Food Sci. Biotechnol. Vol. 17, No. 5, pp. 959 ~ 964 (2008)

Food Science and Biotechnology

Effects of Rice Bran Fiber on Quality of Low-fat *Tteokgalbi*

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Abstract This study evaluated the effects of dietary fiber extracted from rice bran (rice bran fiber) on the quality of low-fat *tteokgalbi*. The controls were formulated with 20% added fat. Test samples of *tteokgalbi* were produced with 5 different formulations containing 1, 2, 3, 4, and 5% rice bran fiber as a fat replacer, in addition to 10% fat. The control had the highest fat content, energy value, cooking loss, reduction in diameter, reduction in thickness, CIE L*-value (lighness), and color of sensory properties. The *tteokgalbi* containing rice bran fiber had higher moisture, protein, ash, and carbohydrate contents than the controls. *Tteokgalbi* with 3% rice bran fiber had the lowest cooking loss, reduction in diameter, and reduction in thickness. Meat products containing 2 and 3% rice bran fiber had a higher overall acceptability similar to the high fat control.

Keywords: *tteokgalbi*, dietary fiber, rice bran, low-fat, quality property

Introduction

The traditional Korean ground meat product called *tteokgalbi* is a very popular meat product in South Korea. It is different from western style meat products in its preparation (1). In particular, the product contains a lot of animal fat (20-30%). However, modern consumers are increasingly interested in their personal health and therefore prefer healthier foods that are lower in fat while retaining good flavor and overall attractiveness. Although fat plays a major role in the juiciness, texture, and flavor of a product, it may cause health problems such as obesity, some types of cancer, high blood cholesterol, hypertension, and coronary heart disease (2,3). As a result, the popularity of meat products with high levels of animal fat has decreased (4). Many researchers have reported that low fat diets have led the food industry to develop or modify traditional food products to contain less fat (5-7).

In low-fat meat products, fat may be partly replaced by water and non-meat ingredients such as dietary fiber (8), carrageenan (9), starch (10), maltodextrins (11), isolated soy protein (5), and *konjac* (12), which help to improve rheological properties and stability. There are many reports on the use of dietary fiber in meat products. Dietary fiber from lemon albedo (13), mugwort (14), citron peel (15), grapefruit (16), and hazelnut pellicle (2) has been used in meat products. Thebaudin *et al.* (17) also reported that dietary fiber can be used in meat products to increase the cooking yield due to its water and fat binding properties, and to improve texture.

Rice bran provides energy, dietary fiber, proteins, minerals, and vitamins required for human health (18). In recent years, rice bran has been studied regarding its potential use in developing functional foods (19-21). However rice bran does not store well and thus its quality deteriorates very rapidly, resulting in the development of off-flavor and a high content of free fatty acids due to the presence of enzymes such as lipase (22,23). The utilization of rice bran in commercial products has so far been limited to the production of bran oil and animal feed (24). Also, meat products are not enough to apply on the addition of dietary fiber from rice bran (20). Then, traditional meat products include a lot of animal fat due to fat replaced need to develop in low-fat meat product, which used apply to obtained dietary fiber from defatted rice bran to remove lipid.

Therefore, the aim of this study was to investigate the effects of various levels of added dietary fiber from rice bran on the quality characteristics of low-fat *tteokgalbi.*

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Received November 26, 2007; Revised March 3, 2008;
Accepted March 7, 2008

Materas and Methods

Extraction of dietary fiber from rice bran The proximate compositions of rice bran and dietary fiber extracted from rice bran (rice bran fiber) are given in Table 1. Rice bran fiber was extracted using the modified AOAC enzymatic-gravimetric method (25). Rice bran from a Japonica rice cultivar (*Oriza sativa L.*) was purchased from a market in Geochang, Gyeongnam, 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 (Lab. Companion, BS-11; Dongbang Hitech Co., Seoul, Korea) overnight to remove lipids. The defatted rice bran was gelatinized with 0.6% termamyl (heat stable alpha-amylase) at 95°C for 1 hr to remove starch, followed by filtration. The residue was then washed 3 times with 4 volumes of heated water (100°C) and allowed to equilibrate to room temperature (20°C, 6 hr). The residue was then washed with 99.9% ethanol (preheated to 60°C), followed by filtration. The residue was then dried (55°C) overnight in an air oven and cooled. The rice bran fiber was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL; Fujee Tech, Seoul,

