

Quality Characteristics of Chicken Emulsion Sausages with Different Levels of *Makgeolli* Lees Fiber

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Abstracts

Makgeolli lees is a by-product of the *makgeolli* brew processing. *Makgeolli* lees contains high levels of fibers, which can be separated and used to develop foods rich in dietary fibers. The purpose of this study was to determine the effect of *makgeolli* fibers (0-4%) on proximate composition, caloric content, pH, color, cooking yield, textural profile, and sensory characteristics of chicken-emulsion sausages. The moisture content of 1, 2, and 3% *makgeolli* lees fiber-amended product was higher than the control, while that of the 4% product was not. Total calorie estimates of *makgeolli* lees fiber-amended sausages were lower than the control, except for in the case of the 4% treatment. Moreover, chicken sausages supplemented with *makgeolli* lees fiber had higher cooking yields and improved textural properties. Chicken emulsion sausages prepared with *makgeolli* lees fiber had improved overall acceptability, and the best results of sensory characteristics were obtained for the emulsion sausages containing 2% *makgeolli* lees fiber.

Key words: *makgeolli* lees, dietary fiber, chicken, emulsion sausage, sensory characteristics

Introduction

Chicken meat and products have grown in popularity due to their nutritional characteristics, while also providing an excellent source of animal protein for consumers in developing countries (Deumier and Collignan, 2003). Chicken meat provides high protein and low fat, and chicken lipids are characterized by relatively high levels of unsaturated fatty acids, which are considered to be positive and healthy by consumers (Bonoli *et al.*, 2007; Hwang *et al.*, 2011). In particular, chicken emulsion sausage is a popular chicken meat-based product. Chicken meat processors are responding to the marketplace demand by producing reduced fat chicken meat products (Hwang *et al.*, 2011). The production and consumption of chicken sausages has been increasing globally. These sausages are becoming more popular due to their sensory characteristics and ease of preparation, which reflects the development of more functionality-enhanced chicken

emulsion sausages with added dietary fiber.

Traditional Korean rice wine (*makgeolli*) is one of the most popular alcoholic beverages in Korea (Bae *et al.*, 2010). Korean rice wine is brewed by conventional methods using *nuruk* or *koji* and is comprised of water, yeast, and rice that have been fermented for about 16 days without distillation (Jeong *et al.*, 2006; Kim *et al.*, 1995; Park and Lee, 2002). *Makgeolli* contains polyphenols, polysaccharides, and polysaccharide-peptide complexes (Blandino *et al.*, 2003; Jeong and Park, 2006; Lee *et al.*, 1996; Lee *et al.*, 2009), and assorted bioactive components have been evaluated for their positive effects on health.

Makgeolli lees (also known as *juback* or *sulchigegie*) is a by-product of *makgeolli* brew processing. Commonly used as animal feeds or fertilizers (Won *et al.*, 2006). *Makgeolli* lees is produced in large amounts annually in Korea, and it provides energy, dietary fiber, proteins, minerals, vitamins, alcohol, and organic acids required for human health (Jeong and Park, 2006; Park and Lee, 2002). *Makgeolli* lees is highly nutritious, lowers blood cholesterol, decreases the incidence of atherosclerosis, and has a laxative effect (Kim and Cho, 2006). *Makgeolli* powder has been studied for use in functional foods (Jeong and Park, 2006). However, no studies have yet

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been reported on the *makgeolli* lees extracted from *makgeolli* fiber, and its incorporation into chicken meat emulsion sausage. Dietary fiber has been studied alone or combined with other ingredients to prepare meat product formulations. The technological effect on foods differs according to the quantity and nature of the dietary fiber. Thus, *makgeolli* lees fiber is not only desired for its nutritional properties, but also for its functional and technological properties (Cho and Lee, 1996). Therefore, the objective of this study was to evaluate and compare the compositional, nutritional, and sensory properties of chicken emulsion sausages produced with different concentrations of *makgeolli* lees fiber.

