



## Physicochemical and Sensory Characterization of Korean Blood Sausage with Added Rice Bran Fiber

Yun-Sang Choi, Ji-Hun Choi, Doo-Jeong Han, Hack-Youn Kim, Mi-Ai Lee, Hyun-Wook Kim, Chi-Ho Lee, Hyun-Dong Paik, and Cheon-Jei Kim\*

Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea

### Abstract

This study was conducted to determine the effects of added rice bran fiber on the physicochemical and sensory characterization of blood sausage. Blood sausages were supplemented with rice bran fiber at levels of 0% (control), 1%, 2%, and 3%. The moisture, hardness, gumminess, and chewiness of treatments with added rice bran fiber were higher than those of controls ( $p < 0.05$ ). The pH, lightness, redness, and yellowness of uncooked as well as cooked blood sausages increased with increasing addition levels of rice bran fiber levels, but energy values were lower in blood sausage treatments with containing rice bran fiber than that of controls ( $p < 0.05$ ). As the increase levels of rice bran fiber in blood sausage the energy levels were decreased ( $p < 0.05$ ). All sensory scores of treatments containing rice bran fiber were higher than controls, and the highest overall acceptability was attained when 2% rice bran fiber was added to blood sausage. The blood sausage with 2% rice bran fiber can be manufactured with high quality characteristics.

**Key words :** blood sausage, rice bran fiber, sensory properties, energy value

### Introduction

The Korean blood sausage is a popular cooked meat product (*Soondae*) produced in the region in Korea (Sohn *et al.*, 1999a). It consists of a mixture of chopped meat, animal fat, vegetable, pork blood, salt and different spices such as soybean paste, clear strained rice wine, black pepper, and sesame oil (Sohn *et al.*, 1999b). The Korean blood sausage is similar to the western-type blood sausages (Diez *et al.*, 2008; Santos *et al.*, 2003). Also, blood sausage is one of the most common sausages in Europe, where animal blood and the internal organs of by-products on livestock industry are used (Caldironi and Ockerman, 1982; Stiebing, 1990), thereby reducing industrial waste, increasing utility of available protein, and minimizing environmental contamination. A number of studies have been conducted on the manufacturing of blood sausage (Diez *et al.*, 2008; Koh *et al.*, 1984; Oteiza *et al.*, 2006).

The blood is one of the most important animal by-products and has high biological (Silva *et al.*, 2003). Porcine

blood was limitedly used because it has defects such as an offensive smell (Dávila *et al.*, 2007), dark brown color of final product due to blood contains around 14% hemoglobin (Oellingrath and Slinde, 1985), and acidification promotion due to excess of iron content (Piske, 1982). Especially, the dark color is main sensory quality problem when blood is added to meat product (Mielnik and Slinde, 1983). However, it is an important by-product of the meat industry with many potential uses (Dávila *et al.*, 2007; Kim *et al.*, 1990; Nakamura *et al.*, 1984). Therefore, several researchers reported that blood put to use binder and additive at sausage, surimi, and bakery due to nutritional and financial benefits (Benjakul *et al.*, 2004; Howell and Lawrie, 1984; Kim *et al.*, 1993; Yang, 2000). Consumption of blood such as blood plasma, serum, plasma concentrate, plasma isolate, and enzymic hydrolysate of red blood cells is quite popular in many European countries, although the ingredients used differ according to the region (Hamann *et al.*, 1990; Oellingrath and Slinde, 1985; Stiebing, 1990). The protein content of blood is about 18%, similar to protein content of lean meat, and its iron content is 400-500 mg/L (Sandoval, 1985; Sohn *et al.*, 1999b). Especially, the heme receptor of blood can not only be abundant in iron, but also small intestine absorbed readily (Grasbeck *et al.*, 1982).

\*Corresponding author : Cheon-Jei Kim, Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea. Tel: 82-2-450-3684, Fax: 82-2-444-6695, E-mail: kimej@konkuk.ac.kr

Rice is the staple food of many countries such as Korea, Japan and China, so annually huge amounts of rice bran are produced as an agricultural by-product from rice milling (Choi *et al.*, 2008b). Rice bran contains valuable nutritional components including dietary fiber, proteins, minerals and vitamin B groups (Choi *et al.*, 2008a). Several studies on a dietary fiber among the rice bran fiber have been introduced in the food technology as a fiber source (Choi *et al.*, 2007a; Choi *et al.*, 2009). Also, according to Chotimarkorn and Silalai (2008), the removal of lipids from rice bran reduces the rate of lipid oxidation, thus dietary fiber from rice bran has potential for use in various foods. And dietary fiber is not only desirable for their nutritional properties but also for their functional and technological properties (Choi *et al.*, 2008b; Saunders, 1990; Thebaudin *et al.*, 1997). In meat products, dietary fiber enhances the cooking yield and improve the texture because of its water and fat binding properties (Cofrades *et al.*, 2000; Thebaudin *et al.*, 1997). Many studies have been carried out on meat products with added dietary fiber, which helps to improve rheological properties and stability (Akoh, 1998; Hughes *et al.*, 1997; Luruena-Martinez *et al.*, 2004). Especially, Choi *et al.* (1997b) found that meat products made with 2% wheat fiber resulted in improving textural properties. Also, beef patties containing 1 or 2% oat fiber and pea fiber showed excellent quality characteristics (Trout *et al.*, 1992). These attempts have also been made to upgrade the texture of meat products in order to supplement them with functional foods. However, no research has been carried out on the direct or indirect addition of rice bran fiber into blood sausages.

Therefore, the objective of this study was to investigate the effect of adding rice bran fiber to Korean blood sausages on their proximate compositions, energy value, pH, color, cooking yield, texture profile analysis, and sensory evaluations.

