

Effects of Replacing Pork Back Fat with Brewer's Spent Grain Dietary Fiber on Quality Characteristics of Reduced-fat Chicken Sausages

Min-Sung Choi¹, Yun-Sang Choi², Hyun-Wook Kim¹, Ko-Eun Hwang¹, Dong-Heon Song¹,
Soo-Yeon Lee¹, and Cheon-Jei Kim^{1,*}

¹Department of Food science and Biotechnology of Animal Resources, Konkuk University, Seoul, Korea

²Food and Biological Resources Examination Division, Korean Intellectual Property Office, Daejeon, Korea

Abstract

The effects of replacing pork back fat with brewer's spent grain (BSG) pre-emulsion for physicochemical, textural properties, and sensory evaluations of reduced-fat chicken sausages are evaluated. Control was prepared with 15% pork back fat, and three reduced-fat chicken sausages were formulated with the replacement of 20, 25, and 30% pork back fat with BSG pre-emulsion. The pH level of reduced-fat sausages formulated with BSG pre-emulsion is lower than that of the control ($p < 0.05$). The redness, yellowness, and apparent viscosity of reduced-fat chicken sausages increase proportionally with increasing BSG pre-emulsion ($p < 0.05$). With increasing BSG pre-emulsion concentration, the fat contents and energy values are decreased in reduced-fat chicken sausages ($p < 0.05$). The BSG pre-emulsion improves the hardness, gumminess, and chewiness of reduced-fat chicken sausages ($p < 0.05$), and the reduction in fat and the addition of BSG pre-emulsion had no influence on the cohesiveness of the chicken sausage. And there is no significant difference in the overall acceptability among control, T1 (chicken sausage with 20% of BSG pre-emulsion, 10% of fat addition), and T2 (chicken sausage with 25% of BSG pre-emulsion, 5% of fat addition) ($p > 0.05$). Therefore, our results indicate that BSG is effective dietary fiber source for manufacturing of reduced-fat meat product and suggest that 20-25% of BSG pre-emulsion is suitable for pork back fat in chicken sausages.

Key words: brewer's spent grain, chicken sausage, dietary fiber, reduced-fat

Introduction

Emulsion sausages are one of the most popular processed meat products, and include frankfurters and bologna. In general, the fat content in traditional emulsion sausages is up to 30% (Choi *et al.*, 2009). Consumers have increasing health concerns and demand low-fat and highly-nutritious meat product. It is well known that a high consumption of animal fat is lead to risk of coronary heart disease, obesity and cancer (Ozvural and Vural, 2008). However, the production of low-fat sausages is difficult, because fat plays an important role in a number of the meat product characteristics. Fat interacts with other ingredients and affects the stabilization of meat emulsions, influencing the cooking yield, flavor, and texture of the final product (Choi *et al.*, 2010; Youssef and Barbut, 2009). For

these reasons, the meat industry has encouraged the development of new technologies and many studies have been conducted to develop low-fat meat and meat products (Aleson-carbonell *et al.*, 2004).

The most common method is using fat substitutes such as dietary fiber. Meat emulsion products with dietary fiber have been studied by Kaack and Pedersen (2005). Dietary fibers are beneficial to human health and have technological properties. Xanthan gum, carrageenan, and locust bean gum have been used in many low-fat products for the improvement of rheological properties and emulsion stability (Grigelmo-Miguel *et al.*, 1999). It improves cooking yield and reduces cost in meat products (Aleson-Carbonell *et al.*, 2004). Also, Choi *et al.* (2012) reported that reduced-fat pork patties containing *Laminaria japonica* obtained high sensory scores.

Barley is an important cereal and is used in the production of many food and alcoholic drinks. Brewer's spent grain (BSG) which is one of the largest by-products of the brewing process, is recognized as functional material which is rich in protein and fiber (Mussatto *et al.*, 2006).

