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Physico−chemical Properties of Chicken Meat Emulsion Systems with Dietary Fiber Extracted from *Makgeolli* Lees

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Abstract

Makgeolli lees is a *jigaemi* by product produced by *makgeolli* brew processing. *Jigaemi* has high fiber content and therefore can potentially be used in the development of foods rich in dietary fiber. The effects of *makgeolli* lees fibers on the composition and physico-chemical properties of chicken emulsion systems were studied. The moisture and ash contents, yellowness, and viscosity of chicken meat emulsion systems with *makgeolli* lees fiber were all higher than those of control. Moreover, chicken batters supplemented with *makgeolli* lees fiber were characterized by lower cooking loss and better emulsion stability. Chicken emulsion systems with *makgeolli* lees fiber also had improved emulsion stability and emulsion viscosity, and the best results were obtained with meat batter containing 2% *makgeolli* lees fiber.

Key words: chicken, emulsion systems, *makgeolli* lees, dietary fiber, *jigaemi*

Introduction

Makgeolli is a traditional Korean rice and cereal wine that is one of the most popular alcoholic drinks in Korea (Bae *et al*., 2010). In general, *makgeolli* is brewed by conventional methods using *nuruk* or *koji* (Lee *et al*., 1996; Lee *et al*., 2009a; Park and Lee, 2002). *Makgeolli* is comprised of water, yeast, and cereal such as rice, wheat, barley, corn, and sweet potato that have been fermented for approximately 16 d without distillation (Jeong *et al*., 2006; Kim *et al*., 1995; Shin *et al*., 2005).

Large amounts of *makgeolli* lees (*jigaemi*) are produced annually in Korea, and the by-products of *makgeolli* brew processing are commonly used as animal feeds or fertilizers. *Makgeolli* lees provides energy, dietary fiber, proteins, minerals, vitamins, alcohol, and organic acids required for human health (Lee *et al*., 2009b; Won *et al*., 2006). *Jigaemi* also has a high nutritive value, and contributes to lower blood cholesterol, decreases the incidence of atherosclerosis disease, and has a laxative effect. In recent years, *jigaemi* has been studied regarding its potential use in developing functional foods (Jeong and Park, 2006; Kim and Cho, 2006; Lee *et al*., 2009b).

Dietary fiber is a major component of many by-products from food industry. The major component of dietary fiber in *makgeolli* lees can lower the risk of cancer formation and coronary heart disease, and can be used to reduce blood cholesterol levels and to prevent obesity (Hughes *et al*., 1997; Jeong and Park, 2006; Kim and Cho, 2006). Also, dietary fibers are not only desirable for their nutritional properties, but also for their functional and technological properties (Fernández-Ginés *et al*., 2004; Hughes *et al*., 1998; Thebaudin *et al*., 1997). According to Jiménez-Colmenero (1996), dietary fiber has been successful in improving cooking yield, reducing formulation cost, and enhancing texture properties due to its water and fat binding properties and ability to improve texture.

The different types of dietary fiber have been studied alone or combined with other ingredients for formulations of meat products. The technological effect on foods differs according to the quantity and nature of dietary fiber. Dietary fiber sources such as *makgeolli* lees are not only desirable for their nutritional properties, but also for their functional and technological properties (Cho and Lee, 1996). However, no studies have yet been reported on the

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dietary fiber extracted from *makgeolli* lees into chicken meat emulsion systems.

Therefore, the aim of this study was to investigate the effects of various levels of dietary fiber from *makgeolli* lees on proximate composition, pH, color, cooking loss, emulsion stability, viscosity, and protein solubility of chicken meat batter.

Materials and Methods

Preparation and processing of *makgeolli* lees fiber extract

Dietary fiber was extracted using the modified AOAC enzymatic-gravimetric method (AOAC, 1995). *Makgeolli* lees was obtained from Seoul TAKJU Map Association, Seoul, 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), followed by filtration. The residue was dried (55°C) overnight in an air oven and then 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%; L*-value: 67.35±1.02; a*-value: 4.62±0.45; b*-value: 16.09±0.85; pH: 4.76±0.24) was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea) and stored at 4°C until used for product manufacture.