## Materials and Methods

### Extraction of dietary fiber from rice bran

The proximate composition of rice bran and dietary fiber extracted from rice bran is given in Table 1. The dietary fiber was extracted using the modified AOAC enzymatic-gravimetric method (AOAC, 1995). Rice bran of a Japonica rice cultivar (*Oriza sativa* L.) was purchased from a market in Geochang, Gyeongsangnam-do, Korea, ground in a mill, and passed through a 25 mesh sieve. The rice bran was roasted to about 105°C, and defatted with hexane (n-hexane 95%) using a shaker (BS-11, Lab. Companion, Korea) overnight. The defatted rice bran was gelatinized with 0.6% termamyl (heat stable alpha-amylase) at 95°C for 1 h to remove starch, followed by filtration. The residue was then washed three times with four volumes of heated water (100°C) and allowed to equilibrate to room temperature (20°C, 6 h). The residue was then washed with 99.9% ethanol (preheated to 60°C), followed by filtration. The residue was dried (55°C) overnight in an air oven and then cooled. Dietary fiber extracted from rice bran was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL, Fufee Tech, Korea) and stored at 4°C until required for product manufacture.

### Blood sausage preparation

Fresh pork ham (*M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus*), pork back fat (moisture 12.61%, fat 85.64%), pork skin, and pork blood were purchased from a local processor at 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from fresh hams. Lean materials were initially ground through an 8 mm plate. The pork back fat was also ground through an 8 mm plate. The ground tissue was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL, Fufee Tech, Korea) and stored at 0°C until required for product manufacture. Suitable amounts of the muscle, fat, and skin were tempered at 4°C for 24 h prior to blood sausage

**Table 1. Chemical and physical properties of rice bran and dietary fiber extracted from rice bran (rice bran fiber)**

Parameters	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Digestible carbohydrates (%)	Dietary fiber (%)	pH	CIE L*-value	CIE a*-value	CIE b*-value
Rice bran	12.12 ±0.25 <sup>A</sup>	12.32 ±0.24 <sup>B</sup>	20.31 ±0.92 <sup>A</sup>	8.73 ±0.08 <sup>A</sup>	17.92 ±0.26 <sup>A</sup>	28.60 ±0.32 <sup>B</sup>	6.85 ±0.10 <sup>B</sup>	68.85 ±0.18 <sup>A</sup>	3.49 ±0.05 <sup>B</sup>	18.07 ±0.08 <sup>A</sup>
Rice bran fiber	11.73 ±0.32 <sup>B</sup>	21.91 ±0.43 <sup>A</sup>	4.31 ±0.43 <sup>B</sup>	7.42 ±0.24 <sup>B</sup>	1.38 ±0.18 <sup>B</sup>	53.25 ±0.79 <sup>A</sup>	7.07 ±0.04 <sup>A</sup>	66.10 ±0.20 <sup>B</sup>	4.73 ±0.04 <sup>A</sup>	16.06 ±0.06 <sup>B</sup>

All values are mean±SD of three replicates

<sup>A, B</sup> Means within a column with different letters are significantly different ( $p < 0.05$ ).

preparation. Meat packages were thawed (approx. 24 h at  $5\pm 2^\circ\text{C}$ , up to between  $-1$  and  $-2^\circ\text{C}$ ). And, blood was used immediately purchased from local processor before blood sausage processing. The blood sausage manufacturing process is presented Fig. 1. Each batch of samples consisted of four blood sausages, which differed in composition with respect to rice bran fiber levels (0, 1, 2, and 3%). Four different blood sausages were formulated as follows: raw meat was homogenized and ground for 1 min in silent cutter (Cutter Nr-963009, Hermann Scharfen GmbH & Co., Germany). NPS (1.5%, Nitrite pickling salt;  $\text{NaCl}:\text{NaNO}_2 = 99.4:0.6$ ), 0.8% sugar, 4.0% onion powder, 3.0% garlic powder, 0.7% ginger powder, 2% black pepper, 0.7% MSG (mono sodium glutamate), 0.7% carrageenan, 2.0% ISP (isolated soy protein), and rice bran fiber were added to the meat that had been previously meat stock (5%) and chilled ( $2^\circ\text{C}$ ), and then mixed for 1 min. Porcine blood (20%) and skin (5%) was added to same sample and the batter were homogenized for 5 min. A temperature probe (Kane-May, KM330, Harlow, UK) was used to monitor the temperature of the blood sausage batter, which was maintained below  $10^\circ\text{C}$  during batter preparation. After mixed, blood sausage batter was stuffed into natural pork casings at around 35 diameters that were preserved with salt and rinsed in

clean water before use using a stuffer (Stuffer IS-8, Sirman, Italy). The blood sausages were then transferred to a cooking container and boiled in water at  $95\pm 2^\circ\text{C}$  for around 1 h, air cooled to  $8-10^\circ\text{C}$  and vacuum packaged at polyethylene bag. The blood sausages were stored at  $4\pm 1^\circ\text{C}$  until required for experiment (until 3 days). The 10 kg batches of each blood sausages were prepared in this manner.

### pH

The pH values of blood sausage 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). All determinations were performed in triplicate.