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

Parameter	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Digestible carbohydrates (%)	Dietary fiber (%)	pH	L*	a*	b*
Rice bran	12.12± 0.25[a1)]	12.32± 0.24[b]	20.31± 0.92[a]	8.73± 0.08[a]	17.92± 0.26[a]	28.60± 0.32[b]	6.85± 0.10[b]	68.85± 0.18[a]	3.49± 0.05[b]	18.07± 0.08[a]
Dietary fiber extracted rice bran (rice bran fiber)	11.73± 0.32[b]	21.91± 0.43[a]	4.31± 0.43[b]	7.42± 0.24[b]	1.38± 0.18[b]	53.25± 0.79[a]	7.07± 0.04[a]	66.10± 0.20[b]	4.73± 0.04[a]	16.06± 0.06[b]

[1)]All values are mean±SD of 3 replicates; [a,b]means within a row with different letters are significantly different (p<0.05).

Korea) and stored at 4°C until required for product manufacture.

***Tteokgalbi* preparation** Fresh pork ham (*M. biceps femoris, M. semitendinosus,* and *M. semimembranosus*) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor at 48 hr postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from fresh ham muscle. 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 and stored at 0°C until required for product manufacture. Suitable amounts of the muscle and fat were tempered at 4°C for 24 hr prior to *tteokgalbi* preparation.

Tteokgalbi was produced according to the following traditional recipe (1). Lean meat (max. 1.5% fat) mixed with seasonings (3.0% Korean soy sauce, 0.4% garlic powder, 0.2% ginger powder, 1.0% onion powder, and 0.1% ground black pepper) and other ingredients (1.1% sugar, 1.0% isolated soy protein, 0.4% starch syrup, 0.4% sesame oil, 0.4% cooking wine, and 0.2% phosphate) were added (Table 2). The mix was kneaded for 15 min at 4°C by hand and the *tteokgalbi* mixtures were divided into 6 equal portions. The first batch was used as a control and adjusted to a fat content of 20% by the addition of back fat. The other batches were supplemented with various levels (1, 2, 3, 4, and 5%) of rice bran fiber and adjusted to a fat content of 10% with the addition of back fat. Each portion was kneaded for an additional 15 min to obtain homogeneous mixtures. The mixtures were stored in a cold room (+4°C) for 1 day, and then shaped into approximately 75 mm diameter and 15 mm thickness meat products with a weight of about 90 g before cooking.

Table 2. The basic formulation of low-fat *tteokgalbi* with rice bran fiber and other ingredients (units:%)

Ingredients	Control	Rice bran fiber (%)				
		1	2	3	4	5
Korean soy sauce	3.0	3.0	3.0	3.0	3.0	3.0
Garlic powder	0.4	0.4	0.4	0.4	0.4	0.4
Ginger powder	0.2	0.2	0.2	0.2	0.2	0.2
Onion powder	1.0	1.0	1.0	1.0	1.0	1.0
Ground black pepper	0.1	0.1	0.1	0.1	0.1	0.1
Sugar	1.1	1.1	1.1	1.1	1.1	1.1
Isolated soy protein	1.0	1.0	1.0	1.0	1.0	1.0
Starch syrup	0.4	0.4	0.4	0.4	0.4	0.4
Sesame oil	0.4	0.4	0.4	0.4	0.4	0.4
Cooking wine	0.4	0.4	0.4	0.4	0.4	0.4
Phosphate	0.2	0.2	0.2	0.2	0.2	0.2
Rice bran fiber	-	1.0	2.0	3.0	4.0	5.0

pH The pH values of *tteokgalbi* 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, Schwerzenbach, Switzerland). All determinations were performed in triplicate.

Proximate composition Moisture, protein (N×6.25), fat, and ash contents (%) were determined according to AOAC (25) procedures. Carbohydrate contents (%) were calculated by the difference among parameters.

Caloric content Total calorie estimates (kcal) for *tteokgalbi* 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) (26).

