Korean J. Food Sci. An.
Vol. 32, No. 5, pp. 618~626(2012)
DOI http://dx.do.org/10.5851/kosfa.2012.32.5.618

ARTICLE

Effects of Dietary Fiber Extracted from Citrus (*Citrus unshiu S.* Marcoy) Peel on Physicochemical Properties of a Chicken Emulsion in Model Systems

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Abstracts

Citrus (*Citrus unshiu S.* Marcoy) industry by-products were used as a source of dietary fiber, and the effects of dietary fiber extracted from citrus peel on the proximate composition, pH, color, protein solubility, cooking loss, emulsion stability, and apparent viscosity of a chicken emulsion in model systems were examined. Chicken emulsions were prepared by adding citrus peel fiber at four different concentrations (1, 2, 3, and 4%). The apparent viscosity, redness, and yellowness of the chicken emulsion with citrus peel fiber were higher than those of the control (p<0.05). The lightness values of the chicken emulsions were lower in treatments containing citrus peel fiber (p<0.05). Furthermore, moisture content, cooking loss, and emulsion stability of the chicken emulsion with 1-2% citrus peel fiber were higher than those of other treatments (p<0.05). Fat content was lower in the treatments with added citrus peel fiber than that in the control (p<0.05). Chicken emulsions with added citrus peel fiber had improved quality characteristics, and the best results were obtained for the chicken emulsion with 2% added citrus peel fiber.

Key words: citrus peel fiber, chicken emulsion, model systems, dietary fiber, emulsion stability

Introduction

Citrus fruit is a major product of Jeju island in Korea, and many varieties are cultivated. Thus, the citrus industry produces a significant quantity of peel as a by-product. If the peels are not processed, they become waste and a possible source of environmental pollution (Wang *et al*., 2008; Yang *et al*., 2008). Citrus peel is a good source of pectin and dietary fiber and has various bioactive components, including vitamins, minerals, flavonoids, coumarin, carotenoids, synephrine, terpenoids, and limonoids required for human health (Kang *et al*., 2006; Kim *et al*., 2011). Citrus peel also has high nutritive value and contributes to lower blood cholesterol, decrease cancer risk, protect against coronary heart disease, improve glucose tolerance and insulin response, and reduce hyperlipidemia and hypertension (Fernández-Ginés *et al*., 2004; Kurita *et al*., 2008; Viuda-Martos *et al*., 2010). Thus, recent approaches to develop products from citrus peel have placed an emphasis on the production of potentially important secondary metabolites such as recovering dietary fiber (Kim and Song, 2010; Kurita *et al*., 2008; Wang *et al*., 2008; Viuda-Martos *et al*., 2010).

Nutritionists recommend a dietary fiber intake of 35 g per person per day, but intake in many industrialized countries is currently estimated to be <25 g per person per day (Choi *et al*., 2010; Vidua-Martos *et al*., 2010). Therefore, increasing the amount of dietary fiber in the diet without changing eating habits is particularly difficult. In recent years, dietary fiber has been studied regarding its potential use for developing functional foods, including meat products, fish products, breakfast cereals, bakery products, and dairy products (Sánchez *et al*., 2007; Vergara-Valencia *et al*., 2007). Dietary fiber is regularly incorporated into foods for its nutritional, functional, and technological properties (Choi *et al*., 2010;

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Grigelmo-Miguel and Martin-Belloso, 1999). Dietary fiber generally improves the stability, water holding capacity, swelling capacity, cooking yield, and textural properties of emulsions due to its water and fat binding properties and its ability to improve viscosity (Choi *et al*., 2009; Choi *et al*., 2010; Lee *et al*., 2008; Sarýçoban *et al*., 2008; Shand, 2000; Wong and Cheung, 2000). Sarýçoban *et al*. (2008) reported that dietary fiber is not only desirable for their nutritional properties but also for functional and technological properties such as improving cooking yield, reducing formulation cost, and enhancing texture in food products. Furthermore, various types of dietary fiber have been used alone or combined with other ingredients to prepare meat-product formulations such as emulsion sausage, meat patties, restructured jerky, nuggets, and fermented sausage (Ajila *et al*., 2008; Choi *et al*., 2008; Eim *et al*., 2008; Turhan *et al*., 2005; Wong and Cheung, 2000; Yilmaz, 2004). Additionally, many studies have evaluated various sources of natural dietary fiber (Ajila *et al*., 2008; Choi *et al*., 2008; Eim *et al*., 2008; Turhan *et al*., 2005; Wong and Cheung, 2000; Yilmaz, 2004), but a limited number of studies have reported on dietary fiber from citrus peel added to chicken meat products.