### Proximate composition

Compositional properties of the blood sausages were performed using AOAC (1995). Moisture content was determined by weight loss after 12 h of drying at  $105^\circ\text{C}$  in a drying oven (SW-90D, Sang Woo Scientific Co., Korea). Fat content was determined by Soxhlet method with a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Sweden) and protein was determined by Kjeldahl method with an automatic

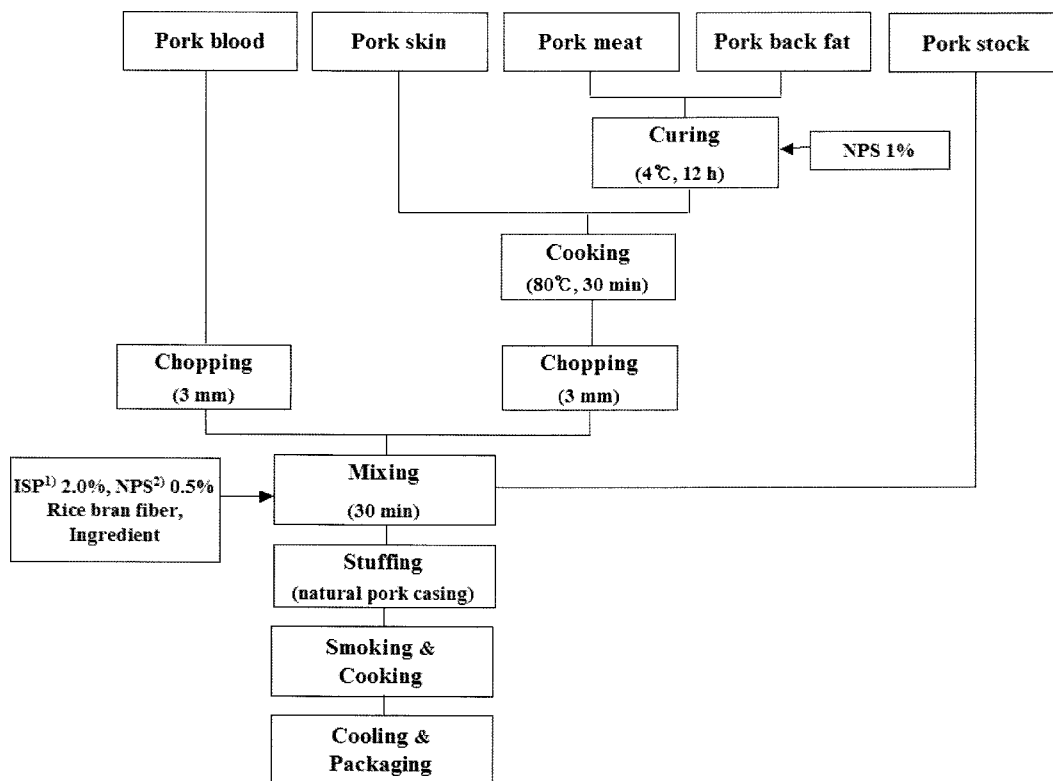


Fig. 1. The diagram of Korea blood sausage manufacturing. <sup>1</sup>ISP: isolated soy protein. <sup>2</sup>NPS: nitrite pickling salt ( $\text{NaCl}:\text{NaNO}_2 = 99.4:0.6$ ).

Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Sweden). Ash was determined according to AOAC method 923.03. Carbohydrate contents were calculated by the difference among the parameters. All determinations were performed in triplicate.

### Caloric content

Total calorie estimates (kcal) for blood sausages were calculated on the basis of a 100 g portion using Atwater values for fat (9 kcal/g), protein (4.02 kcal/g), and carbohydrate (3.87 kcal/g). All determinations were performed in triplicate (Mansour and Khalil, 1999).

### Cooking loss

Cooking loss was determined by calculating the weight differences before and after cooking as follows (Choi *et al.*, 2009);

Cooking loss (%)

$$= \frac{\text{weight of raw blood sausage} - \text{weight of cooked blood sausage}}{\text{weight of cooked blood sausage}} \times 100$$

### Color evaluation

The color values of the surface of cooked and uncooked blood sausages were measured by the CIE Lab system using a color meter (Minolta Chroma meter CR-210, Minolta Ltd., Japan; illuminate C, calibrated with white plate,  $L^*=+97.83$ ,  $a^*=-0.43$ ,  $b^*=+1.98$ ). Six measurements for each of five replicates were taken. Lightness ( $L^*$ ), redness ( $a^*$ ), and yellowness ( $b^*$ ) values were recorded.

### Texture profile analysis (TPA)

Texture measurements in the form of texture profile analysis were performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems, England). Blood sausage samples (size: diameter 3.5 cm, height 5 cm) were taken from the central portion of each sausage. Prior to analysis, samples were allowed to equilibrate to room temperature (20°C, 3 h). The conditions of texture analysis were as follows: 0.25ø spherical probe, 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. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (N), springiness, cohesiveness, gumminess (N), and chewiness (N) were determined as described (Bourne, 1978). All determinations were performed in each of five replicates.

### Sensory evaluation

Each blood sausage was evaluated for color of appearance, flavor, juiciness, tenderness and overall acceptability. Blood sausages were cooked a  $95\pm 2^\circ\text{C}$  for around 1 hr, air-cooled to 8-10°C, and the cooked samples were cooled to room temperature at 21°C, cut into quarters and served to the panelists in random order. Each sample (size: diameter 3.5 cm, height 5 cm) was coded with a randomly selected 3-digit numbers. Sensory evaluations were performed by the panelists under fluorescent lighting (350 lux). Panelists were instructed to cleanse their palates between samples using warm water ( $30\pm 2^\circ\text{C}$ ). 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. The panel consisted of 11 members from the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea.