*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

Also, BSG is available in large continuing supply and at a low cost. BSG has been studied for its inclusion in human foods such as bread and cookies (Prentice *et al.*, 1978; Salama *et al.*, 1995). Özvural *et al.* (2009) produced a frankfurter containing BSG. In their study, BSG was a good source of protein and dietary fiber in emulsion sausage. However, few studies have been conducted on the dietary fiber extracts of BSG in chicken products, and there is no previous study of the application BSG to pre-emulsion type. Chantaro *et al.* (2008) reported that dietary fiber needed a number of processing steps prior to application to real food system.

Therefore, the aim of this study was to evaluate the effects of replacing pork back fat with dietary fiber extracted from BSG on the quality characteristics of reduced-fat chicken sausages, in terms of cooking loss, pH, color evaluation, emulsion stability, texture profile analysis, sensory characteristics, proximate composition of sausages.

Materials and Methods

Preparation of dietary fiber extracts from brewers' spent grain (BSG)

Dietary fiber was extracted using the modified method of Choi *et al.* (2011) based on the AOAC enzymatic-gravimetric method (2007). BSG was obtained from a commercial brewery (HITEJINRO Co., Ltd., Korea). BSG was washed three times with five volume of distilled water to remove alcoholic components and foreign bodies. The residues were defatted with five volume of hexane (n-hexane 95%) on a shaker (BS-11, Lab. Companion, Korea) for 24 h. The defatted BSG was gelatinized with 0.6% termamyl (heat stable alpha-amylase) in a 95°C water bath for 1 h to remove starch. After filtration, the residues were washed three times with four volumes of heated distilled water (100°C) and cooled to equilibrate to room temperature (20°C). And then, the residues were washed with 99.9% ethanol (preheated to 60°C) followed by filtration. The residues were dried in a 55°C hot air dryer (Enex-Co-600, Enexs, Korea) for 24 h. The dried residues were pulverized using a milling machine (DK504, SEJUNG-TECH, Korea), and the powder was passed through the 270 mesh testing sieves (Chunggye, Korea).

Pre-emulsion of brewers' spent grain (BSG) preparation

Firstly, 5% carboxymethyl cellulose and 80% ice were homogenized and ground for 1 min in a silent cutter (Cutter Nr-963009, Scharfen, Germany). BSG dietary fiber ex-

tracts (15%) were added to the pre-emulsion, which were then homogenized for 5 min. After emulsification, BSG pre-emulsion stored at 0°C until required for product manufacture.

Reduced-fat chicken sausages preparation and processing

Fresh chicken breast meat (*Musculus pectoralis major*) and pork back fat were purchased from a local processor at 48 h postmortem. The chicken materials were initially ground through an 8 mm plate. The pork back fat was also ground through an 8 mm plate. The first meat batter served as the control and was prepared with 15% pork back fat. The next samples consisted of three meat batters which differed in composition with respect to the replacement of 20, 25, and 30% pork back fat with BSG pre-emulsion (20, 25, and 30%). The four different chicken sausages were formulated (Table 1) as follows: raw meat was homogenized and ground for 1 min in a silent cutter (Cutter Nr-963009, Scharfen, Germany). 1.4% nitrite pickled salt (NPS), 0.5% ascorbic acid, 0.8% sugar, 0.3% monosodium L-glutamate, 0.3% garlic powder, and 0.6% spice were added to the meat. The pre-emulsion was added to meat batters, which were then homogenized for 6 min. A temperature probe (Kane-May, KM330, Germany) was used to monitor the temperature of the emulsion, which was maintained below 10°C during batter pre-

Table 1. Reduced-fat chicken sausage formulations with brewer's spent grain (BSG) pre-emulsion levels (units: %)

Ingredients	Treatments ¹⁾			
	Control	T1	T2	T3
Chicken breast meat	70	70	70	70
Pork back fat	15	10	5	0
BSG pre-emulsion	0	20	25	30
Ice	15	(16) ²⁾	(20)	(24)
CMC ³⁾	0	(1)	(1.25)	(1.5)
BSG ⁴⁾ dietary fiber	0	(3)	(3.75)	(4.5)
Total	100	100	100	100
NPS ⁵⁾	1.4	1.4	1.4	1.4
Ascorbic acid	0.5	0.5	0.5	0.5
Sugar	0.8	0.8	0.8	0.8
Garlic powder	0.3	0.3	0.3	0.3
Monosodium L-glutamate	0.3	0.3	0.3	0.3
Spice	0.6	0.6	0.6	0.6