Therefore, the aim of this study was to investigate the effects of adding different amounts of dietary fiber extracted from citrus peel on proximate composition, pH, color, protein solubility, cooking loss, emulsion stability, and apparent viscosity of a chicken emulsion in model systems.

Materials and Methods

Preparation and processing of the citrus peel dietary fiber extract

Organic citrus (*Citrus unshiu S.* Marcoy) peel was obtained from local grocery store (Seoul, Korea), and insecticides residuals were washed out three times with four volumes of water, and then the residue was washed three times with three volumes of heated water (Lee, 1999). The residue was dried (50°C) overnight in an air oven, cooled, and then washed with 99.9% ethanol (preheated to 60°C), followed by filtration. The residue was dried (50°C) overnight in an air oven and then cooled. The residue was ground using a blender (KA-2610, Jworld Tech, Korea) for 1 min and passed through a 35 mesh sieve (particle size, <0.5 mm). The citrus peel fiber (dietary fiber: 74.67±3.69%, moisture content: 6.48±0.71%, protein content: 3.60±0.36%, fat content: 2.79±0.12%, ash content: 2.39±0.10%) 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. The lightness, redness, and yellowness values of the citrus peel fiber were 71.95±3.14, 3.44±1.14, and 65.01±1.74, respectively, and the pH was 5.06±0.03.

Preparation and processing of the chicken emulsion in model system

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: 0.09±0.12%, ash content: 1.31 ±0.09%) and pork back fat (moisture content: 12.61%, fat content: 85.64%) were purchased from a local processor. The chicken breast meat and pork back fat were first ground through an 8-mm plate and then ground through a 3-mm plate. The ground tissue was placed in polyethylene bags, vacuum-packaged using a vacuum packaging system, and stored at 0°C until used for product manufacture (within 1 wk). Suitable amounts of muscle (12.5 kg) and fat (8 kg) were tempered at 4°C for 24 h prior to preparing the meat batter. Each batch of samples consisted of five different meat emulsion in model systems with different percentages of added dietary fiber extracted from citrus peel (0, 1, 2, 3, and 4%). Thus, five different chicken emulsions in model systems were formulated (Table 1) as follows: raw meat was homogenized and ground for 1 min in a silent cutter (Cutter Nr-963009, Germany). NaCl (1.5%) and sodium tripolyphosphate (0.2%) were added to the chicken breast meat, which had been previously dissolved in water and chilled (2°C), and then mixed for 1 min. Citrus peel fiber was added to the chicken meat

Table 1. Chicken meat emulsion formulations with various levels of citrus peel fiber (units: g/100 g)

Ingredients	Treatments[1)]				
	Control	T1	T2	T3	T4
Chicken breast meat	50	49	48	47	46
Back fat	30	30	30	30	30
Ice	20	20	20	20	20
Citrus peel fiber	-	1.0	2.0	3.0	4.0
Total	100	100	100	100	100
Salt	1.5	1.5	1.5	1.5	1.5
Sodium tripolyphosphate	0.15	0.15	0.15	0.15	0.15

[1)]Control, chicken meat emulsion system without citrus peel fiber; T1, chicken meat emulsion system with 1% citrus peel fiber; T2, chicken meat emulsion system with 2% citrus peel fiber; T3, chicken meat emulsion system with 3% citrus peel fiber; T4, chicken meat emulsion system with 4% citrus peel fiber

emulsions in model systems and they were homogenized for 6 min. A temperature probe (Kane-May, KM330, UK) was used to monitor temperature in the emulsions and was maintained <10°C during batter preparation. Five kg batches of each chicken emulsion in model systems were prepared in this manner. All analyses were carried out in triplicate for each formulation.