Cooking loss Cooking loss (%) was determined for individual samples by calculating the weight differences before and after cooking as follows:

Cooking loss (%)=[(weight of raw *tteokgalbi*–weight of cooked *tteokgalbi*)/weight of raw *tteokgalbi*]×100

Instrumental color evaluations The color of cooked and uncooked *tteokgalbi* samples were measured by the CIE LAB system using a color meter (Chroma meter CR-210; Minolta, Osaka, Japan; illuminate C, calibrated with white plate, L*=+97.83, a*=–0.43, b*=+1.98). Six measurements for each of 5 replicates were taken. Lightness (L*), redness (a*), and yellowness (b*) values were recorded.

Reductions in diameter and thickness Reduction in diameter (%) was determined for individual samples by calculating the diameter differences before and after cooking as follows.

Reduction in diameter (%)=[(raw *tteokgalbi* diameter–cooked *tteokgalbi* diameter)/raw *tteokgalbi* diameter]×100

Reduction in thickness (%) was determined for individual samples by calculating the thickness differences before and after cooking as follows.

Reduction in thickness (%)=[(raw *tteokgalbi* thickness− cooked *tteokgalbi* thickness)/raw *tteokgalbi* thickness]× 100

Texture profile analysis (TPA) Texture measurements in the form of texture profile analysis were performed at room temperature with a texture analyzer (TA-XT2*i*; Stable Micro Systems, Surrey, England). Meat product portions were taken from the central part of each sample. Prior to analysis, samples were allowed to equilibrate to room temperature (20°C, 3 hr). The conditions of texture analysis were as follows: pre-test speed 2.0 mm/sec, post-test speed 5.0 mm/sec, maximum load 2 kg, head speed 2.0 mm/sec, 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 (27).

Sensory evaluation *Tteokgalbi* samples were evaluated for color, flavor, juiciness, tenderness, and overall acceptability. *Tteokgalbi* was cooked by grilling to a center temperature of 75°C, the cooked samples were cooled to room temperature at 21°C, cut into quarters and served to the panelists in random order. Each sample (sample size: 5×5×3 cm) was coded with a randomly selected 3-digit number. All sensory evaluations were performed under fluorescent lighting. Panelists were instructed to cleanse their palates between samples using water. 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 (28). The panel consisted of 11 members from the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea.

Statistical analysis An analysis of variance were performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package (29). Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

Results and Discussion

Proximate composition and energy values The proximate compositions and energy values of *tteokgalbi* formulated with different levels of rice bran fiber are given in Table 3. The differences in moisture, protein, fat, ash, carbohydrate, and energy values of *tteokgalbi* were statistically significant ($p<0.05$). *Tteokgalbi* had a moisture content ranging from 59.62 to 64.87%. The moisture content was higher in samples containing rice bran fiber than in the control. *Tteokgalbi* with a low level of rice bran fiber (1-3%) had higher moisture content than other formulations. The lowest moisture content seen with the control was due to the adjustment of fat to 20%. Similar results were obtained by Turhan *et al.* (2), Fernández-Ginés *et al.* (13), Anderson and Berry (30), Crehan *et al.* (11), and Pietrasik and Duda (31), in which the moisture content of high-fat products was lower than that of *tteokgalbi* containing dietary fiber. The protein levels of *tteokgalbi* with added rice bran fiber ranged from 16.13 to 16.97% with no significant difference among the different formulations. The lowest protein content was 15.32% for the control with no added rice bran fiber. Candogan (32) reported similar results for meat made with the addition of tomato paste.

The fat content of the 20% fat control was 21.57%, and the fat content of the samples formulated with 10% fat ranged from 11.25 to 13.85%. The fat content decreased as the amount of rice bran fiber increased ($p<0.05$), and the measured fat contents of *tteokgalbi* samples were close to the targeted levels. These results agree with those reported by Yang *et al.* (33) and Garcia *et al.* (6) who reported significantly decreased fat contents for pork sausages and dry fermented sausages with added dietary fiber to reduce the fat content. The lowest ash content was 1.88% for the control *tteokgalbi*. In *tteokgalbi* with rice bran content ranging from 2.17 to 2.30%, the ash levels were similar. These results are in agreement with those obtained by Fernández-Ginés *et al.* (13) who studied the characteristics of low-fat sausages to which lemon albedo was added. The carbohydrate content was highest in *tteokgalbi* with 5% rice bran fiber (7.40%), and on the contrary, the control showed the lowest carbohydrate content (1.88%) ($p<0.05$). The carbohydrate content increased with the increasing amounts of rice bran fiber. Turhan *et al.* (2) reported similar results for beef burgers made with the addition of