¹⁾Control: chicken sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion. ²⁾Figure in parenthesis is calculated as content pre-emulsion ingredients based on total weight. ³⁾Carboxymethyl cellulose. ⁴⁾Brewer's spent grain. ⁵⁾NPS: nitrite pickled salt (99.4:0.6).

paration. After emulsification, chicken meat batter was stuffed into collagen casings (#240, NIPPI Inc., Tokyo, Japan; approximate diameter of 25 mm) using a stuffer (Stuffer IS-8, Sirman, Italy). The meat batters were then heated at $75\pm 2^\circ\text{C}$ for 30 min in a water bath (Model 10-101, Dae Han Co., Korea). The cooked meat sausages were then cooled with cold water.

pH

The pH values of batter and 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, Schwerzenbach, Switzerland). All determinations were performed in triplicate.

Color evaluations

The color of batters in petri dish and sausages (cross-section) were measured by the CIE LAB system using a color meter (Minolta Chroma meter CR-210, Japan; illuminate C, calibrated with white plate, $L^*=+97.83$, $a^*=-0.43$, $b^*=+1.98$). Six measurements for each of five treatments were taken. Lightness (L^* -value), redness (a^* -values), and yellowness (b^* -values) values were recorded.

Proximate composition

Moisture (950.46B, oven air-drying method), protein (981.10) ($N\times 6.25$), fat (960.69, ether extractable component), and ash (920.153, muffle furnace) contents were determined according to the AOAC (2000) procedure. Carbohydrate contents were calculated by the difference among the parameters.

Caloric content

Total calorie estimates (Kcal) for 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) (Mansour and Khalil, 1999).

Cooking yield

Sausages were weighted before heat processing and after chilling. The cooking yield was determined from their weights and expressed as a percentage of the initial weight;

Cooking yield (%) = $[\text{cooked sausage weight (g)} / \text{raw sausage weight (g)}] \times 100$

Salt soluble protein solubility

The solubility of the salt soluble (myofibrillar) protein

was determined following the modification of procedures described by Saffle and Galbreath (1964). A 5 g sample was blended with 50 mL 3% sodium chloride solution at 6,000 g for 2 min using homogenizer (AM-7, Nihonseiki Kaisha, Japan). The mixture was centrifuged at 1,100 g for 15 min. The protein concentration of supernatant was determined using the biuret method (Gornall *et al.*, 1949) and bovine serum albumin (Sigma Chemical Co., USA) was used as the standard curve.

Apparent viscosity

The chicken emulsion meat batter viscosity was measured in triplicate with a rotational viscometer (HAKKE Viscotester[®]500, Thermo Electron Corporation, Karlsruhe, Germany) set at 10 rpm. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with batter and allowed to rotate under a constant share rate at 60/s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time ($18\pm 1^\circ\text{C}$) of viscosity testing was also recorded (Shand, 2000).

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). Reduced-fat chicken sausage samples were taken from the central portion of each sausages. Prior to analysis, samples covered with cling film were allowed to equilibrate to room temperature (20°C , 3 h). The conditions of texture analysis were as follows: 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, springiness, cohesiveness, gumminess, and chewiness were determined as described (Bourne, 1978).

Sensory evaluation

Each reduced-fat chicken sausage was evaluated for visual color, flavor, off-flavor, tenderness, juiciness, and overall acceptability. Reduced-fat chicken 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 was coded with a randomly selected 3-digit numbers. Sensory evaluations were performed by the panelists under fluorescent lighting. Panelists were instructed to cleanse their palates between samples using water.

