) in low-fat beef burgers with additions of various types of wheat fibers; Cofrades *et al.* (2000) in bologna sausages with plasma protein and soy fiber; Yilmaz (2004) in low-fat meatballs with added rye bran; Aleson-Carbonell *et al.* (2005) in beef burgers with additions of various types of lemon albedo; and Turhan *et al.* (2005) in low-fat beef burgers with added hazelnut pellicle, who found that added fiber decreased cooking loss in treatments. Furthermore, Chen *et al.* (1984) found that the addition of fiber improved the water and fat-binding properties of liver sausages.

Emulsion stability represents the retention of unseparated fat and moisture in the meat emulsion during cooking (Sariçoban *et al.*, 2008). It was observed that water exudation was affected, while fat exudation was just slightly affected, when the kimchi powder was added to the meat batter (Fig. 2). A previous study (Jiménez Colmenero *et al.*, 2003) showed a similar result for water exudation in restructured beef steak with added walnuts. Hughes *et al.* (1997) reported that the addition of dietary fiber improved the stability of a pork emulsion, and Ledward (1994) reported that interactions between the carboxyl groups of anionic polysaccharides formed more stable complexes than those with native protein. In the present study, the fat exudation of the meat batter with pork skin was not different compared to the control. And the water exudation of the meat batter with pork skin increased compared to the control at 75°C ($p<0.05$). Both fat and water exudation increased as temperature increased for all treatments due to the decreasing heat stability of the pork skin as the cooking temperature increased (Kim and Lee, 1988).

Viscosity

The viscosity values of the liver sausage meat batters made with pork skin and kimchi powder are presented in Fig. 3. The results show that the addition of the pork skin increased the viscosity values of the meat batter. In contrast to this, Kim and Lee (1988) reported that the viscosity and hardness of sausage emulsions decreased as the pork skin gelatin gel substitution ratio increased. Increasing kimchi powder concentration resulted in increased viscosity in the sausages ($p<0.05$). This is due to the fact that increased meat batter viscosity is related to its water binding capacity and dietary fiber concentration. Similar results for viscosity were observed by the following: Choi *et al.* (2007) who found that increasing the addition of extracted rice bran fiber increased ($p<0.05$) meat batter viscosity; Claus and Hunt (1991) who found that the addition of dietary fiber increased emulsion viscosity in sausages; and Lee *et al.* (2008) who also found that the addition of kimchi powder increased the viscosity of breakfast sausages. Consequently, the addition of kimchi powder is useful in meat products because it increases viscosity, emulsion stability, and cooking yield (Aktas and Gençcelep, 2006).

Texture profile analysis (TPA)

The textural properties of the liver sausages made with pork skin and kimchi powder are presented in Table 5. These results indicate that changes, due to the addition of the pork skin and fiber, affected the textural characteristics of the liver sausages. The data show that the hardness of the control was lowest. Similar results were obtained in a previous study where the hardness and firmness of a pork loaf product increased by the addition of pork skin (Quint *et al.*, 1987). The hardness values of the SK3 samples were lowest among the treatments containing pork skin, and this was probably due to their higher moisture contents. However, Kim and Lee (1988) found that the hardness of sausage emulsion decreased by increasing the pork skin gelatin gel substitution ratio. It was also reported that textural properties were affected by the amount and type of fiber (Thebaudin, 1997). Thus, various meat products with fiber have resulted in both hardening and softening. Insoluble fibers can influence food texture due to their water-binding ability and swelling properties. The control had significantly higher values than the other treatments for cohesiveness, gumminess,