Chicken meat batter preparation and processing

Fresh chicken breast meat (*M. pectoralis major*) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor. Chicken breast meats 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, Fujee Tech, Korea), and stored at 0°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 batch of samples consisted of five meat batters differing in composition with respect to the addition of *makgeolli* lees fiber levels (0, 1, 2, 3, and 4%). The five

different emulsion sausages were formulated as follows: raw meat was homogenized and ground for 1 min in a silent cutter (Cutter Nr-963009, Scharfen, Germany). 1.5% NaCl and 0.2% sodium tripolyphosphate were added to the meat that had been previously dissolved in water and chilled (2°C), and then mixed for 1 min. The *makgeolli* lees fiber 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 preparation. Ten kg batches of each chicken emulsion were prepared in this manner.

Proximate composition

Compositional properties of the raw meat batters were determined using AOAC (1995). Moisture content was determined by weight loss after 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scienctific 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 Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Sweden). Ash was determined according to AOAC method 923.03.

Dietary fiber measurements

Duplicate fat free dry was analyzed for total dietary fiber using the method of Lee *et al*. (1992). The method includes enzymatic hydrolysis with amylase, protease, and amyloglucosidase, using the Mes-Tris buffer. Triplicate of approximately 1 g samples were suspended in 40 mL Mes-Tris buffer, and submitted to an enzymatic hydrolysis sequence: 50 mL of thermo-resistant -amylase, a water bath for 35 min, and 100 μL of protease in water bath at 60°C for 30 min. After that, the pH was corrected to the range of 4.0-4.7, and in water bath at 60°C for 30 min, 300 μL amyloglucosidase was added. Finally, the fiber was precipitated with 95% ethanol at 60°C. The sample was filtered in fritted glass crucibles, with glass wool as a filtration agent. The crucibles containing the residue were dried in a 105°C dry oven, cooled in a dessicator, and weighed.

pH

The pH values of meat batters 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.

Color evaluation

The color of each meat emulsion system was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta Co., Japan; illuminate C, calibrated with a white plate, $L^*=+97.83$, $a^*=-0.43$, $b^*=+1.98$). Six measurements for each of five replicates were taken. Lightness (L^*-value), redness (a^*-value), and yellowness (b^*-value) values were recorded.

Cooking loss

Cooking loss was determined by calculating the weight differences before and after cooking as follows:

Cooking loss (%) = [(weight of raw meat batter (g)
　　　　　　　　 – weight of cooked meat batter (g))/
　　　　　　　　 weight of raw meatbatter (g)] × 100

Emulsion stability

The meat batters were analyzed for emulsion stability using the method of Bloukas and Honikel (1992) with the following modifications. In the middle of a 15 mesh sieve, pre-weighed graduated glass tubes (Pyrex Chojalab Co., Korea, Volume: 15 mL, Graduated units: 0.2 mL) were filled with batter. The glass tubes were closed and heated for 30 min in a boiling water bath to a core temperature of 75±1°C. After cooling to approximately 4±1°C to facilitate fat and water layer separation, the total expressible fluid and fat separated in the bottom of each graduated glass tube was measured and calculated (Choi *et al.*, 2007).

Total expressible fluid separation (mL/g)
= [(the water layer (mL) + the fat layer (mL))
　/weight of raw meat batter (g)] × 100

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

Apparent viscosity

Meat batter viscosity was measured in triplicate with a rotational viscometer (HAKKE Viscotester® 550, Thermo Electron Corporation, 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 s^{-1} for 60 s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time (18±1 °C) of viscosity testing was also recorded (Shand, 2000).

Protein solubility

Protein solubility was utilized as an indicator of protein denaturation (Joo *et al.*, 1999). Sarcoplasmic protein solubility was determined by dissolving 2 g of meat batters in 20 mL of ice-cold 25 mM potassium phosphate buffer (pH 7.2). The meat batter samples and buffer were homogenized on ice with a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Japan) set at 1,500 g, and were left to stand on a shaker at 4°C overnight. The mixtures were centrifuged at 1,500 g for 20 min, and the protein concentrations of the supernatants were determined using the Biuret method (Gornall *et al.*, 1949). Total protein solubility was determined by homogenizing 2 g of muscle powder in 20 mL of ice-cold 1.1 mol/L potassium iodide in a 100 mol/L phosphate buffer (pH 7.2). The procedures for homogenization, shaking, centrifugation, and protein determination are described above. Myofibrillar protein solubility was obtained by determining the difference between the total and sarcoplasmic protein solubilities.