Table 2. Effects of brewer's spent grain (BSG) pre-emulsion on pH and color (L*-, a*-, and b*-values) of uncooked and cooked reduced-fat chicken sausage

Treatments ¹⁾	Uncooked				Cooked			
	pH	L*.-value	a*.-value	b*.-value	pH	L*.-value	a*.-value	b*.-value
Control	5.30±0.02 ^b	76.16±0.64 ^a	4.03±0.37 ^c	16.08±0.83 ^b	5.62±0.02	83.21±0.48 ^a	2.92±0.13 ^c	13.06±0.34 ^d
T1	5.34±0.02 ^a	64.07±1.45 ^b	4.80±0.20 ^b	19.91±0.42 ^a	5.61±0.04	74.58±0.84 ^b	3.42±0.17 ^b	17.50±0.28 ^c
T2	5.35±0.02 ^a	60.18±0.65 ^c	4.97±0.27 ^b	20.12±0.64 ^a	5.61±0.04	73.61±0.46 ^c	3.43±0.17 ^b	18.05±0.33 ^b
T3	5.36±0.02 ^a	54.60±0.77 ^d	5.68±0.37 ^a	20.50±0.64 ^a	5.63±0.03	69.97±0.37 ^d	3.71±0.13 ^a	19.83±0.32 ^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 sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion.

The visual color (1=extremely undesirable, 10=extremely desirable), flavor (1=extremely undesirable, 10=extremely desirable), off-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 hedonic 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

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

Results and Discussion

pH and color

The pH values of uncooked and cooked reduced-fat sausages formulated with various BSG pre-emulsion levels are given in Table 2. Meat batters with BSG pre-emulsion showed a higher pH value than control ($p < 0.05$). However, there were no significant differences in the pH values of reduced-fat sausages ($p > 0.05$). The color values of uncooked and cooked reduced-fat sausages formulated with various BSG pre-emulsion levels are shown in lightness (L*.-value), redness (a*.-value), and yellowness (b*.-value). Table 2 shows the color values of uncooked and cooked reduced-fat sausages were affected by the color of BSG pre-emulsion. Lightness in uncooked and cooked reduced-fat sausages treated with BSG pre-emulsion were lower than that of control ($p < 0.05$). Caceres *et al.* (2004) found that the lightness of reduced-fat meat sausages was lower than that of control. There were significant differ-

ences in redness and yellowness. As the content of BSG pre-emulsion increased among treatments, redness and yellowness values also increased ($p < 0.05$). These results indicate that the addition of BSG pre-emulsion increases the redness and yellowness of reduced-fat sausages. Özvural *et al.* (2009), who studied the frankfurter with added BSG, reported that the redness of frankfurters increased due to the addition of BSG. Also, dietary fiber from cereal in meat products increased yellowness. Yılmaz and Dağlıoğlu (2003) indicate that oat bran in the meatball increased yellowness. Thus, the color values of reduced-fat sausages were affected by BSG pre-emulsion.

Fat contents and energy value

Fig. 1 shows the results for fat contents and energy values of reduced-fat chicken sausages formulated with var-

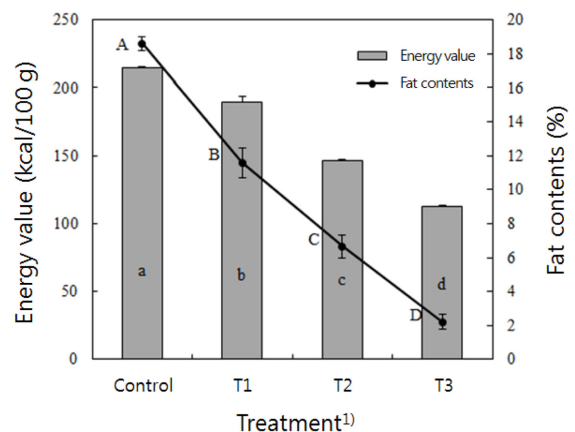


Fig. 1. Fat contents and energy value of reduced-fat chicken sausages formulations with various brewer's spent grain (BSG) pre-emulsion levels. All values are mean±SD. ^{A-D}Mean sharing different letters in fat contents are significantly different ($p < 0.05$). ^{a-d}Mean sharing different letters in Energy value are significantly different ($p < 0.05$). ¹⁾Control: chicken sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion.