Table 3. Proximate composition and energy values of low-fat *tteokgalbi* formulated with various levels of rice bran fiber

Parameter	Control	Rice bran fiber (%)				
		1	2	3	4	5
Moisture (%)	59.62±0.40$^{c1)}$	64.32±0.49^{a}	64.87±0.39^{a}	64.01±0.38^{a}	63.29±0.55^{b}	62.78±0.51^{b}
Protein (%)	15.32±0.67^{b}	16.97±0.40^{a}	16.65±0.63^{a}	16.59±0.26^{a}	16.23±0.15^{a}	16.13±0.04^{a}
Fat (%)	21.58±0.64^{a}	13.85±0.75^{b}	12.46±1.33^{c}	12.37±0.95^{c}	11.55±1.15^{c}	11.25±0.49^{c}
Ash (%)	1.88±0.13^{b}	2.17±0.22^{a}	2.21±0.14^{a}	2.29±0.20^{a}	2.39±0.12^{a}	2.44±0.13^{a}
Carbohydrate (%)	1.60±0.53^{e}	2.69±0.70^{d}	3.81±1.51^{d}	4.74±1.42^{c}	6.54±0.93^{b}	7.40±0.60^{a}
Energy value (kcal/100 g)	264.55±5.52^{a}	203.28±5.12^{b}	193.82±5.04^{c}	196.37±6.85^{c}	194.50±7.04^{c}	194.73±2.13^{c}

[1)]All values are mean±SD of 3 replicates; $^{a-e}$means within a row with different letters are significantly different ($p<0.05$).

Table 4. Cooking loss and dimensional changes of low-fat *tteokgalbi* formulated with various levels of rice bran fiber

Parameter	Control	Rice bran fiber (%)				
		1	2	3	4	5
Cooking loss (%)	25.86±1.61[a1)]	14.78±2.32[b]	9.42±2.58[c]	6.60±1.23[d]	10.26±2.97[c]	10.55±2.87[c]
Reduction in diameter (%)	18.85±2.09[a]	15.87±1.13[b]	14.75±1.40[c]	13.19±0.67[d]	14.31±0.48[c]	14.45±0.84[c]
Reduction in thickness (%)	18.12±2.51[a]	14.31±3.01[b]	11.09±3.31[cd]	10.66±2.00[d]	11.62±2.20[cd]	13.49±2.18[bc]

[1)]All values are mean±SD of 3 replicates; [a-d]means within a row with different letters are significantly different (p<0.05).

Table 5. Comparison pH and CIE Lab attributes on low-fat *tteokgalbi* formulated with various levels of rice bran fiber

Parameter		Control	Rice bran fiber (%)				
			1	2	3	4	5
Uncooked	pH	5.91±0.18[1)]	5.94±0.18	6.04±0.11	6.02±0.18	6.07±0.20	6.07±0.21
	L*-value	58.29±0.40[a]	53.97±0.70[b]	52.91±0.94[c]	51.20±0.56[d]	50.26±1.34[e]	50.24±0.77[e]
	a*-value	12.05±0.46[a]	10.19±0.54[b]	9.69±0.33[c]	8.51±0.16[d]	8.18±0.19[e]	7.96±0.16[f]
	b*-value	13.68±0.37[a]	13.40±0.28[ab]	13.47±0.43[ab]	13.04±0.30[c]	12.55±0.71[d]	13.18±0.49[bc]
Cooked	pH	6.05±0.21	6.13±0.21	6.16±0.22	6.16±0.21	6.16±0.19	6.17±0.20
	L*-value	59.23±1.91[a]	57.22±1.95[b]	55.05±2.50[c]	54.08±2.14[d]	52.86±1.73[e]	52.83±1.47[e]
	a*-value	7.43±1.31[a]	8.05±1.07[a]	7.65±1.36[a]	7.66±0.67[a]	6.89±0.66[b]	6.70±0.71[b]
	b*-value	10.12±1.14[d]	10.42±0.54[bc]	10.80±0.55[abc]	10.35±0.72[bc]	11.11±0.85[a]	10.98±0.70[ab]

[1)]All values are mean±SD of 3 replicates; [a-f]means within a row with different letters are significantly different (p<0.05).

hazelnut pellicle.