### Statistical analysis

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

## Results and Discussion

### Proximate composition and energy value

The proximate composition and energy value of blood sausages formulated with various rice bran fibers are given in Table 2. The differences in moisture, fat, ash, and carbohydrate contents and energy values of blood sausages were statistically significant. The moisture content was higher in the treatment with containing rice bran fiber than control in no added rice bran fiber ( $p < 0.05$ ). However, there was no significant difference in moisture content between the rice bran treatments. Protein and fat content were not significantly different between control sausages and sausages containing rice bran ( $p > 0.05$ ). Among the blood sausage treatments, ash content was the highest in 3% rice bran fiber treatment, as increasing the rice bran fiber content significantly increased ash content ( $p < 0.05$ ). Carbohydrate content was higher in controls without rice bran fiber than treatments with containing

**Table 2. Proximate composition and caloric content of blood sausages with various levels of rice bran fiber**

Parameters	Control	Rice bran fiber levels (%)		
		1	2	3
Moisture (%)	50.07±1.31 <sup>B</sup>	53.27±1.25 <sup>A</sup>	54.01±1.56 <sup>A</sup>	52.79±0.82 <sup>A</sup>
Protein (%)	22.24±0.53	22.29±0.66	22.17±0.59	22.97±0.50
Fat (%)	15.74±0.50 <sup>A</sup>	15.33±0.35 <sup>AB</sup>	15.02±0.54 <sup>B</sup>	15.75±0.33 <sup>A</sup>
Ash (%)	2.27±0.14	2.39±0.05	2.48±0.09	2.73±0.16
Carbohydrate (%)	9.69±1.61 <sup>A</sup>	6.72±1.75 <sup>B</sup>	6.32±1.16 <sup>B</sup>	5.75±0.96 <sup>B</sup>
Energy value (kcal/100 g)	268.23±5.67 <sup>A</sup>	253.45±4.88 <sup>B</sup>	248.58±8.27 <sup>B</sup>	256.22±3.76 <sup>B</sup>

All values are mean±SD of three replicates

<sup>A, B</sup> Means within a row with different letters are significantly different ( $p < 0.05$ ).

rice bran fiber due possibly to moisture content increasing related by rice bran fiber. This has been noted previously for various types of meat products (Cengiz and Gokoglu, 2005; Choi *et al.*, 2008c; Lee *et al.*, 2008b). Similar results were obtained by Choi *et al.* (2008a) for ground pork meat products containing rice bran fiber and by Fernández-Ginés *et al.* (2004) who studied the characteristics of bologna sausages with added lemon albedo as a new source of dietary fiber. Energy values of the blood sausages ranged from 287.28 to 306.93 kcal/100 g. Among the all the treatments, the highest energy values was found in the control, and the treatments with containing rice bran fiber was lower when compared with control ( $p < 0.05$ ). It means that the sausages with added dietary fiber was increased more moisture retention. These results are in agreement with the results obtained by Choi *et al.* (2008b) for low-fat *teokgalbi* where they found that the addition of dietary fiber decreased the energy values. However, according to Cengiz and Gokoglu (2005), energy values of the sausage with added citrus fiber was significantly higher than those of control sausages.

### pH and color

Table 3 shows the pH, lightness (CIE L\*-value), red-

ness (CIE a\*-value), and yellowness (CIE b\*-value) values of uncooked and cooked blood sausages formulated with various rice bran fiber levels (0, 1, 2, and 3%). The pH of uncooked blood sausage range from 6.24 to 6.42, and the pH of cooked blood sausage ranged from 6.42 to 6.50. The pH of uncooked and cooked blood sausages was the lowest in the control without rice bran fiber, as increasing rice bran fiber levels of blood sausage lead to higher pH values due to added rice bran fiber, as well as high levels of minerals such as iron, phosphorus, and calcium (Watchararuji *et al.*, 2008). These results are similar to those reported by Turhan *et al.* (2007), who found significantly increased pH with increasing levels of added wet *okara* levels for beef patties. Choi *et al.* (2008a) noted that pH values of ground pork meat products were higher in the treatments with containing rice bran fiber levels. In contrast to these results, Choi *et al.* (2007b) showed that pH of meat batter was not significantly different with added wheat fiber, isolated soy protein, and concentrated soy protein. Also, the pH was higher in the cooked blood sausages than uncooked blood sausages. According to Forrest *et al.* (1975) and Choi *et al.* (2007b), the pH of meat products was increased when they were heated due to imidazolium, which is basic activity in his-

**Table 3. Effect of pH and color (L-, a-, and b-values) on blood sausage formulated with various levels of rice bran fiber**

Parameters	Traits	Control	Rice bran fiber levels (%)		
			1	2	3
Uncooked	pH	6.24±0.03 <sup>C</sup>	6.40±0.03 <sup>B</sup>	6.45±0.02 <sup>A</sup>	6.46±0.02 <sup>A</sup>
	CIE L*-value	34.76±0.47 <sup>C</sup>	35.23±0.29 <sup>B</sup>	35.40±0.56 <sup>AB</sup>	35.83±0.65 <sup>A</sup>
	CIE a*-value	4.25±0.07 <sup>B</sup>	4.27±0.11 <sup>B</sup>	4.40±0.16 <sup>A</sup>	4.48±0.11 <sup>A</sup>
	CIE b*-value	1.37±0.15 <sup>D</sup>	1.50±0.08 <sup>C</sup>	1.77±0.06 <sup>B</sup>	1.93±0.06 <sup>A</sup>
Cooked	pH	6.42±0.04 <sup>B</sup>	6.45±0.05 <sup>AB</sup>	6.48±0.02 <sup>A</sup>	6.50±0.03 <sup>A</sup>
	CIE L*-value	36.47±0.80 <sup>B</sup>	37.34±1.37 <sup>B</sup>	39.76±1.33 <sup>A</sup>	40.02±0.81 <sup>A</sup>
	CIE a*-value	5.50±0.28 <sup>B</sup>	5.53±0.45 <sup>B</sup>	6.03±0.33 <sup>A</sup>	6.24±0.50 <sup>A</sup>
	CIE b*-value	1.70±0.27 <sup>B</sup>	1.77±0.30 <sup>B</sup>	2.22±0.27 <sup>A</sup>	2.29±0.37 <sup>A</sup>

All values are mean±SD of three replicates

<sup>A-D</sup> Means within a row with different letters are significantly different ( $p < 0.05$ ).

tidine of amino acid, was unfolded to expose.