Materials and Methods

Preparation and processing of *makgeolli* lees fiber extract

Dietary fiber was extracted using the modified AOAC enzymatic-gravimetric method (2007). *Makgeolli* lees was obtained from the Seoul Takju Map Association (Korea). Alcoholic components were removed by washing three times with four volumes of water (25°C), and the residue was dried (55°C) overnight in an air oven and then cooled. The *makgeolli* lees 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) and filtered. The residue was dried (55°C) overnight in an air oven and cooled. The *makgeolli* lees fiber (moisture content: 3.42±0.14%; fat content: 5.98±0.28%; protein content: 15.51±0.78%; ash content: 0.60±0.06%; dietary fiber content: 60.39±3.81%; CIE L*-value: 67.35±1.02; CIE a*-value: 4.62±0.45; CIE b*-value: 16.09±0.85; pH: 4.76±0.24) was then placed in polyethylene bags and vacuum packaged using a model FJ-500XL vacuum packaging system (Fujee Tech, Korea) and stored at 4°C until used for product manufacture (Choi *et al.*, 2010a).

Chicken meat batter preparation and processing

Fresh chicken breast meat (broilers, *Muscularis pectoralis major*, 5 wk of age, approximately 1.5-2.0 kg live weight, moisture content: 74.95±0.97%, protein content: 22.58±0.43%, fat content: 1.09±0.12%, ash content: 1.31±0.09%) and pork back fat (moisture content: 12.73±0.14%, fat content: 85.73±1.34%) were purchased from a local

processor. Chicken breast meat and pork back fat were initially ground through an 8-mm plate. The ground tissue was then placed in polyethylene bags, vacuum-packaged using the aforementioned vacuum packaging system, and stored at -15°C until used for product manufacture. Suitable amounts of the muscle and fat were tempered at 4°C for 24 h prior to meat batter preparation. Each sample batch consisted of five meat batters differing in composition with respect to the addition of *makgeolli* lees fiber level (0, 1, 2, 3, and 4%). All emulsion sausages were composed by 50% chicken breast meat, 30% pork back fat, and 20% ice. Raw meat was homogenized and ground for 1 min in a model Nr-963009 silent cutter (Hermann Scharfen, Germany), and 1.5% salt (NaCl), 0.15% sodium tripolyphosphate, 0.4% sorbitol, 0.08% monosodium L-glutamate, 0.07% onion powder, and 0.07% ginger powder were added to meat that had been previously dissolved in water, chilled (2°C), and then mixed for 1 min. *Makgeolli* lees fiber was added to the meat batter, which was homogenized for 6 min. A model KM330 temperature probe (Kane-May, Germany) was used to monitor the temperature of the emulsion, which was maintained below 10°C during batter preparation. After emulsification, the chicken meat batter was stuffed into collagen casings (#240, NIPPI, Japan; approximate diameter of 25 mm) using a model IS-8 stuffer (Sirman, Italy). The meat batter was then heated at 75±2°C for 30 min in a water bath (Dae Han Co, Model 10-101, Korea), and internal temperature of emulsion sausage is 75°C. The cooked meat batter was then cooled with cold water. Ten kilogram batches of each chicken emulsion sausage were prepared in this manner. All analyses were carried out in triplicate for each formulation.

Proximate composition

Compositional properties of the chicken meat sausages were determined using AOAC guidelines (2007). Moisture content was determined by weight loss after 12 h of drying at 105°C in a model SW-90D drying oven (Sang Woo Scientific Co., Korea). Crude fat content was determined by the Soxhlet method using a Soxtec® Avanti2050 solvent auto-extraction system (Foss Tecator AB, Sweden), and crude protein was determined by the Kjeldahl method with a Kjeltec® 2300 automatic Kjeldahl nitrogen analyzer (Foss Tecator). Crude ash was determined according to AOAC method 923.03.