ious BSG pre-emulsion. In our study, the differences in fat contents and energy values of reduced-fat chicken sausages were statistically significant ($p < 0.05$). The fat contents varied between 2.20 and 23.61%. As expected, the fat contents were lower in all treatments than in the control ($p < 0.05$). Energy values are greatly related to fat contents (Brauer *et al.*, 1993). It is considered that the reduction in fat content lead to reduced energy values of all treatments. As BSG pre-emulsion increased among the treatments, energy values decreased ($p < 0.05$) and the T3 treatment showed the lowest energy value. Cengiz and Gokoglu (2005) reported that the calorie content of low-fat meat product with added citrus fiber were significantly lower than that of the control. Yılmaz and Dağlıoğlu (2003), who replaced animal fat with oat bran in meatballs, obtained a 50% reduction in fat content. Also, reduced-fat pork patties with added *Laminaria japonica* had approximately 35% lower energy content than that of the control (Choi *et al.*, 2012).

Cooking yield and salt protein solubility

Table 3 shows the results obtained from the cooking yield and salt protein solubility of reduced-fat chicken sausages. The addition of BSG pre-emulsion significantly affected the cooking yield of reduced-fat chicken sausages ($p < 0.05$). The cooking yield of samples with added BSG pre-emulsion was higher than that of the control. Choi *et al.* (2010) reported that the cooking yield of meat products relies on the cooking time and temperature, condition of meat emulsion, added level of fat and dietary fiber. In our study, dietary fiber in BSG pre-emulsion may improve the cooking yield of reduced-fat chicken sausage. In particular, dietary fiber has the ability to bind water and fat, restricting molecular mobility (Grigelmo-Miguel *et al.*,

Table 3. Effects of brewer's spent grain (BSG) pre-emulsion on cooking yield and salt soluble protein solubility of reduced-chicken sausage

Treatments ¹⁾	Cooking yield (%)	Salt soluble protein solubility (mg/g)
Control	89.37±2.89 ^b	8.62±0.48
T1	95.74±0.64 ^a	8.77±0.40
T2	95.28±0.99 ^a	9.11±0.88
T3	95.42±0.31 ^a	9.20±0.29

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 sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion.

1999; Fernández-Ginés *et al.*, 2004). However, there were no significant differences among treatments (T1, T2, and T3). Similar results were obtained by Grigelmo-Miguel *et al.* (1999), who studied the effects of peach fiber on low-fat sausages. They reported that low-fat sausages containing peach fiber have higher cooking yields than that of the control.

Salt soluble protein solubility is associated with gel formation and cooking yield of final product (McCord *et al.*, 1998). However, there were no significantly different values throughout all samples ($p > 0.05$).

Apparent viscosity

The various levels of BSG pre-emulsion significantly affected the viscosity of reduced-fat meat emulsion systems (Fig. 2). Yapar *et al.* (2006) reported that the meat emulsion system containing high-fat had increased the viscosity. Although the all treatments with added BSG pre-emulsion had lower fat contents than that of the control, the control had the lowest apparent viscosity. Among the treatments, T2 had the highest maximum apparent viscosity. It is considered that dietary fiber has a water holding ability and improved apparent viscosity. Claus and Hunt (1991) found that high fiber content in Bologna increased viscosity. In our study, these results were due to the dietary fiber in BSG pre-emulsion which has water holding ability. Also Choi *et al.* (2013) observed a redu-