The difference in lightness, redness, and yellowness values of uncooked and cooked blood sausages are shown in Table 3. The lightness and yellowness of uncooked blood sausage was higher in treatments with rice bran fiber than those of control without rice bran fiber. Sausages with 3% rice bran fiber had the highest levels of lightness and yellowness. The redness of uncooked and lightness of cooked samples were lower in 2% and 3% rice bran fiber treatments than in controls, and there were no significantly difference between controls and 1% rice bran fiber treatment. The redness and yellowness of cooked blood sausages had lower control and 1% rice bran fiber treatments than other treatments and all the treatments added as increasing rice bran fiber levels was higher. Similar results have been obtained by Lee *et al.* (2008a) who reported on the effects of hot air dried *Kimchi* powder on the quality characteristics of emulsion type sausages. Choi *et al.* (2008c) reported that emulsion-type sausages with added dietary fiber had lower lightness and redness levels with increasing amounts of added dietary fiber. Kim *et al.* (1997) reported that noodles with added rice bran fiber had higher redness as increasing rice bran fiber levels. Yilmaz (2004) noted that low-fat meatball added as increasing rye bran levels had higher yellowness levels. However, Mansour and Khalil (1999) showed that meat products containing wheat bran was not significantly different between control and treatments with wheat bran. Turhan *et al.* (2005) reported that low-fat beef burgers containing hazelnut pellicles had lower lightness and redness.

### Cooking loss

The cooking loss of blood sausages formulated with various rice bran fiber levels are shown in Fig. 2. Cooking loss is occurred by release of fat and moisture (Mittal and Osborne, 2005). Cooking loss was the highest in the control samples and lower in the treatment formulated to contain rice bran fiber. That is, the addition of rice bran fiber decreased the cooking loss of blood sausages. A reduction in cooking loss is also associated with an increase in binding ability between meat protein, fat and moisture (Shand, 2000), and low cooking loss corresponded to emulsion stability (Aktas and Genccelep, 2006). Trout *et al.* (1992) noted similar results for beef patties made with added oat fiber and pea fiber. Their beef patties containing 1 or 2% oat fiber and pea fiber had cooking loss 20-40% less than those of control. Claus and Hunt (1991) indicated that cooking loss of frankfurter

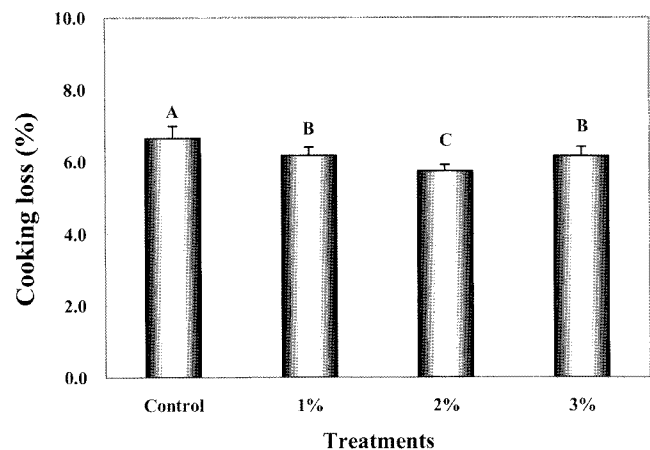


Fig. 2. Effect of cooking loss of blood sausages formulated with various levels of rice bran fiber. <sup>A-C</sup> Means in the treatments with different letters are significantly different ( $p < 0.05$ ).

with 2% carrageenan and oat fiber was reduced about 7 to 8%. Also, meatballs containing added wheat bran, oat bran, and rye bran showed decreased cooking loss (Yilmaz and Daglioglu, 2003; Yilmaz, 2004; Yilmaz, 2005). However, Sohn *et al.* (1999a) indicated that cooking loss in *soondae* was not significantly different between control and treatments with 5, 10% or 15% blood plasma and egg white. In general, meat products containing added isolated soy protein, carrageenan, and dietary fiber had reduced levels of moisture and fat loss due to increased salt-soluble protein at high binding capacity of fat and moisture (Lee *et al.*, 2008b). In other words, cooking loss is an indicator of unseparated fat and moisture retained by meat proteins. Our results are consistent with Choi *et al.* (2007a) who demonstrated that rice bran fiber has good potential for increasing moisture retention.

### Texture profile analysis

The texture profile analysis of blood sausages formulated with various rice bran fiber levels are shown in Table 4. The hardness of blood sausages were higher in treatments with added 2% and 3% rice bran fiber than control. Among them, the 2% rice bran fiber treatment had the highest hardness. García *et al.* (2002) indicated that hardness of sausages increased with added cereal fiber, while the addition of fruit fiber decreased the hardness of the same meat product. Lee *et al.* (2008b) reported that kimchi powder levels significantly affect the hardness of breakfast sausage. In general, the significant increases in hardness that were recorded in the meat products with added dietary fiber were due to the fact that treatments samples added dietary fiber had stronger bind-

**Table 4. Effect of textural attributes of blood sausage formulated with various levels of rice bran fiber**

Parameters	Control	Rice bran fiber levels (%)		
		1	2	3
Hardness (N)	5.17±0.60 <sup>C</sup>	5.76±0.64 <sup>BC</sup>	6.66±0.73 <sup>A</sup>	6.11±0.46 <sup>AB</sup>
Springiness	0.96±0.02	0.98±0.01	0.98±0.02	0.97±0.02
Cohesiveness	0.42±0.02	0.45±0.05	0.46±0.04	0.44±0.03
Gumminess (N)	2.19±0.33 <sup>B</sup>	2.63±0.54 <sup>A</sup>	3.04±0.53 <sup>A</sup>	2.69±0.24 <sup>A</sup>
Chewiness (N)	2.18±0.33 <sup>C</sup>	2.65±0.57 <sup>B</sup>	3.34±0.49 <sup>A</sup>	2.77±0.45 <sup>B</sup>