Proximate composition

The compositional properties of the chicken emulsions in model systems were determined using AOAC methods (2007). Moisture content was determined by weight loss after 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific, Korea). Fat content was determined by the Soxhlet method with a solvent extraction system (Soxtec Avanti 2050 Auto System, Foss Tecator AB, Sweden), and protein was determined by the Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec 2300 Analyzer Unit, Foss Tecator AB). Ash was determined according to AOAC method 923.03.

Dietary fiber measurements

Duplicate fat free dry was analyzed for total dietary fiber of citrus peel fiber using the method of Lee *et al.* (1992). This method includes enzymatic hydrolysis with α-amylase (heat-stable, A3306-10ML, Sigma, St. Louis, USA), protease (protease from *Aspergillus oryzae*, P6110-250ML, Sigma), and amyloglucosidase (amyloglucosidase from *Aspergillus niger*, solution, A9913-10ML, Sigma), using MES-TRIS buffer. Triplicates 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 á-amylase, a water bath for 35 min, and 100 μL of protease in a water bath at 60°C for 30 min. Subsequently, the pH was corrected to 4.0-4.7, and 300 μL amyloglucosidase was added to the mixture in the water bath at 60°C for 30 min. Finally, fiber was precipitated with 95% ethanol at 60°C. The sample was filtered into fritted glass crucibles using glass wool as the filtration agent. Crucibles containing the residue were dried in a 105°C dry oven, cooled in a dessicator, and weighed.

pH

The pH values of the chicken emulsions in model systems were measured in a homogenate prepared with 5 g of sample and distilled water (45 mL) using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). All determinations were performed in triplicate.

Color evaluation

The color of each chicken emulsion in model systems 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 from each of five replicates were taken. Lightness (CIE L^*-value), redness (CIE a^*-value), and yellowness (CIE b^*-value) values were recorded.

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 batter in 20 mL of ice-cold 25 mM potassium phosphate buffer (pH 7.2). The chicken emulsion samples and buffer were homogenized (Model AM-7, Nihonseiki Kaisha Ltd., Japan) on ice set at 1,500×*g* and were left to stand on a shaker at 4°C overnight. The mixtures were then 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 M potassium iodide in a 100 M phosphate buffer (pH 7.2). The procedures for homogenization, shaking, centrifugation, and protein deter-mination were the same as those described above. Myofibrillar protein solubility was obtained by determining the difference between the total and sarcoplasmic protein solubilities.

Cooking loss

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

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

Emulsion stability

The chicken emulsions in model systems were analyzed for emulsion stability using the method of Bloukas and Honikel (1992) with the following modifications. Pre-weighed graduated glass tubes 15 mL-0.2 mL graduated units (Pyrex Chojalab Co., Korea) were filled with batter in the middle of a 15 mesh sieve. The glass tubes were covered and heated for 30 min in a boiling water bath to a core temperature of 75±1°C. After cooling to 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*., 2009).

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

Chicken emulsion in model systems viscosity was measured in triplicate with a rotational viscometer (HAKKE Viscotester 550, Thermo Electron Corporation, Germany) set at 10 rpm. A 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 for 30 s before each reading was taken. Apparent viscosity values were obtained in centipoises. The temperature of each sample at the time (18±1°C) of viscosity testing was also recorded (Shand, 2000).

Statistical analysis

All tests were conducted at least three times for each experimental condition, and mean values are reported. An analysis of variance was performed on all variables using the general linear model procedure of the SAS statistical package (2008). Duncan's multiple range test ($p<0.05$) was used to determine differences among treatments.