Caloric content

Total calorie estimates (kcal) for the chicken meat

emulsion sausages were calculated based on a 100-g portion using Atwater values for fat (9 kcal/g), protein (4.02 kcal/g), and carbohydrate (3.87 kcal/g) (Mansour and Khalil, 1999).

pH

The pH values of the chicken sausages were measured in a homogenate prepared with 5 g of sample and distilled water (20 mL) using a model 340 pH meter (Mettler-Toledo GmbH, Switzerland). All determinations were performed in triplicate.

Color evaluation

The color of each chicken emulsion sausage was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta, Japan; illuminate C, calibrated with a white plate, CIE L^* = +97.83, CIE a^* = -0.43, CIE b^* = +1.98). The emulsion sausages were sliced parallel to the flat surface in the center of samples. Six measurements for each of five replicates were measured on a cut surface taken. Lightness (CIE L^* -value), redness (CIE a^* -value), and yellowness (CIE b^* -value) values were recorded.

Cooking yields

Chicken emulsion sausages were weighed before heat processing and after chilling at 4°C for 24 h. The cooking yield was determined from their weights and expressed as a percentage of initial weight (Lee *et al.*, 2008).

Cooking yields (%)

$$= \frac{[\text{emulsion sausage weight after cooking (g)}]}{[\text{emulsion sausage weight before cooking (g)}]} \times 100$$

Texture profile analysis (TPA)

Texture measurements in the form of a TPA were performed at room temperature with a TA-XT2i texture analyzer (Stable Micro Systems, UK). Chicken emulsion sausage samples were taken from the central portion of each sample. Prior to analyses, samples were allowed to equilibrate to room temperature (20°C, 3 h). The conditions for the texture analysis were 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; and force, 5 g. TPA values were calculated using force and time plots. Values for hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described previously (Bourne, 1978).

Sensory evaluation

Each chicken emulsion sausage was evaluated for

appearance color, flavor, juiciness, tenderness, and overall acceptability (Choi *et al.*, 2008). Emulsion sausages were cooked with a center temperature of 75°C, and the cooked samples were cooled to room temperature at 21°C, cut into quarters, and served to panelists in random order. Each sample (height×diameter; 3.0×2.5 cm) was coded with randomly selected 3-digit numbers. Sensory evaluations were performed by the panelists under fluorescent lighting. Panelists were instructed to cleanse their palates with water between samples. 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, Konkuk University.

Statistical analysis

An analysis of variance was performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package (SAS, USA) (2008). Duncan's multiple range test ($p < 0.05$) was used to determine the differences between treatment means.

Results and Discussion

Proximate composition and caloric content of chicken emulsion sausages

Table 1 shows the proximate composition of the chicken emulsion sausages formulated with various *makgeolli* lees fiber levels. The moisture content of the chicken emulsion sausages samples containing *makgeolli* lees fiber were higher than that of the control sample ($p < 0.05$), except for the 4% *makgeolli* lees fiber sample. The latter result likely reflected the reduced water retention in the presence of excess dietary fiber (Choi *et al.*, 2008). Choi *et al.* (2010a) reported similar quality characteristics of chicken emulsion plus dietary fiber extracted from *takju* lees. In another study, the moisture content increased with increasing rice wine residue in high fiber breads (Cho and Lee, 1996). These results agree with those reported by Choi *et al.* (2009), in which the moisture content increased in rice bran fiber added to meat emulsion systems. Also, Lee *et al.* (2008) indicated that *kimchi* fiber produces meat products with higher moisture content. Presently, no significant difference was observed for the