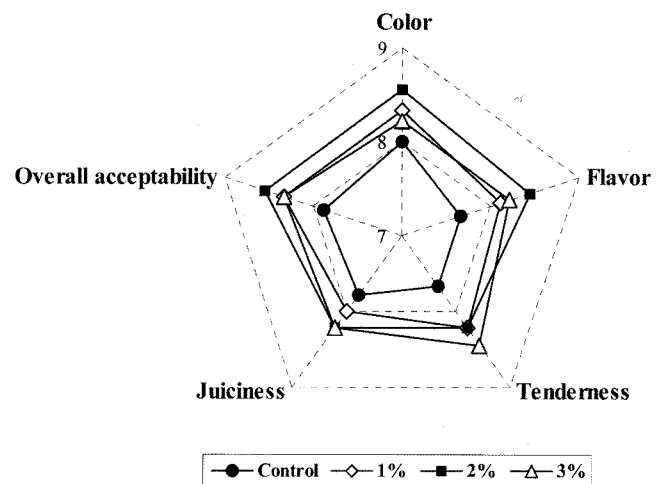
All values are mean±SD of three replicates

<sup>A-C</sup> Means within a row with different letters are significantly different ( $p < 0.05$ ).

ing ability between meat products than those without dietary fiber (Choi *et al.*, 2007b). Springiness and cohesiveness of blood sausages were not significantly different between control and all the treatments. Gumminess and chewiness of blood sausages, as compared with the control treatment, were significantly higher in sausages with added rice bran fiber. Similar results were obtained by Choi *et al.* (2007b) for meat batters containing added isolated protein, concentrated soy protein, and wheat fiber. Also, Cofrades *et al.* (2000) and Aleson-Carbonell *et al.* (2003) reported that meat products with added dietary fiber had improved textural properties. However, Lee *et al.* (2008a) noted that low-fat sausages with added hot air dried *kimchi* powder had decreased textural properties. According to Herrero *et al.* (2007), texture profile analysis may define the quality of the finished product and can contribute to the selection of the best functional ingredients.

### Sensory evaluation

Sensory traits for blood sausages added with rice bran fiber are shown in Fig. 3. The meat values of color, flavor, tenderness, and juiciness were evaluated along with overall acceptability. Blood sausages containing rice bran fiber had slightly higher color and juiciness scores than the controls, but there were no significant differences among all the treatments containing rice bran fiber. Flavor, tenderness, and overall acceptability scores of blood sausages with added rice bran fiber were significantly higher than controls without rice bran fiber, but were not significantly different among the addition level of bran fiber. These results agree with those reported by Aleson-Carbonell *et al.* (2003), who noted significantly high scores in dry cured sausages on the addition of lemon albedo. Leheska *et al.* (2006) showed that flavor and taste were influenced pork breakfast sausage with fruit purees. According to Choi *et al.* (2008c) and Turhan *et al.* (2005), various meat products with containing dietary



**Fig. 3. Sensory properties of blood sausages formulated with various levels rice bran fiber.**

fiber had higher overall acceptability scores due to dietary fiber which enhancing the consistency of meat products through the formation of a three-dimensional network capable of modifying rheological properties. Many researchers have also shown that dietary fiber improved sensory properties of meat products (Fernández-Ginés *et al.*, 2004; Turhan *et al.*, 2005).

In summary, rice bran fiber could have potential as a source of dietary fiber which be used as functional ingredient for meat products. Blood sausage containing rice bran fiber could be commercially acceptable meat products. The blood sausage with 2% rice bran fiber can be readily manufactured with high quality. Korean-type blood sausage could be satisfactorily marketed by the global meat industry as well as Korean meat industry.

### Acknowledgement

This research was supported (20080201-033-066-001-01-00) by the Rural Development Administration (Republic of Korea). The authors also partially supported by the

Brain Korean 21 (BK 21) Project from Ministry of Education and Human Resources Development.