Results and Discussion

Proximate composition of the chicken emulsions in model systems

The proximate compositions of the chicken emulsions in model systems formulated with different levels of citrus peel fiber are presented in Table 2. Moisture content was affected by the citrus peel fiber concentration. Among the control and all citrus peel fiber treatments, the 1 and 2% citrus peel fiber treatments had higher moisture concentration ($p<0.05$). This increase in moisture content could have been due to water released from the meat matrix that was retained by the citrus peel fiber during the emulsion process (Lee *et al*., 2008). These results agree with those reported by Fernández-Ginés *et al*. (2004), in which moisture content increased significantly with the addition of dietary fiber to meat products from lemon albedo, due to the pectin in the lemon albedo, which may constitute up to 25% of lemon albedo. Protein content was lower in treatments with 3 and 4% added citrus peel fiber than that in the control and treatments with 1 and 2% added citrus peel fiber samples ($p<0.05$), because these meat batters were formulated initially with more citrus peel fiber and less chicken breast (Table 1). Fat content was lower in the treatments with added citrus peel fiber than that in the control samples ($p<0.05$). Fat content may have been affected by the added citrus peel fiber, whose moisture content increased. These results agree with those reported by Choi *et al*. (2012), in which fat content showed similar results to reduced-fat patties with added dietary fiber from *Laminaria japonica*. Ash content increased when citrus peel fiber was added depending on the citrus peel fiber concentration ($p<0.05$), as the ash content of citrus peel fiber was 2.39%. Similar results were reported by Choi *et al*. (2010) for meat emulsion systems with added rice bran fiber. These results indicate that ash content significantly increased with the addition of rice bran fiber to the meat systems.

pH and color of the chicken emulsions in model systems

The pH, lightness (CIE L^*-value), redness (CIE a^*-value), and yellowness (CIE b^*-value) values of the raw and cooked chicken emulsions in model systems are pre-

Table 2. Proximate composition (%) of chicken emulsion formulated with various levels of citrus peel fiber

Treatments[1)]	Moisture	Protein	Fat	Ash
Control	59.63±0.98^{B}	12.67±0.18^{A}	23.92±0.48^{A}	2.06±0.04^{B}
T1	61.03±0.80^{A}	12.38±0.15^{A}	21.34±1.48^{B}	2.07±0.04^{B}
T2	61.96±0.34^{A}	12.40±0.16^{A}	22.27±0.75^{AB}	2.10±0.12^{AB}
T3	60.12±0.43^{AB}	11.96±0.21^{B}	22.31±0.16^{AB}	2.20±0.07^{A}
T4	59.39±0.35^{B}	11.57±0.25^{B}	22.43±0.18^{AB}	2.23±0.04^{A}

All values are mean±SD of three replicates.

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

[1)]Control, chicken meat emulsion system without citrus peel fiber; T1, chicken meat emulsion system with 1% citrus peel fiber; T2, chicken meat emulsion system with 2% citrus peel fiber; T3, chicken meat emulsion system with 3% citrus peel fiber; T4, chicken meat emulsion system with 4% citrus peel fiber

sented in Table 3. Increasing citrus peel fiber levels significantly decreased pH (p<0.05), which may have occurred because the pH of the citrus peel fiber was 5.06. Kim and Song (2010) reported that adding citrus powder decreases the pH of food due to the effects of organic acids such as citric acid, tartaric acid, and ascorbic acid. Lee *et al*. (2008) reported that the pH of emulsion-type sausage with added citron peel powder decreased with a decrease in added citron peel powder, because the citron peel power contained an acidic ingredient. However, Fernández-Ginés *et al*. (2004) indicated that the pH of bologna sausages did not differ between control and treatments containing lemon albedo. Generally, the pH of meat products with added dietary fiber is affected depending on the acidity and alkalinity of the natural source of dietary fiber.