Table 1. Proximate composition of cooked chicken emulsion sausage formulations with various concentrations of makgeolli lees fiber

| Treatments ¹⁾ | Moisture (%) | Protein (%) | Fat (%) | Ash (%) |
|--------------------------|-------------------------|-------------|--------------------------|-------------------------|
| Control | 55.87±0.54 ^b | 14.18±0.83 | 27.40±0.88 ^a | 2.28±0.02 ^c |
| T1 | 57.18±0.48 ^a | 14.11±1.01 | 25.75±0.25 ^b | 2.29±0.06 ^c |
| T2 | 57.42±0.38 ^a | 14.15±1.14 | 25.12±0.62 ^b | 2.32±0.03 ^{bc} |
| T3 | 57.10±0.61 ^a | 14.27±0.96 | 26.04±0.53 ^{ab} | 2.34±0.05 ^b |
| T4 | 55.40±0.05 ^b | 14.34±1.09 | 27.11±0.78 ^a | 2.38±0.07 ^a |

All values are mean±standard deviation of three replicates.

^{a-c}Means within a column with different letters are significantly different ($p < 0.05$).

¹⁾Control, chicken emulsion sausage without makgeolli lees fiber; T1, chicken emulsion sausage with 1% makgeolli lees fiber; T2, chicken emulsion sausage with 2% makgeolli lees fiber; T3, chicken emulsion sausage with 3% makgeolli lees fiber; T4, chicken emulsion sausage with 4% makgeolli lees fiber

protein content of the chicken emulsion sausages samples ($p > 0.05$). The fat content of the makgeolli lees fiber in the chicken emulsion sausages was the lowest in the 1%- and 2%-treated samples ($p < 0.05$). These results may be affected by increasing moisture content of emulsion sausages due to added makgeolli lees fiber. The fat and moisture contents are closely related in meat products. Garcia *et al.* (2002) reported that cereal and fruit fiber decreases the fat content of sausages, and the results differ significantly between the control and treatments. Choi *et al.* (2010b) indicated that the addition of rice bran fiber decreased the fat content of frankfurters significantly. The ash content of chicken emulsion sausages with makgeolli lees fiber was higher than that of control samples, and sausages treated with increasing amounts of makgeolli lees fiber were higher in ash content, as the ash content of makgeolli lees fiber is about 0.60%. Similar results were reported by Choi *et al.* (2008) for meat products containing rice bran fiber. Chung (2009) reported on the influence of adding purple sweet potato powder on the quality characteristics of cookies, as increasing the purple sweet potato powder content increased the ash content of the cookies.

The total calorie estimates of the chicken emulsion sausages formulated with different levels of makgeolli lees fibers are shown in Fig. 1. The higher energy values occurred in the control (308.01 kcal/100 g) and treatments with 4% makgeolli lees fiber (T4, 303.84 kcal/100 g) compared to the other treatments ($p < 0.05$). The energy values of the other chicken emulsion sausages ranged from 294.40 to 298.75 kcal/100 g, whereas the 2% makgeolli lees fiber treatment (T2, 290.86 kcal/100 g) had the

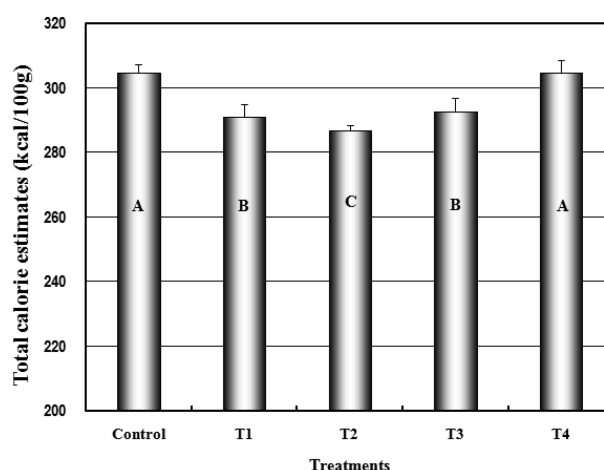


Fig. 1. Effects of makgeolli lees fiber on total calorie estimates of chicken emulsion sausages. ^{A-C}Means in the treatments with different letters are significantly different ($p < 0.05$). Control, chicken emulsion sausage without makgeolli lees fiber; T1, chicken emulsion sausage with 1% makgeolli lees fiber; T2, chicken emulsion sausage with 2% makgeolli lees fiber; T3, chicken emulsion sausage with 3% makgeolli lees fiber; T4, chicken emulsion sausage with 4% makgeolli lees fiber