## References

- Akoh, C. C. (1998) Fat replacers. *Food Technol.* **52**, 47-53.
- Aktas, N. and Genccelep, H. (2006) Effect of starch type and its modifications on physicochemical properties of bologna-type sausage produced with sheep tail fat. *Meat Sci.* **4**, 404-408.
- Aleson-Carbonell, L., Fernandez-Lopez, J., Sayas-Barbera, E., Sendra, E., and Perez-Alvarez, J. A. (2003) Utilization of lemon albedo in dry-cured sausages. *J. Food Sci.* **68**, 1826-1830.
- AOAC. (1995) Official methods of analysis of AOAC, 16th ed. Association of Official Analytical Chemists. Washington DC.
- Benjakul, S., Visessanguan, W., and Chantarasuwan, C. (2004) Effect of porcine plasma protein and setting on gel properties of surimi produced from fish caught in Thailand. *LWT - Food Sci. Technol.* **37**, 177-185.
- Bourne, M. C. (1978) Texture profile analysis. *Food Technol.* **32**, 62-66.
- Caldironi, H. and Ockerman, H. W. (1982) Incorporation of blood proteins into sausage. *J. Food Sci.* **47**, 405-408.
- Cengiz, E. and Gokoglu, N. (2005) Changes in energy and cholesterol contents of frankfurter-type sausages with fat reduction and fat replacer addition. *Food Chem.* **91**, 443-447.
- Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Jeong, J. Y., Paik, H. D., and Kim, C. J. (2008a) Effect of adding levels of rice bran fiber in the quality characteristics of ground pork meat product. *Korean J. Food Sci. Ani. Resour.* **28**, 319-326.
- Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Jeong, J. Y., and Kim, C. J. (2009) Characteristics of low-fat meat emulsion systems with pork fat replaced by vegetable oils and rice bran fiber. *Meat Sci.* **82**, 266-271.
- Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Lee, E. S., Jeong, J. Y., Paik, H. D., and Kim, C. J. (2008b) Effects of rice bran fiber on quality of low-fat *tteokgalbi*. *Food Sci. Biotechnol.* **17**, 959-964.
- Choi, Y. S., Jeong, J. Y., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Shim, S. Y., Paik, H. D., and Kim, C. J. (2007a) Quality characteristics of meat batters containing dietary fiber extracted from rice bran. *Korean J. Food Sci. Ani. Resour.* **27**, 228-234.
- Choi, Y. S., Jeong, J. Y., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Paik, H. D., and Kim, C. J. (2008c) Effects of containing dietary fiber extracted from rice bran on quality characteristics of emulsion-type sausage. *Korean J. Food Sci. Ani. Resour.* **28**, 14-20.
- Choi, Y. S., Lee, M. A., Jeong, J. Y., Choi, J. H., Han, D. J., Kim, H. Y., Lee, E. S., and Kim, C. J. (2007b) Effects of wheat fiber on the quality of meat batter. *Korean J. Food Sci. Ani. Resour.* **27**, 22-28.
- Chotimarkorn, C., and Silalai, N. (2008) Oxidative stability of fried dough from rice flour containing rice bran powder during storage. *LWT-Food Sci. Technol.* **41**, 561-568.
- Claus, J. R. and Hunt, M. C. (1991) Low-fat, high added-water bologna formulated with texture-modifying ingredient. *J. Food Sci.* **56**, 643-647.
- Cofrades, S., Guerra, M. A., Carballo, J., Fernandes-Martin, F., and Colmenero, F. J. (2000) Plasma protein and soy fiber content effect on bologna sausage properties as influenced by fat level. *J. Food Sci.* **65**, 281-287.
- Dàvila, E., Parés, D., Cuvelier, G., and Perla Relkin, P. (2007) Heat-induced gelation of porcine blood plasma proteins as affect by pH. *Meat Sci.* **76**, 216-225.
- Diez, A. M., Santo, E. M., Jaime, I., and Rovira, J. (2008) Application of organic acid salts and high-pressure treatments to improve the preservation of blood sausage. *Food Microbiol.* **25**, 154-161.
- Fernández-Ginés, J. M., Fernández-López, J., Sayas-Barberá, E., Sendra, E., and Pérez-Álvarez, J. A. (2004) Lemon albedo as a new source of dietary fiber: application to bologna sausages. *Meat Sci.* **67**, 7-13.
- Forrest, J. C., Aberle, E. D., Hedrick, H. B., Judge, M. D., and Merkel, R. A. (1975) Principles of meat processing. Principles of meat science. W. H. Freeman and Company. San Francisco, CA. pp. 190-226.
- García, M. L., Dominguez, R., Galvez, M. D., Casas, C., and Selgas, M. D. (2002) Utilization of cereal and fruit fibres in low fat dry fermented sausages. *Meat Sci.* **60**, 227-236.
- Grasbeck, R., Majuri, J., Kouvonen, I., and Thohunen, R. (1982) Spectral and other studies on the intestinal heme receptor of the pig. *Biochem. Biophys. Acta.* **700**, 137-142.
- Hamann, D. D., Amato, M. C., Wu, M. C., and Foegeding, E. A. (1990) Inhibition of *modori* (gel weakening) in surimi by plasma hydrolysate and egg white. *J. Food Sci.* **55**, 665-669.
- Herrero, A. M., Ordóñez, J. A., Romero de Avila, Herranz, B., L, de la Hoz, and Cambero, M. I. (2007) Breaking strength of dry fermented sausages and their correlation with texture profile analysis (TPA) and physico-chemical characteristics. *Meat Sci.* **77**, 331-338.
- Howell, N. K. and Lawrie, R. A. (1984) Functional aspects of blood plasma proteins.. Separation and characterization. *J. Food Technol.* **19**, 289-295.
- Hughes, E., Cofrades, S., and Troy, D. J. (1997) Effects of fat level, oat fiber and carrageenan on frankfurters formulated with 5, 12 and 30% fat. *Meat Sci.* **45**, 273-281.
- Kim, C. J., Han, E. S., Ko, W. S., Choi, D. Y., Lee, C. H., Joung, K. Y., and Choe, B. K. (1993) Effect of heating temperature, time and protein concentration on the gel properties and heat stability of a mixed system of pork myofibrillar and plasma proteins. *Korean J. Food Sci. Technol.* **25**, 295-298.
- Kim, Y. B., Kim, K. S., Yoo, I. J., Lee, S. K., and Kim, S. M. (1990) Studies on the quality of meat product made with blood protein. *Korean J. Anim. Sci.* **32**, 428-433.
- Kim, Y. S., Ha, T. Y., Lee, S. H., and Lee, H. Y. (1997) Effect of rice bran dietary fiber on flour rheology and quality of wet noodles. *Korean J. Food Sci. Technol.* **29**, 90-95.