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 (1999). Duncan's multiple range test ($p<0.05$) was used to determine the differences between treatment means.

Results and Discussion

Proximate composition of chicken model system emulsions

The proximate composition of meat emulsion systems formulated with different levels of *makgeolli* lees fibers are presented in Table 1. The moisture content of chicken emulsion system samples containing *makgeolli* lees fiber were higher than that of the control sample ($p<0.05$). Choi *et al.* (2007) reported similar quality characteristics for meat emulsions supplemented with wheat fiber. These results agree with those reported by Cho and Lee (1996), in which the moisture content increased with the addition of *makgeolli* (rice wine) residue to high-fiber breads. Choi *et al.* (2009) indicated that rice bran fiber give meat emulsion systems a higher moisture content. The difference in protein content of meat batters of control and treatment samples containing *makgeolli* lees fiber was not statistically significant ($p>0.05$). Among control and all treatments, the control had the highest fat content ($p<0.05$). These results agree with those reported by Kim *et al.* (2010), in which sea tangle increased the fat content of emulsion sausages,

Table 1. Proximate composition of chicken meat emulsion systems formulations with various levels of *makgeolli* lees fiber

Treatments[1]	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Control	54.94±0.10[c]	13.46±0.04	29.42±0.93[a]	2.34±0.05[d]
T1	56.34±0.51[ab]	13.32±0.45	28.72±0.35[b]	2.39±0.10[c]
T2	57.09±0.18[a]	13.17±0.08	28.44±1.02[b]	2.40±0.07[c]
T3	56.47±0.10[ab]	13.45±0.03	28.73±0.73[b]	2.42±0.04[b]
T4	55.48±0.07[b]	13.40±0.06	29.11±0.81[ab]	2.46±0.14[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, meat batter without *makgeolli* lees fiber; T1, meat batter with 1% *makgeolli* lees fiber; T2, meat batter with 2% *makgeolli* lees fiber; T3, meat batter with 3% *makgeolli* lees fiber; T4, meat batter with 4% *makgeolli* lees fiber.

Table 2. Effects of chicken meat batters formulated with various *makgeolli* lees fiber levels on pH and color (L*-, a*-, and b*-values)

Treatments[1]	pH	L*-value	a*-value	b*-value
Control	6.39±0.03[a]	81.75±0.41[a]	6.29±0.09[a]	9.45±0.21[d]
T1	6.27±0.04[b]	78.27±0.35[b]	5.39±0.07[b]	10.49±0.31[c]
T2	6.27±0.03[b]	76.26±0.42[c]	4.85±0.07[c]	10.81±0.41[c]
T3	6.25±0.06[b]	74.73±0.38[d]	4.51±0.06[d]	11.35±0.23[b]
T4	6.25±0.05[b]	73.35±0.26[e]	4.36±0.05[e]	11.81±0.25[a]

All values are mean ± standard deviation of three replicates
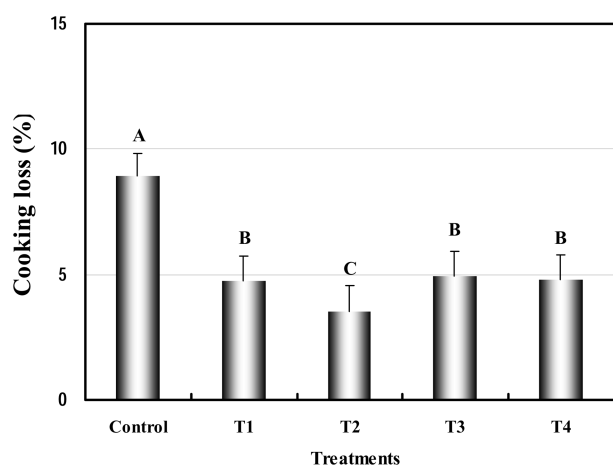[a-e]Means within a column with different letters are significantly different ($p<0.05$).
[1]Control, meat batter without *makgeolli* lees fiber: T1, meat batter with 1% *makgeolli* lees fiber; T2, meat batter with 2% *makgeolli* lees fiber; T3, meat batter with 3% *makgeolli* lees fiber; T4, meat batter with 4% *makgeolli* lees fiber.