The highest energy value (264.55 kcal/100 g) was obtained for the control *tteokgalbi* (p<0.05). The energy values of *tteokgalbi* containing dietary fiber extracted from rice bran ranged between 194.50 and 203.28 kcal/100 g. The energy values were closely related to the fat content. Similar results were obtained by Turhan *et al.* (2) for low-fat beef burgers with hazelnut pellicle.

Cooking loss and dimensional changes Table 4 shows cooking loss and reduction in the diameter and thickness of *tteokgalbi* samples containing rice bran fiber (1-5%) and the control. Cooking loss was highest in the control *tteokgalbi* (25.86%) due to the high loss of fat and moisture during cooking (2). The cooking loss of samples containing rice bran fiber was lower than that of the control, and the *tteokgalbi* samples with 3% rice bran fiber had the lowest cooking loss (6.60%). Similar results were obtained by Turhan *et al.* (2) for low-fat beef burgers with added hazelnut pellicle, and Fernaández-Ginés *et al.* (13) for bologna sausages with raw and cooked lemon albedo.

The reduction in diameter and thickness of the control was larger than *tteokgalbi* containing rice bran fiber, and *tteokgalbi* formulated with 3% rice bran fiber had the lowest reduction in diameter (p<0.05). Similar results were obtained for *tteokgalbi* made with various sources of added dietary fiber (2,10,26). Reductions in the thickness of *tteokgalbi* with 2 and 3% rice bran fiber were as low as 11.09 and 10.66%, respectively. Different results were obtained by Turhan *et al.* (2) for low-fat beef burgers with added hazelnut pellicle added.

pH and color The pH, lightness (L*-value), redness (a*-value), and yellowness (b*-value) values are shown in Table 5. The pH of uncooked *tteokgalbi* ranged from 5.91 to 6.07, and that of cooked *tteokgalbi* ranged from 6.05 to 6.17. The addition of rice bran fiber to the formulation did not significantly affect the pH of the product. Similar results were obtained by Turhan *et al.* (2) for low-fat beef burgers with added hazelnut pellicle, and Candogan (32) for beef patties made with the addition of tomato paste. The pH also increased when the *tteokgalbi* was heated because imidazolium, which acts as a base in the amino acid histidine, is exposed due to the denaturation of proteins (34,35).

The differences in lightness, redness, and yellowness values of *tteokgalbi* were significant (p<0.05) (Table 5). The highest lightness values of uncooked and cooked *tteokgalbi* were obtained in the control *tteokgalbi*. The lightness of uncooked and cooked *tteokgalbi* decreased with increasing levels of rice bran fiber. Similar results were obtained by Turhan *et al.* (2) for low-fat beef burgers containing added hazelnut pellicle. The highest redness values for uncooked *tteokgalbi* were obtained with the control, and decreased with increasing levels of rice bran fiber. Yilmaz (36) and Yilmaz and Daðlioðlu (37) showed similar results in meatballs containing rye and oat bran. There were no significant differences among the control and *tteokgalbi* containing 1, 2, and 3% rice bran fiber in the redness values of cooked meat products (p>0.05). The yellowness values of uncooked meat products ranged from 12.55 to 13.68 and in cooked *tteokgalbi* ranged from 10.12 to 11.11. Choi *et al.* (20) reported similar yellowness values for cooked *tteokgalbi*.

Texture profile analysis A comparison of textural properties among *tteokgalbi* formulated with various levels of rice bran fiber is shown in Table 6. Low-fat meat products have different textural characteristics (38), therefore fat replacers could be included in the products in order to give them similar textural characteristics to regular fat products. Also, textural parameters are dependent on both the fat and

Table 6. Comparison textural properties on low-fat *tteokgalbi* formulated with various levels of rice bran fiber

Parameter	Control	Rice bran fiber (%)				
		1	2	3	4	5
Hardness (N)	7.28±0.92[b1)]	7.07±0.83[b]	7.28±0.77[b]	7.35±0.89[b]	9.62±1.36[a]	10.11±1.50[a]
Springiness	0.90±0.06[a]	0.93±0.04[a]	0.93±0.06[a]	0.94±0.05[a]	0.92±0.05[a]	0.91±0.06[a]
Cohesiveness	0.50±0.04[a]	0.49±0.03[a]	0.48±0.03[a]	0.50±0.04[a]	0.50±0.04[a]	0.50±0.04[a]
Gumminess (N)	3.63±0.52[c]	3.48±0.30[c]	3.52±0.41[c]	3.61±0.36[c]	4.84±0.69[b]	5.02±0.70[a]
Chewiness (N)	3.23±0.52[b]	3.24±0.31[b]	3.20±0.32[b]	3.31±0.41[b]	4.45±0.63[a]	4.58±0.65[a]

[1)]All values are mean±SD of 3 replicates; [a-c]means within a row with different letters are significantly different (p<0.05).