31. Koh, J. B., Moon, Y. H., Kim, J. Y., and Moon, Y. D. (1984) Studies on the development of blood sausage from by-products – Appreciation of blood sausage qualities from the animal experiments. *J. Korean Soc. Food Nutr.* **13**, 319-325.
32. Lee, M. A., Han, D. J., Choi, J. H., Choi, Y. S., Kim, H. Y., Jeong, J. Y., Paik, H. D., and Kim, C. J. (2008a) Effect of hot air dried kimchi powder on the quality characteristics of low-fat sausages. *Korean J. Food Sci. Resour.* **28**, 146-153.
33. Lee, M. A., Han, D. J., Jeong, J. Y., Choi, J. H., Choi, Y. S., Kim, H. Y., Paik, H. D., and Kim, C. J. (2008b) Effect of kimchi powder level and drying methods on quality characteristics of breakfast sausage. *Meat Sci.* **80**, 708-714.
34. Leheska, J. M., Boyce, J., Brooks, J. C., Hoover, L. C., Thompson, L. D., and Miller, F. (2006) Sensory attributes and phenolic content of precooked pork breakfast sausage with fruit purees. *J. Food Sci.* **71**, S249-S252.
35. Luruena-Martinez, M. A., Vivar-Quintana, A. M., and Revilla, I. (2004) Effect of locust bean/xanthan gum addition and replacement of pork fat with olive oil on the quality characteristics of low-fat frankfurters. *Meat Sci.* **68**, 383-389.
36. Mansour, E. H. and Khalil, A. H. (1999) Characteristics of low-fat beef burgers as influenced by various types of wheat fibers. *J. Sci. Food Agric.* **79**, 493-498.
37. Mielnik, J. and Slinde, E. (1983) Sausage color measured by integrating sphere reflectance spectrophotometry when whole blood or blood cured by nitrite is added to sausages. *J. Food Sci.* **48**, 1723-1725.
38. Mittal, G. S. and Osborne, W. R. (2005) Meat emulsion extender. *Food Technol.* **39**, 121-130.
39. Nakamura, R., Hayakawa, S., Yasuda, K., and Sato, Y. (1984) Emulsifying properties of bovine blood globin: a comparison with some proteins and their improvement. *J. Food Sci.* **49**, 102-113.
40. Oellingrath, I. M. and Slinde, E. (1985) Color, pigment and iron content of meat loaves with blood, blood emulsion, or mechanically deboned meat added. *J. Food Sci.* **50**, 1551-1555.
41. Oteiza, J. M., Chinen, I., Miliwebsky, E., and Rivas, M. (2006) Isolation and characterization of *Shiga* toxin-producing *Escherichia coli* from precooked sausages (*morcillas*). *Food Microbiol.* **23**, 283-288.
42. Piske, D. (1982) Aproveitamento de sangue de abate para alimentacao humana. *Boletim do Instituto de Tecnologia de Alimentos.* **19**, 253-308.
43. Sandoval, A. E. (1985) Effect of dried blood protein fractions on characteristics of emulsion type meat product MS thesis. Iowa state University.
44. Santos, E. M., González-Fernández, C., Jaime, I., and Rovira, J. (2003) Physicochemical and sensory characterisation of *Morcilla de Burgos*, a traditional Spanish blood sausage. *Meat Sci.* **65**, 893-898.
45. SAS. (1999) SAS/STAT Software. Release 8.1, SAS Institute Inc., Cary, NC, USA.
46. Saunders, R. M. (1990) The properties of rice bran as a food stuff. *Cereal Foods World* **35**, 632-635.
47. Shand, P. J. (2000) Textural, water holding, and sensory properties of low-fat pork bologna with normal and waxy starch hull-less barley. *J. Food Sci.* **65**, 101-107.
48. Silva, J. G., Morais, H. A., Oliveira, A. L., and Silvestre, M. P. C. (2003) Addition effects of bovine blood globin and sodium caseinate on the quality characteristics of raw and cooked ham pâté. *Meat Sci.* **63**, 177-184.
49. Sohn, J. W., Lee, S. M., and Yum, C. A. (1999a) Effects of binding materials on nutrients of *Soondae*. *Korean J. Soc. Food Sci. Nutr.* **15**, 244-248.
50. Sohn, J. W., Yum, C. A., and Kim, C. J. (1999b) Effects of binding materials sensory and cooking properties of *Soondae*. *Korean J. Soc. Food Sci. Nutr.* **15**, 191-196.
51. Stiebing, A. (1990) Blood sausage technology. *Fleischwirtsch Inter.* **3**, 34-40.
52. Thebaudin, J. Y., Lefebvre, A. C., Harrington, M., and Bourgeois, C. M. (1997) Dietary fibres: nutritional and technological interest. *Trends Food Sci. Technol.* **8**, 41-48.
53. Trout, E. S., Hunt, M. C., Johnson, D. E., Claus, J. R., Kastner, C. L., and Kropf, D. H. (1992) Characteristics of low fat ground beef containing texture modifying ingredients. *J. Food Sci.* **57**, 19-24.
54. Turhan, S., Sagir, I., and Ustun, N. S. (2005) Utilization of hazelnut pellicle in low-fat beef burgers. *Meat Sci.* **71**, 312-316.
55. Turhan, S., Temiz, H., and Sagir, I. (2007) Utilization of wet okara in low-fat beef patties. *J. Muscle Food* **18**, 226-235.
56. Watchararujji, K., Goto, M., Sasaki, M., and Shotipruk, A. (2008) Value-added subcritical water hydrolysate from rice bran and soybean meal. *Bioresource Technol.* **99**, 6207-6213.
57. Yang, C. Y. (2000) Rheological properties of Vienna sausage by addition of dried bovine plasma. *Korean J. Food Sci. Ani. Resour.* **20**, 264-271.
58. Yilmaz, I. (2004) Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. *Meat Sci.* **67**, 245-249.
59. Yilmaz, I. (2005) Physicochemical and sensory characteristics of low fat meatballs with added wheat bran. *J. Food Eng.* **69**, 369-373.
60. Yilmaz, I. and Daglioglu, O. (2003) The effect of replacing fat with oat bran on fatty acid composition and physicochemical properties of meatballs. *Meat Sci.* **65**, 819-823.

(Received 2008.11.27/Revised 1st 2009.3.30, 2nd 2009.4.7/  
Accepted 2009.4.16)