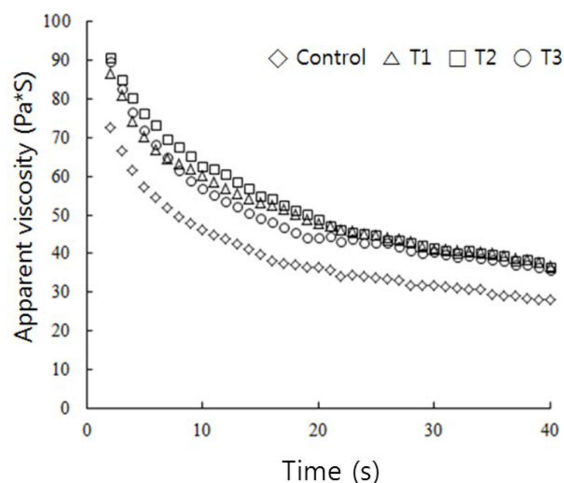


Fig. 2. Change in apparent viscosity of uncooked reduced-fat chicken sausages containing brewer's spent grain (BSG) pre-emulsion stirred for 40 s. (◇) Control: chicken sausage with 15% pork back fat; (△) T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; (□) T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; (○) T3: chicken sausage with 30% BSG pre-emulsion.

ced-fat frankfurter containing *makgeolli* lees dietary fiber. They reported that the addition of dietary fiber increased the apparent viscosity of a reduced-fat meat emulsion system. These results agree with those of our study. According to Dogan *et al.* (2005), the water holding ability of additives played an important role on the viscosity of meat batter. Aktas and Genccelep (2006) reported that in general, the high viscosity in meat batters is not easily broken, and has a high yield of final product. Thus, BSG pre-emulsion could improve the viscosity of reduced-fat emulsion.

Texture profile analysis

Table 4 shows the results of texture properties of reduced-fat chicken sausages. The mean values are shown for hardness, springiness, gumminess, and chewiness ($p < 0.05$). Increased BSG pre-emulsion levels increased hardness and gumminess values ($p < 0.05$). The reduced-fat sausage with 30% BSG pre-emulsion had the highest hardness values. Similar results were obtained by Özvural *et al.* (2009), for frankfurters containing BSG. They found that the addition of BSG to frankfurters improves hardness and gumminess values. The chewiness values of samples with BSG pre-emulsion had higher chewiness than that of the control. However, there were no significantly different mean values among treatments (T1, T2, and T3) ($p > 0.05$). These improvements in textural properties may due to the dietary fiber, which has abilities of binding water

and fat absorption (Choi *et al.*, 2009). In contrast, springiness was the lowest for the T3 treatment. As the BSG pre-emulsion content increased in reduced-fat sausages, springiness decreased ($p < 0.05$). Choi *et al.* (2013) reported similar results of decreasing springiness by replacement of back fat with sunflower seed oil and dietary fiber extracted from *makgeolli* lees. There were no significant differences in cohesiveness among all samples ($p > 0.05$).

Sensory evaluation

The sensory scores for cooked chicken sausages with different added levels of BSG pre-emulsion are given in Table 5. The mean values of color, flavor, and overall acceptability were evaluated. The color scores of reduced-fat sausages varied from 7.36 to 8.55. The color and flavor values were decreased as increased in BSG pre-emulsion concentration. However, there were no significant differences among control, T1, and T2 treatments ($p > 0.05$). As regarded Özvural *et al.* (2009), the increased BSG concentration in frankfurters lead to decreased flavor scores. Also, it is considered that the replacement of pork back fat by BSG pre-emulsion decreases color score and flavor score. Choi *et al.* (2010) reported that fat provides juiciness and hardness to meat products. Although T1 and T2 treatments had lower pork back fat content than that of the control, there were no differences in mean values of tenderness or juiciness ($p > 0.05$). According to Grigelmo-Miguel *et al.* (1999), low-fat sausages formulated with

Table 4. Textural attributes of reduced-fat chicken sausage formulated with varying brewer's spent grain (BSG) pre-emulsion levels

Treatments ¹⁾	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Control	0.23±0.18 ^c	0.87±0.02 ^a	0.51±0.02	0.12±0.02 ^c	0.10±0.02 ^b
T1	0.32±0.02 ^b	0.84±0.03 ^a	0.51±0.03	0.16±0.03 ^b	0.14±0.03 ^a
T2	0.33±0.02 ^b	0.83±0.04 ^{ab}	0.51±0.02	0.17±0.02 ^b	0.14±0.02 ^a
T3	0.36±0.02 ^a	0.79±0.03 ^c	0.51±0.03	0.18±0.02 ^a	0.15±0.02 ^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 sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion.