but did not significantly differ between control and treatments. The ash content was higher in the emulsion systems formulated with *makgeolli* lees fiber than the control sample, because the ash content of *makgeolli* lees fiber was 0.60%. Also, the higher the *makgeolli* lees fiber levels in meat batter, the higher their ash contents. These results agree with those reported by Choi *et al*. (2010), in which the ash content significantly increased with the addition of rice bran fiber to meat systems. Choi *et al*. (2007) indicated that the addition of wheat fiber increased the ash contents of meat batters. Also, Fernández-Ginés *et al*. (2004) noted that bologna sausages containing dietary fiber with lemon albedo had higher ash content.

pH and color of chicken model system emulsions

Table 2 shows the pH, lightness (L*-value), redness (a*-value), and yellowness (b*-value) values of chicken meat emulsion systems formulated with various *makgeolli* lees fiber levels. The pH values of meat batters were higher in batters formulated with *makgeolli* lees fiber than in the control, and did not significantly differ among the treatments with *makgeolli* lees fiber ($p>0.05$). Jeong and Park (2006) reported that the addition of *makgeolli* powder decreased the pH value of loaf bread due to the effects of organic acids, saccharides, and lactic acid bacteria in *makgeolli* powder. Similar results were obtained by Saricoban *et al*. (2008) for meat emulsion systems with added lemon albedo fiber. Lee *et al*. (2008) reported that in the effects of kimchi powder on quality characteristics of breakfast sausages, their pH decreased with added kimchi powder levels. However, Choi *et al*. (2010) reported that the pH values of meat emulsion systems with added rice bran fiber increased because of the alkaline components of rice bran fiber. Chin and Ban (2008) indicated that in

evaluation of the effect of acorn powder as a fat replacer on the product quality of low-fat sausages, pH values did not significantly differ. Overall, the addition of fiber either increases, does not affect, or reduces pH values of meat products, depending on the type of fiber (Choi *et al*., 2010; Lee *et al*., 2008).

The differences in lightness, redness, and yellowness values of chicken meat emulsion systems with various *makgeolli* lees fiber levels were statistically significant ($p<0.05$) (Table 2). The lightness and redness values of chicken meat emulsion systems are lower in batter with added *makgeolli* lees fiber compared to control samples, and increasing the *makgeolli* lees fiber levels significantly decreased the lightness and redness values ($p<0.05$). However, the lowest yellowness value for chicken emulsion systems was for the control ($p<0.05$), and increasing the *makgeolli* lees fiber levels significantly increased the yellowness of meat emulsion systems ($p<0.05$). Similar results were reported by Choi *et al*. (2010) on meat emulsion systems with added rice bran fiber. Kim *et al*. (2010) also reported that instrumental color evaluations of meat batters with added sea tangle powder showed decreased lightness and redness values, and increased yellowness values. Sánchez-Zapata *et al*. (2010) reported that pork burgers formulated with tiger nut fiber had higher lightness and yellowness values, and decreased redness values, compared to control samples. According to Jeong and Park (2006), loaf bread with added *makgeolli* powder did not significantly affect the lightness, redness, and yellowness values. In general, the lightness, redness, and yellowness values of meat and meat products have been shown to be affected by the color of the added dietary fiber sources (Eim *et al*., 2008; Jiménez-Colmenero *et al*., 2003; Saricoban *et al*., 2008).