lowest energy values ($p < 0.05$), reflecting the fact that 2% makgeolli lees fiber provides higher water retention. Choi *et al.* (2010b) indicated lower energy and cholesterol contents of reduced-fat frankfurters with rice bran fiber used for fat reduction and as a fat replacer. Furthermore, Grigelmo-Miguel *et al.* (1999) reported that low-fat frankfurters supplemented with high dietary fiber provide lower energy values. These results are in agreement with the results obtained by Choi *et al.* (2008) that the energy values of *tteokgalbi* with added rice bran fiber were significantly higher than those of control sausages. Similar results were reported by Cengiz and Gokoglu (2005) for sausages containing citrus fiber and by Turhan *et al.* (2005) for low-fat frankfurters with added hazelnut pellicle.

Cooking yields of chicken emulsion sausages

The data concerning cooking yields of the chicken emulsion sausages made with different makgeolli lees fibers levels are shown in Fig. 2. The treatments containing makgeolli lees fiber had higher cooking yields than the control ($p < 0.05$) and no significant differences among treatments containing makgeolli lees fiber ($p > 0.05$) were observed. Similar studies have reported that adding dietary fiber such as kimchi fiber, rice bran fiber, oat fiber, inner pea fiber, hazelnut pellicle fiber, lemon albedo fiber, tiger nut fiber, or carrot fiber increases cooking yields in meat products (Choi *et al.*, 2009; Desmond *et al.*, 1998;

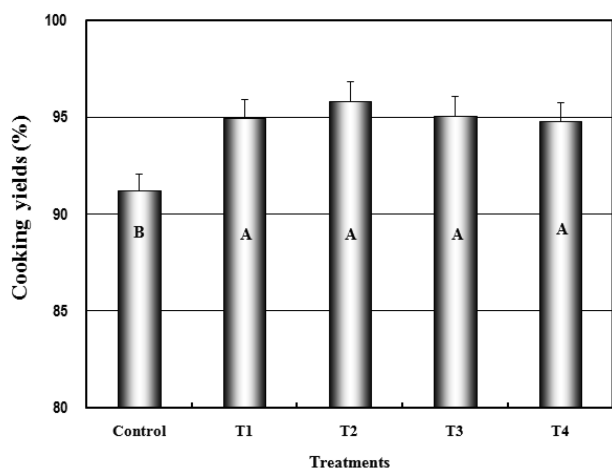


Fig. 2. Effects of *makgeolli* lees fiber on cooking yields of chicken emulsion sausages. ^{A,B}Means in the treatments with different letters are significantly different ($p < 0.05$). Control, chicken emulsion sausage without *makgeolli* lees fiber; T1, chicken emulsion sausage with 1% *makgeolli* lees fiber; T2, chicken emulsion sausage with 2% *makgeolli* lees fiber; T3, chicken emulsion sausage with 3% *makgeolli* lees fiber; T4, chicken emulsion sausage with 4% *makgeolli* lees fiber

Eim *et al.*, 2008; Fernández-Ginés *et al.*, 2004; Lee *et al.*, 2008; Turhan *et al.*, 2005). Xiong *et al.* (1999) indicated that locust bean gum was particularly effective for increasing cooking yield in low-fat sausages, due to its ability to form hydrogen bonds with water. Adding dietary fiber to meat products significantly increases cooking yields by improving emulsion stability. Dietary fiber from different sources and prepared with different processing methods has been studied alone or combined with other ingredients in various meat products to improve cooking yields (Desmond *et al.*, 1998; Lee *et al.*, 2008). In general, water binds to dietary fiber through capillary action or by hydrogen bonds, ionic bonds, hydrophobic interactions, or by surface tension in the matrix pores (Grigelmo-Miguel *et al.*, 1999; Lee *et al.*, 2008). Thus, dietary fiber extracted from *makgeolli* lees powder is potentially useful because it enhances these properties in meat products.