Table 5. Effects of brewer's spent grain (BSG) pre-emulsion on the sensory evaluation of reduced-chicken sausage

Treatments ¹⁾	Color	Flavor	Off-flavor	Tenderness	Juiciness	Overall acceptability
Control	8.55±0.52 ^a	8.40±0.70 ^a	8.10±1.10	7.80±1.03	8.80±0.92	8.10±0.57 ^a
T1	8.00±0.77 ^{ab}	7.90±0.99 ^{ab}	8.10±1.29	7.50±1.08	8.50±1.08	7.70±0.67 ^{ab}
T2	8.09±0.70 ^{ab}	8.10±0.88 ^{ab}	8.20±1.23	7.50±1.18	8.50±0.71	7.60±0.70 ^{ab}
T3	7.36±0.92 ^b	7.50±0.71 ^b	8.00±1.41	7.40±1.43	8.30±1.06	7.10±0.74 ^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 sausage with 15% pork back fat; T1: chicken sausage with 10% pork back fat and 20% BSG pre-emulsion; T2: chicken sausage with 5% pork back fat and 25% BSG pre-emulsion; T3: chicken sausage with 30% BSG pre-emulsion.

peach fiber showed higher hardness and juiciness values than that of the control. The results of overall acceptance between treatments and control similar to color and flavor score trend. T3 treatment had the lowest overall acceptance score, but there were no statically mean differences in control, T1, and T2 ($p>0.05$). Thus, the replacement of 5-10% pork back fat by BSG pre-emulsion in reduced-fat chicken sausages supplemented the problems resulted in reduced fat.

Conclusions

In this study, reduced-fat chicken sausages incorporating BSG pre-emulsion were successfully produced without adversely effect on quality characteristics of reduced-fat sausages. Therefore, the replacement of back fat with 20-25% BSG pre-emulsion can be successfully used to improve reduced-fat chicken sausages.

Acknowledgements

This research was supported by Technology Development Program (608001-05-4-SB310) for Ministry of Agriculture, Food and Rural Affairs, Republic of Korea.