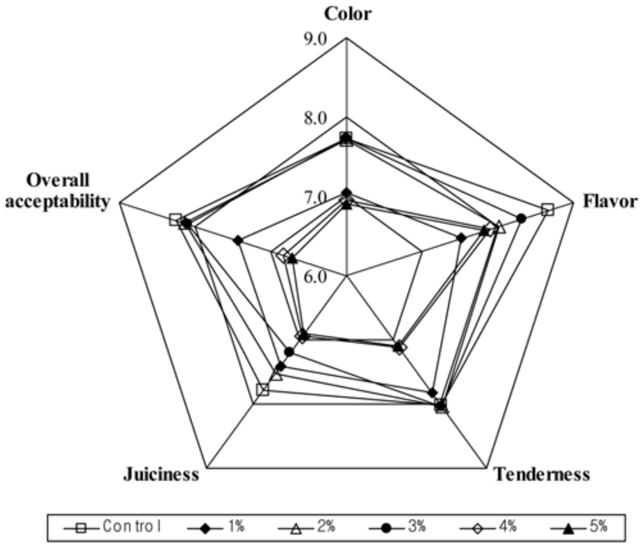

Fig. 1. Sensory properties of low-fat *tteokgalbi* formulated with various levels of rice bran fiber.

moisture contents of the product (7). The hardness, gumminess, and chewiness of *tteokgalbi* samples increased with increasing levels of rice bran fiber, however there were no significant differences in springiness and cohesiveness. The hardness values of treatments containing 4 and 5% rice bran fiber were higher than that of the control, and the low-fat *tteokgalbi* samples containing 1, 2, and 3% rice bran fiber had hardness, gumminess, and chewiness values that were the most similar to the high fat control. Bourne (27) reported that the relationship between gumminess and chewiness is associated with hardness, springiness, and cohesiveness. However, in this study, springiness and cohesiveness showed no significant differences among the formulations, thus showing no relationship with hardness, gumminess, or chewiness. These results indicate that the addition of dietary fiber as a fat replacer decreases most TPA values, resulting in similar textural properties to regular fat meat products (39). Similar results were obtained in previous studies (21,34-36). Textural properties were also affected by protein that has water holding activity, emulsion stability, gelling ability, and adhesiveness between particles (40).

Sensory evaluation Sensory traits for cooked *tteokgalbi* with different levels of rice bran fiber are shown in Fig. 1. The mean values of color, flavor, tenderness, and juiciness were evaluated as well as overall acceptability. The control (7.73) and *tteokgalbi* with 2% (7.72) and 3% (7.73) rice bran fiber received the highest color scores. The control samples also received the highest flavor and juiciness scores. The highest scores of overall acceptability were 8.25, 8.15, and 8.11, respectively, for the control and *tteokgalbi* with 2 and 3% rice bran fiber added (p>0.05). The low-fat *tteokgalbi* samples containing 2 and 3% rice bran fiber had sensory scores that were most similar to the high fat control. Similar results were obtained by Turhan *et al.* (2) for low-fat beef burgers with added hazelnut pellicle, Yilmaz (41) for low-fat meatballs containing wheat bran, and Candogan (32) for beef patties made with the addition of tomato paste. In addition, Hughes *et al.* (10) reported that tapioca starch increased the overall acceptability of low fat frankfurters.

In conclusion, rice bran shows potential as a good source of dietary fiber which can be used as a functional ingredient for meat products. *Tteokgalbi* containing rice bran fiber had improved cooking loss, diameter, and thickness. Low-fat *tteokgalbi* had lower energy values than general meat products. Control (high-fat), 2, and 3% rice bran fiber samples (low-fat) had the highest textural properties and overall acceptability scores. The addition of 2-3% rice bran fiber to traditional Korean low-fat ground meat products results in acceptable and desirable quality characteristics.

Acknowledgments

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 the Ministry of Education and Human Resources Development, Korea.

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