pH and color of chicken emulsion sausages

The pH values of the chicken emulsion sausages containing *makgeolli* lees fibers are provided in Table 2. Chicken emulsion sausages containing *makgeolli* lees fiber had a significantly lower pH than the control, and as increasing the level of *makgeolli* lees fiber lowered the pH ($p < 0.05$). The findings that changes in *makgeolli* lees fiber levels significantly affected the pH of *makgeolli* lees fiber agree with a number of studies. Choi *et al.* (2010a) reported that pH was significantly decreased with the

Table 2. Effects of various *makgeolli* lees fiber on pH and color (L^* , a^* , and b^* -values) of chicken emulsion sausages formulated with various concentrations of *makgeolli* lees fiber

| Treatments ¹⁾ | pH | L^* -value | a^* -value | b^* -value |
|--------------------------|-------------------------|-------------------------|------------------------|--------------------------|
| Control | 6.56±0.03 ^a | 83.34±2.58 ^a | 1.69±0.89 ^a | 10.15±0.26 ^c |
| T1 | 6.53±0.01 ^b | 78.71±0.79 ^b | 1.54±0.24 ^b | 11.00±1.66 ^b |
| T2 | 6.51±0.02 ^{bc} | 78.28±2.02 ^b | 1.31±0.57 ^c | 11.01±1.22 ^b |
| T3 | 6.49±0.02 ^{cd} | 76.80±1.68 ^c | 1.24±0.37 ^d | 11.32±1.50 ^{ab} |
| T4 | 6.47±0.01 ^d | 74.91±3.30 ^d | 1.20±0.65 ^d | 11.52±1.47 ^a |

All values are mean±standard deviation of three replicates

^{a-d}Means within a column with different letters are significantly different ($p < 0.05$).

¹⁾Control, chicken emulsion sausage without *makgeolli* lees fiber; T1, chicken emulsion sausage with 1% *makgeolli* lees fiber; T2, chicken emulsion sausage with 2% *makgeolli* lees fiber; T3, chicken emulsion sausage with 3% *makgeolli* lees fiber; T4, chicken emulsion sausage with 4% *makgeolli* lees fiber

addition of *makgeolli* lees fiber to meat emulsion systems. Jeong and Park (2006) indicated that the pH of bread containing *takju* powder decreases. Choi *et al.* (2008) observed significantly decreased pH with increasing levels of added rice bran fiber levels in chicken emulsion sausages. Eim *et al.* (2008) reported that adding carrot dietary fiber to sausages led to changes in pH. The present and previous results conclusively demonstrate that the pH of meat products is altered by the presence of dietary fiber.

The color values of the chicken emulsion sausages were significantly affected by the *makgeolli* lees fiber powder concentration (Table 2). The control had significantly higher lightness and redness values than treatments containing *makgeolli* lees fiber ($p < 0.05$), and lightness and redness decreased with increasing *makgeolli* lees fiber content ($p < 0.05$). These significant reductions in lightness were due to the lower lightness of the *makgeolli* lees fiber. Choi *et al.* (2009) reported similar results, in which treatments groups had less lightness than the control due to added rice bran fiber. The yellowness values of chicken emulsion sausages with *makgeolli* lees fiber were higher than those of the control ($p < 0.05$), adding *makgeolli* lees fiber resulted in a significant increase in the yellowness value as the *makgeolli* lees fiber level increased ($p < 0.05$). The *makgeolli* lees fiber had lightness, redness, and yellowness values of 67.35, 4.62, and 16.09, respectively, which would likely be the result of the rice, wheat, barley, and rice bran content. Jeong and Park (2006) reported that loaf bread with added *takju* powder did not significantly affect the lightness, redness, and yellowness val-