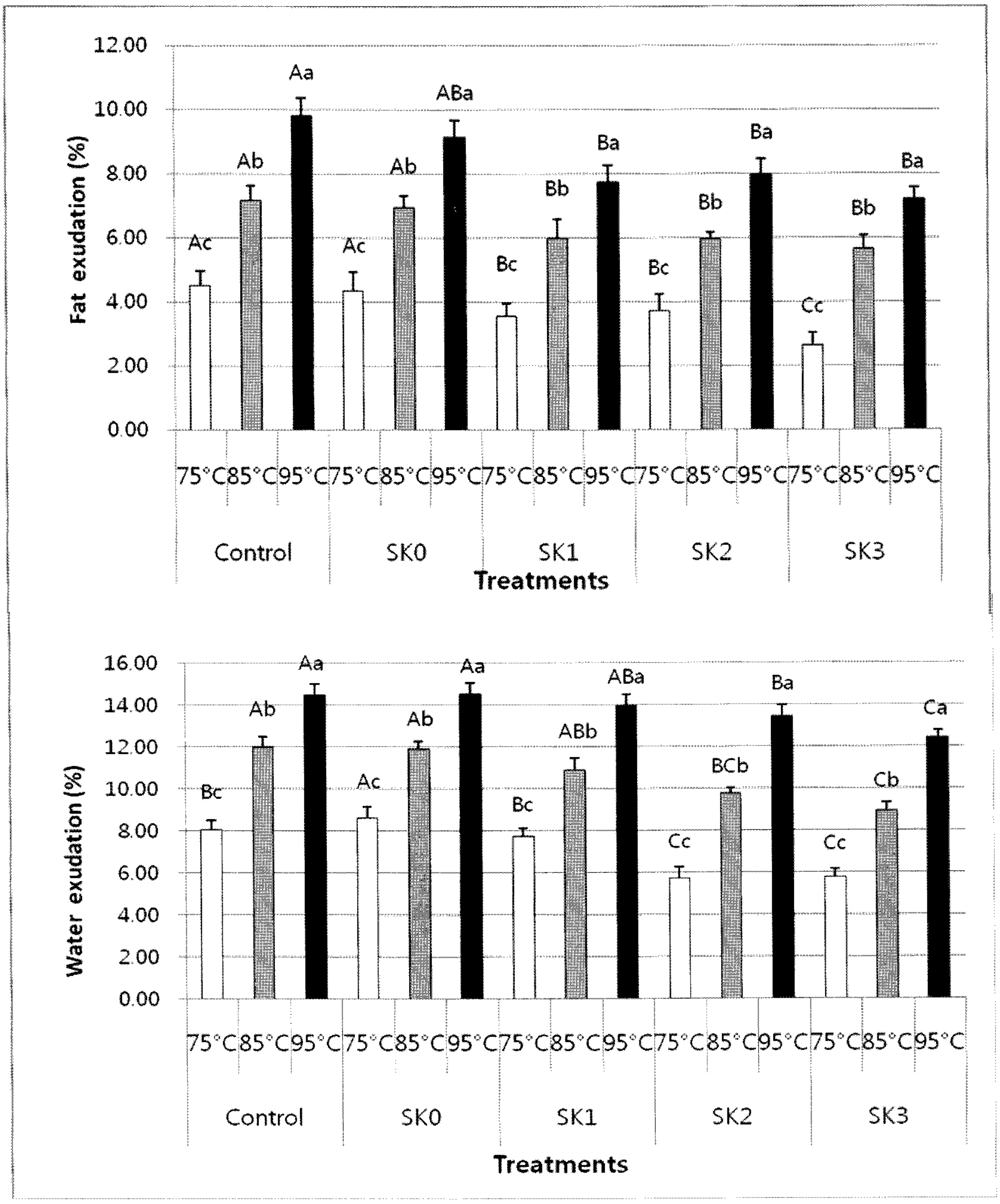

Fig. 2. Emulsion stability (fat exudation and water exudation) of meat batter of liver sausages[1)] with/without pork skin and added various levels of kimchi powder. [1)] For treatments denomination see Table 1. $^{A-C}$ Means in the temperature with different letters are significantly different (p<0.05). $^{a-c}$ Means in the treatments with different letters are significantly different (p<0.05).

and chewiness. And increasing the kimchi powder content decreased the cohesiveness, gumminess, and chewiness values of samples. The SK3 group had the lowest cohesiveness, gumminess, and chewiness values. Yang (2007) showed that increases in hydrated oatmeal content decreased gumminess and chewiness values. On the contrary, Lee *et al.* (2008) reported that gumminess and chewiness were increased by increases in kimchi powder (p<0.05).