Cooking loss and emulsion stability of chicken model system emulsions

The emulsion stability of emulsion systems is an index that estimates the physical properties of a final meat product (Kim *et al*., 2010), and is also an indicator of unseparated water and fat retained by meat proteins (Saricoban *et al*., 2008). The cooking loss of chicken emulsion systems formulated with different levels of *makgeolli* lees fibers are shown in Fig. 1. Cooking loss is lower in meat batters formulated with *makgeolli* lees fiber than in the control without fibers, and the lowest had treatment with 2% *makgeolli* lees fiber samples ($p<0.05$). This was probably due to the dietary fibers in *makgeolli* lees, which have high water holding capacity and binding capacity (Hwang *et al*., 1998; Kim *et al*., 2010). Similar results were obtained by Choi *et al*. (20010) in meat batters with added rice bran fiber decreased cooking loss. Also, Turhan *et al*. (2005) showed that low-fat meat products with added hazelnut pellicle had decreased cooking loss. According to Fernández-Gínes *et al*. (2004), the cooking loss of bologna sausages with lemon albedo was improved. Many studies have also reported that the addition of carrageenan, oat fiber, inner pea fiber, tiger nut fiber, soy fiber, and other fibers decreased cooking loss in meat products (Anderson and Berry, 2000; Cofrades *et al*., 2000; Colmenero *et al*., 2005; Hughes *et al*., 1997; Steenblock *et al*., 2001; Sánchez-Zapata *et al*., 2010). Thus, cooking loss of meat and meat products with added dietary fiber impr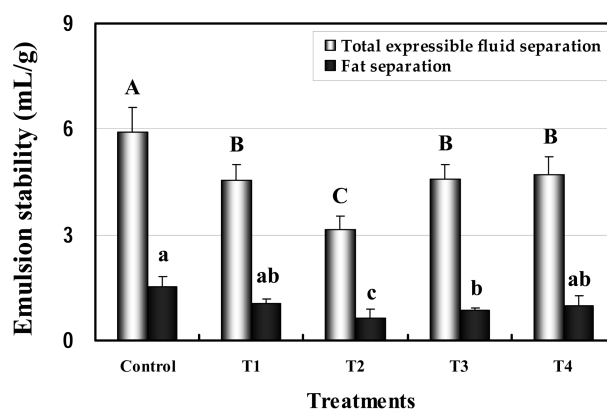oved, and dietary fiber provides higher water retention and improved emulsion stability, such and improves water and fat binding capacities (Hughes *et al*., 1998; Choi *et al*., 2009).

The addition of *makgeolli* lees fiber to meat emulsion batters had significant effects on emulsion stability (Fig. 2). The total expressible fluid separation was the highest in the control but the lowest in 2% *makgeolli* lees fiber treatment ($p<0.05$), while there was no significant difference among 1, 3, and 4% *makgeolli* lees fiber treatments ($p>0.05$). Fat separation was lowest in the treatment with added 2% *makgeolli* lees fiber. As a result, the addition of 2% *makgeolli* lees fiber to meat products provided the greatest emulsion stability among all of the treatments. According to Lee *et al*. (2008), the major contribution to water binding in breakfast sausage was its high dietary fiber content, thus leading to high water absorption. Wong and Cheung (2000) showed that dietary fiber from seaweeds improved the physicochemical properties of meat products by affecting the matrix structure of the meat emulsion systems.

Apparent viscosity of chicken model system emulsions

The various *makgeolli* lees fibers significantly affected the viscosity value of meat emulsion systems (Fig. 3). The control as well as all test treatments included samples with apparent viscosity values that decreased with an increase in rotation time. The addition of *makgeolli* lees fiber to meat emulsion systems resulted in a significantly

Fig. 1. **Effects of *makgeolli* lees fiber on cooking loss of chicken meat emulsion systems.** [A-C]Means in the treatments with different letters are significantly different ($p<0.05$). Control, meat batter without *makgeolli* lees fiber: T1, meat batter with 1% *makgeolli* lees fiber; T2, meat batter with 2% *makgeolli* lees fiber; T3, meat batter with 3% *makgeolli* lees fiber; T4, meat batter with 4% *makgeolli* lees fiber.