Table 3. Effects of *makgeolli* lees fiber on the textural attributes of chicken emulsion sausages formulated with varying concentrations of *makgeolli* lees fiber

| Treatments ¹⁾ | Hardness (kg) | Springiness | Cohesiveness | Gumminess (kg) | Chewiness (kg) |
|--------------------------|-------------------------|-------------|------------------------|------------------------|-------------------------|
| Control | 1.93±0.23 ^c | 0.90±0.06 | 0.55±0.04 ^b | 1.22±0.21 ^d | 1.21±0.18 ^c |
| T1 | 2.58±0.25 ^{bc} | 0.97±0.02 | 0.56±0.02 ^b | 1.44±0.28 ^c | 1.35±0.27 ^{bc} |
| T2 | 2.83±0.27 ^b | 0.95±0.02 | 0.56±0.05 ^b | 1.62±0.31 ^b | 1.42±0.33 ^{bc} |
| T3 | 2.92±0.28 ^b | 0.95±0.04 | 0.57±0.02 ^b | 1.75±0.29 ^b | 1.53±0.25 ^b |
| T4 | 3.42±0.19 ^a | 0.95±0.03 | 0.61±0.04 ^a | 1.97±0.25 ^a | 1.86±0.51 ^a |

All values are mean±standard deviation of three replicates.

^{a-d}Means within a column with different letters are significantly different ($p<0.05$).

¹⁾Control, chicken emulsion sausage without *makgeolli* lees fiber; T1, chicken emulsion sausage with 1% *makgeolli* lees fiber; T2, chicken emulsion sausage with 2% *makgeolli* lees fiber; T3, chicken emulsion sausage with 3% *makgeolli* lees fiber; T4, chicken emulsion sausage with 4% *makgeolli* lees fiber

ues. The lightness, redness, and yellowness values of meat and meat products affect the color of the added sources of dietary fibers extracted from natural products (Choi *et al.*, 2011; Choi *et al.*, 2012; Eim *et al.*, 2008; Grigelmo-Miguel *et al.*, 1999; Lee *et al.*, 2008).

TPA of chicken emulsion sausages

TPA data for the chicken emulsion sausages with different levels of *makgeolli* lees fiber are shown in Table 3. The hardness of samples with added *makgeolli* lees fiber was higher than that of the control and as the *makgeolli* lees fiber levels increased the hardness increased ($p<0.05$). Normally, improving hardness of meat products results from the ability of dietary fiber to become a stronger-binding three-dimensional network (Choi *et al.*, 2009; Choi *et al.*, 2012; Lee *et al.*, 2008). No significant differences in springiness were observed among the control and all of the treatments containing *makgeolli* lees fiber ($p>0.05$). Cohesiveness, gumminess, and chewiness were the highest for the 4% *makgeolli* lees fiber treatment sample ($p<0.05$), and increased as *makgeolli* lees fiber levels increased. Similar increases in hardness, gumminess, and chewiness were obtained for meat products such as frank-

furters, bologna, and ground patties due to added rice bran fiber, *kimchi* fiber, soy fiber, sea tangle fiber, chestnut peel fiber, and other types of fiber (Choi *et al.*, 2009; Choi *et al.*, 2010a; Colmenero *et al.*, 2005; Lee *et al.*, 2008; Steenblock *et al.*, 2001; Thebaudin *et al.*, 1997). In general, dietary fiber enhances the consistency of meat emulsion products by forming an insoluble three-dimensional network capable of modifying the rheological properties of meat emulsion systems (Lee *et al.*, 2008). Thebaudin *et al.* (1997) reported that dietary fiber influences food texture due to its water binding ability and swelling properties.