Sensory evaluations

The sensory evaluations for the liver sausages made with pork skin and kimchi powder are presented in Table 6. The SKO group had higher sensory property scores than the control (p>0.05). All treatments made with kimchi powder had higher (p<0.05) sensory scores for color, flavor, and juiciness than the control treatment. Yilmaz (2004) reported that the perception of juiciness for meatballs decreased as wheat bran fiber content increased. No differences in tenderness were found between the treat-

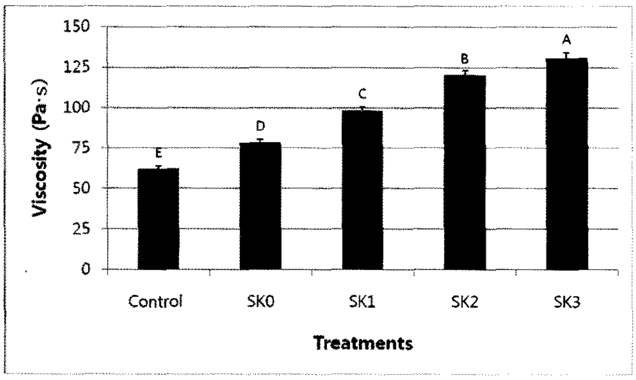

Fig. 3. Viscosity of meat batters[1)] formulated with/without pork skin and added various levels of kimchi powder.
[1)] For treatments denomination see Table 1. [A-E] Means in the treatments with different letters are significantly different ($p<0.05$).

ments despite the additions of pork skin and kimchi powder ($p>0.05$). Added fiber can cause decreases in tenderness, odor, and consistency, regardless of the added amount (Bushway *et al.*, 1982). The SK3 group had the highest ($p<0.05$) scores for kimchi flavor due to its kimchi powder content. The overall acceptability scores of the SK2 group were highest. And overall, the sensory properties of the SK2 sausages were deemed superior ($p<0.05$) to the other treatments.

In brief, this study showed that additions of pork skin and kimchi powder influenced the physicochemical analyses and sensory properties of liver sausages. In terms of quality characteristics, the most desirable results were obtained for sausages made with pork skin and 2% kimchi powder. These results suggest other potential applications for additions of pork skin and kimchi powder in meat products and further study is required.

Acknowledgement

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Table 5. Comparison on textural properties of liver sausages[1)] with/without pork skin and added various levels of kimchi powder

Properties	Treatments[1)]				
	Control	SK0	SK1	SK2	SK3
Hardness (kg)	0.17±0.01[d2)]	0.26±0.03[a]	0.24±0.02[ab]	0.23±0.01[b]	0.21±0.02[c]
Springiness	0.92±0.06	0.92±0.05	0.93±0.04	0.94±0.04	0.94±0.04
Cohesiveness	0.44±0.04[c]	0.50±0.01[a]	0.48±0.03[b]	0.45±0.01[c]	0.44±0.01[c]
Gumminess (kg)	0.06±0.01[d]	0.11±0.01[a]	0.10±0.01[a]	0.09±0.01[b]	0.08±0.02[c]
Chewiness (kg)	0.05±0.01[c]	0.09±0.01[a]	0.09±0.01[a]	0.08±0.01[b]	0.07±0.01[b]

[1)] For treatments denomination see Table 1.
[2)] Mean±SD of three replicates.
[a-d] Means within the same row with different letters are significantly different ($p<0.05$).

Table 6. Comparison on sensory properties of liver sausages[1)] with/without pork skin and added various levels of kimchi powder

Sensory properties[1)]	Treatments[1)]				
	Control	SK0	SK1	SK2	SK3
Color	6.9±0.74[c2)]	7.4±0.70[bc]	8.6±0.52[a]	8.6±0.52[a]	7.9±0.88[b]
Flavor	7.3±0.82[bc]	7.0±0.82[c]	7.5±0.71[bc]	8.4±0.70[a]	7.9±0.32[ab]
Tenderness	7.7±0.82	7.6±0.84	7.6±0.94	8.1±0.88	7.9±0.74
Juiciness	7.3±0.82[c]	7.2±0.79[c]	7.6±0.70[bc]	8.4±0.70[a]	8.2±0.63[ab]
Kimchi flavor	0.8±0.42[c]	1.1±0.32[c]	1.7±0.67[b]	2.6±0.92[ab]	3.2±0.63[a]
Overall acceptability	6.8±0.6[c]	7.1±0.74[bc]	7. 6±0.84[b]	8.4±0.70[a]	8.0±0.67[ab]

[1)] For treatments denomination see Table 1.
[2)] Mean±SD of three replicates.
[a-c] Means within the same row with different letters are significantly different ($p<0.05$).

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