Fig. 2. **Emulsion stability of chicken meat emulsion systems with added *makgeolli* lees fiber.** [A-C]Means in the treatments with different letters are significantly different ($p<0.05$). [a-c]Means in the treatments with different letters are significantly different ($p<0.05$). Control, meat batter without *makgeolli* lees fiber: T1, meat batter with 1% *makgeolli* lees fiber; T2, meat batter with 2% *makgeolli* lees fiber; T3, meat batter with 3% *makgeolli* lees fiber; T4, meat batter with 4% *makgeolli* lees fiber.
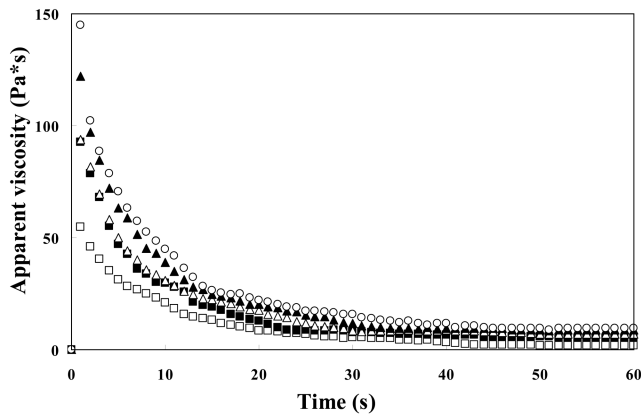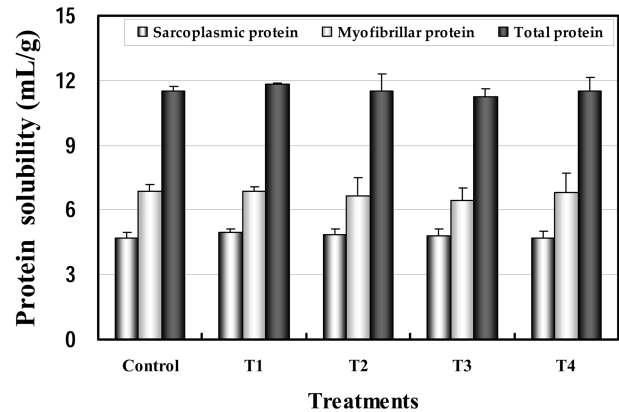
Fig. 3. Change in apparent viscosity of meat batters containing various *makgeolli* lees fiber levels stirred for 1 min. (□) Control, meat batter without *makgeolli* lees fiber; (■) T1, meat batter with 1% *makgeolli* lees fiber; (△) T2, meat batter with 2% *makgeolli* lees fiber; (▲) T3, meat batter with 3% *makgeolli* lees fiber; (○) T4, meat batter with 4% *makgeolli* lees fiber.

Fig. 4. Effect of protein solubility on chicken meat batters containing various *makgeolli* lees fiber levels. Control, meat batter without *makgeolli* lees fiber: T1, meat batter with 1% *makgeolli* lees fiber; T2, meat batter with 2% *makgeolli* lees fiber; T3, meat batter with 3% *makgeolli* lees fiber; T4, meat batter with 4% *makgeolli* lees fiber.

higher batter viscosity compared to the control, and increasing the *makgeolli* lees fiber levels significantly increased the apparent viscosity. According to Lee *et al*. (2008), elevating the viscosity of meat emulsion is mainly associated with the water binding capacity and dietary fiber content. Choi *et al*. (2010) indicated that rice bran fiber provides higher water retention and improved viscosity. Shand (2000) reported that an increase in emulsion viscosity is related to an increase in emulsion stability. Also, Zorba *et al*. (1993) and Zayas (1997) showed that emulsion systems had higher correlations between emulsion viscosity and emulsion stability. These results are in agreement with those of Aktas and Genccelep (2006), who found that frankfurters with added high-dietary fiber increased the viscosity of meat batter, and the report of Saricoban *et al*. (2008) that an increase in fat content while maintaining constant dietary fiber levels led to an increase in viscosity.

Protein solubility of chicken model system emulsions

Fig. 4 shows the protein solubility of sarcoplasmic, myofibrillar, and total proteins in chicken meat batters formulated with different levels of *makgeolli* lees fiber. No significant difference was observed in sarcoplasmic, myofibrillar, and total protein solubilities between the control and treatments with *makgeolli* lees fiber. According to Choi *et al*. (2010), protein solubility profiles are effective indicators of the degree of protein denaturation during processing, and these profiles are affected by

cooking time and temperature (Zayas, 1997). Also, Linden and Lorient (1999) and Sarma *et al*. (2000) reported that while myofibrillar proteins in meat emulsions have the most important role, the effect of sarcoplasmic proteins on emulsification is relatively low. Astiasaran *et al*. (1990) indicated that protein solubility of meat products will necessarily affect the textural qualities of sausages. Farouk *et al*. (2002) showed that the solubility of muscle proteins in the raw sausage batter and the gelation of the proteins during cooking can significantly affect sausage quality.

The results of this study indicate that the *makgeolli* lees (*jigaemi*) of meat batter formulations significantly affect physicochemical characteristics of meat batters. *Makgeolli* lees shows potential as a good source of dietary fiber that can be used as a functional ingredient in chicken meat emulsion systems. Added *makgeolli* lees fiber emulsion systems had positive effects on cooking loss, emulsion stability, and viscosity. The best results were shown in meat emulsion systems with addition of 2% *makgeolli* lees fiber.

Acknowledgements

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