Sensory evaluation of the chicken emulsion sausages

Table 4 shows the sensory property comparisons of the chicken emulsion sausages prepared with added *makgeolli* lees fiber. Adding *makgeolli* lees fiber decreased color scores, and all the treatments received lower scores than the control without *makgeolli* lees fiber ($p<0.05$). This result was directly related to the *makgeolli* lees fiber levels added. Color has been a key problem in many studies examining additions of natural sources of dietary fiber

Table 4. Effects of *makgeolli* lees fiber on the sensory characteristics of chicken emulsion sausages formulated with varying concentrations of *makgeolli* lees fiber

| Treatments ¹⁾ | Color | Flavor | Tenderness | Juiciness | Overall acceptability |
|--------------------------|-------------------------|-----------|-------------------------|-------------------------|-------------------------|
| Control | 8.20±0.83 ^a | 7.70±0.93 | 7.30±0.35 ^b | 7.20±0.46 ^b | 7.50±0.46 ^b |
| T1 | 8.10±0.93 ^{ab} | 7.70±0.64 | 7.60±0.46 ^{ab} | 7.60±0.64 ^{ab} | 7.50±0.71 ^{ab} |
| T2 | 8.00±0.99 ^{ab} | 7.80±0.71 | 8.10±0.53 ^a | 7.90±0.53 ^a | 8.00±0.46 ^a |
| T3 | 7.60±0.71 ^{ab} | 7.90±0.64 | 7.70±0.71 ^{ab} | 7.75±0.74 ^{ab} | 7.70±0.64 ^{ab} |
| T4 | 7.50±0.53 ^b | 7.80±0.53 | 7.35±0.46 ^b | 7.15±0.64 ^b | 7.20±0.53 ^b |

All values are mean±standard deviation of three replicates.

^{a, b}Means within a column with different letters are significantly different ($p<0.05$).

¹⁾Control, chicken emulsion sausage without *makgeolli* lees fiber; T1, chicken emulsion sausage with 1% *makgeolli* lees fiber; T2, chicken emulsion sausage with 2% *makgeolli* lees fiber; T3, chicken emulsion sausage with 3% *makgeolli* lees fiber; T4, chicken emulsion sausage with 4% *makgeolli* lees fiber.

(Choi *et al.*, 2010b; Choi *et al.*, 2012; Lee *et al.*, 2008). These results agree with those reported by Jeong and Park (2006), in which *takju* powder decreased the color scores of loaf breads, and increasing *takju* powder levels decreased color scores. Presently, the flavor scores of chicken emulsion sausages were not significantly different among the control and *makgeolli* lees fiber treatments ($p>0.05$). Chicken emulsion sausages containing 2% *makgeolli* lees fiber received the highest scores for tenderness, juiciness, and overall acceptability ($p<0.05$). Similar results were obtained for meat products with added rice bran fiber and hazelnut pellicle fiber with the same sensory properties (Choi *et al.*, 2010a; Turhan *et al.*, 2005). Furthermore, flavor and taste are affected by various additives such as lemon albedo, melon seed meal, acorn powder, and tiger nut fiber (Abiola *et al.*, 2004; Chin and Ban, 2008; Fernández-Ginés *et al.*, 2004; Sánchez-Zapata *et al.*, 2010).

In conclusion, our results indicate that the *makgeolli* lees used in chicken emulsion sausages formulations significantly affects the proximate composition, caloric content, pH, color, cooking yields, textural profile analysis, and sensory evaluation of the chicken emulsion sausages. *Makgeolli* lees shows potential as a good source of dietary fiber that can be used as a functional ingredient in chicken meat emulsion sausages. The chicken emulsion sausages with *makgeolli* lees fiber had improved physico-chemical properties and sensory characteristics, and the best results were obtained for the chicken emulsion sausages with 2% of added *makgeolli* lees fiber.

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