References

1. AOAC. (2007) Official methods of analysis of AOAC. 18th ed., Association of Official Analytical Chemists, Washington, DC.
2. Aktas, N. and Genccelep, H. (2006) Effect of starch type and its modifications on physic-chemical properties of bologna-type sausage produced with sheer tail fat. *Meat Sci.* **74**, 404-408.
3. Aleson-Carbonell, L., Fernández-López, J., Sendra, E., Sayas-Barberá, E., and Pérez-Alvarez, J. A. (2004) Quality characteristics of a non-fermented dry-cured sausage formulated with lemon albedo. *J. Sci. Food Agr.* **84**, 2077-2084.
4. AOAC. (2000) Official methods of analysis of AOAC. 17th ed., Association of Official Analytical Chemists, Washington, DC.
5. Brauer, H. (1993) Fat-reduced frankfurter-type sausage. A technology for preventing too firm and rubbery a bite. *Fleischwirtsch.* **73**, 64-65.
6. Bourne, M. C. (1978) Texture profile analysis. *Food Technol.* **32**, 62-66.
7. Choi, Y. S., Park, K. S., Kim, H. Y., Hwang, K. E., Song, D. H., Choi, M. S., Lee, S. Y., Paik, H. D., and Kim, C. J. (2013) Quality characteristics of reduced-fat frankfurters with pork fat replaced by sunflower seed oils and dietary fiber extracted from *makgeolli* lees. *Meat Sci.* **93**, 652-658.
8. Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Kim, H. W., Lee, M. A., Chung, H. J., and Kim, C. J. (2012) Effects of *Laminaria japonica* on the physic-chemical and sensory characteristics of reduced-fat pork patties. *Meat sci.* **91**, 1-7.
9. 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. (2011) Effects of rice bran fiber on heat-induced gel prepared with pork salt-soluble meat proteins in model system. *Meat Sci.* **88**, 59-66.
10. Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Jeong, J. H., Chung, H. J., and Kim, C. J. (2010) Effects of replacing pork back fat with vegetable oil and rice bran fiber on the quality of reduced-fat frankfurters. *Meat Sci.* **84**, 557-563.
11. 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 system with pork fat replaced by vegetable oils and rice bran fiber. *Meat Sci.* **82**, 266-271.
12. Chantaro, P., Devahastin, S., and Chiewchan, N. (2008) Production of antioxidant high dietary fiber powder from carrot peels. *LWT-Food Sci. Technol.* **41**, 1987-1994.
13. 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.
14. Caceres, E., Garcia, M. L., Toro, J., and Selgas, M. D. (2004) The effect of fructooligosaccharides on the sensory characteristics of cooked sausages. *Meat Sci.* **68**, 87-96.
15. Claus, J. R. and Hunt, M. C. (1991) Low-fat, high added-water bologna formulated with texture-modifying ingredients. *J. Food Sci.* **56**, 643-647.
16. Dogan, S. F., Sahin, S., and Sumnu, G. (2005) Effects of soy and rice flour addition on batter rheology and quality of deep-fat fried chicken nuggets. *J. Food Eng.* **71**, 457-132.
17. 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.* **64**, 7-13.
18. Grigelmo-Miguel, N., Abadías-Serós, M. I., and Martín-Belloso, O. (1999) Characterisation of low-fat high-dietary fibre frankfurters. *Meat Sci.* **52**, 247-256.
19. Gornall, A. G., Bardawill, C. J., and David, M. M. (1949) Determination of serum proteins by means of the Biuret reaction. *J. Biol. Chem.* **177**, 751-766.
20. Kaack, K. and Pedersen, L. (2005) Application of by-products from industrial processing of potato flour and yellow peas as ingredients in low-fat high-fibre sausage. *Eur. Food Res. Technol.* **221**, 313-319.
21. Mussatto, S. I., Dragone, G., and Roberto, I. C. (2006) Brewers' spent grain: generation, characteristics and potential applications. *J. Cereal Sci.* **43**, 1-14.
22. 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.
23. McCord, A., Smyth, A. B., and O'Neill, E. E. (1998) Heat-induced gelation properties of salt-soluble muscle proteins as affected by non-meat proteins. *J. Food Sci.* **63**, 580-583.
24. Özvural, E. B., Vural, H., Gökbulut, Y., and Özboy-Özbaş, Özen. (2009) Utilization of brewer's spent grain in the pro-

- duction of frankfurters. *Int. J. Food Sci. Technol.* **44**, 1093-1099.
25. Ozvural, E. B. and Vural, H. (2008) Utilization of interesterified oil blends in the production of frankfurters. *Meat Sci.* **78**, 211-216.
26. Prentice, N., Kissel, L. T., Lindsay, R. C., and Yamazaki, W. T. (1978) High-fibre cookies containing brewer's spent grain. *Cereal Chem.* **55**, 712-721.
27. SAS. (2008) SAS/STAT software for PC. Release 9.2, SAS Institute Inc., Cary, NC, USA.
28. 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.
29. Salama, A. A., Mesallam, A. S., El-Shan, M. A., and El-Tabey Shehata, A. M. (1995) Chemical, nutritional and microbiological evaluation of brewer's spent grain. *J. Agric. Res.* **40**, 67-99.
30. Saffle, R. L. and Galbreath, J. W. (1964) Quantitative determination of salt-soluble protein in various types of meat. *Food Technol.* **18**, 1943-1944.
31. Youssef, M. K. and Barbut, S. (2009) Effects of protein level and fat/oil on emulsion stability, texture, microstructure and color of meat batter. *Meat Sci.* **82**, 228-233.
32. Yapar, A., Atay, S., Kayacier, A., and Yetim, H. (2006) Effects of different levels of levels of salt and phosphate on some emulsion attributes of the common carp (*Cyprinus carpio L.*, 1758). *Food Hydrocolloid.* **20**, 825-830.
33. Yilmaz, I. and Dağlıoğlu, 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 2013.9.9/Revised 2014.1.21/Accepted 2014.2.10)