The differences in lightness, redness, and yellowness values of chicken emulsions in model systems with added citrus peel fiber were statistically significant compared to those in the control (Table 3). The lightness values of the chicken emulsions were lower in treatments containing citrus peel fiber compared to those of the control (p<0.05). Increasing the proportion of citrus peel fiber significantly decreased the lightness values (p<0.05), due to the added citrus peel fiber. The chicken emulsions in model systems containing increasing citrus peel fiber concentrations resulted in increased redness and yellowness (p<0.05). Similar trends in lightness were observed in a study by Fernández-Ginés *et al*. (2004), when dietary fiber from lemon albedo was added to bologna sausage. Kim and Song (2010) showed that adding citrus mandarin powder to *gamgyul-unjeulmi* resulted in a lower lightness value than that of the control. These results indicate that the redness and yellowness of food increase with increasing added citrus powder content due to the effect of the citrus powder color. These results agree with those reported by Calvo *et al*. (2008) who noted that adding tomato peel to fermented sausage increases redness due to lycopene and carotenoid oxidation. Lee *et al*. (2008) reported that the yellowness of emulsion sausage increases significantly with increasing citron peel fiber content, because citron peel fiber increases yellowness. Generally, color changes in meat products occur by adding different sources of natural dietary fiber from various sources (Choi *et al*., 2009; Eim *et al*., 2010; Fernández-Ginés *et al*., 2004; Jiménez-Colmenero *et al*., 2003; Lee *et al*., 2008; Yang *et al*., 2007).

Protein solubility of the chicken emulsions in model systems

The protein solubility of sarcoplasmic, myofibrillar, and total proteins in the chicken emulsions in model systems formulated with different levels of citrus peel fiber are shown in Fig. 1. The sarcoplasmic, myofibrillar, and total protein solubilities were not significantly different between the control and the citrus peel fiber treatments. These results are in agreement with those of Choi *et al*. (2010), who found that meat batter with added dietary fiber does not result in significantly different protein solubilities between the control and treatments with added dietary fiber. In general, protein solubility of fresh meat is mainly affected by post-mortem glycolysis and water holding capacity of meat, but salt and phosphate levels in the sample are the major factor influencing protein solubility in meat products. Choi *et al*. (2010) reported that protein solubility profiles are an effective indicator of the degree of protein denaturation during meat processing, particularly that the protein solubility of meat products may affect their textural qualities (Astiasaran *et al*., 1990). Furthermore, the sarcoplasmic and myofibrillar protein solubilities in different quality meat products are produced under carefully controlled conditions (Sayre and Briskey, 1963). High total protein and sarcoplasmic protein solubilities are important for high quality processed

Table 3. Effect of various levels of citrus peel fiber on pH and color (CIE L^*-, a^*-, and b^*-values) in chicken emulsions

Treatments[1)]	pH	CIE L^*-value	CIE a^*-value	CIE b^*-value
Control	6.58±0.02^A	84.57±0.99^A	2.69±0.17^A	11.03±0.40^E
T1	6.45±0.03^B	83.85±1.69^{AB}	0.31±0.18^E	27.10±1.14^D
T2	6.34±0.02^C	82.95±1.57^B	0.47±0.14^D	34.73±0.78^C
T3	6.22±0.08^D	81.22±1.50^B	0.66±0.48^C	39.70±1.36^B
T4	6.10±0.04^E	79.29±2.97^C	0.85±0.28^B	43.35±1.08^A

All values are mean±SD of three replicates.

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

[1)]Control, chicken meat emulsion system without citrus peel fiber; T1, chicken meat emulsion system with 1% citrus peel fiber; T2, chicken meat emulsion system with 2% citrus peel fiber; T3, chicken meat emulsion system with 3% citrus peel fiber; T4, chicken meat emulsion system with 4% citrus peel fiber

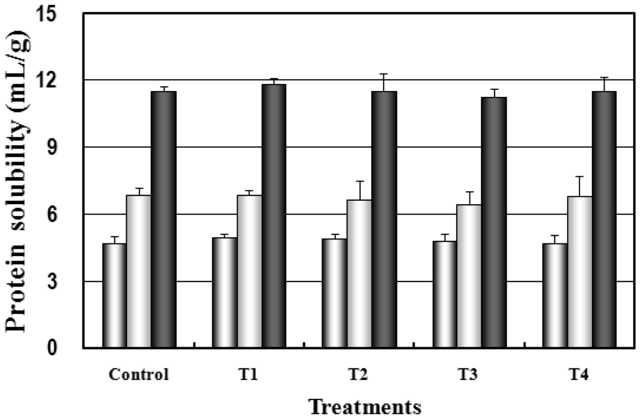

Fig. 1. Effect of protein solubility on chicken emulsion systems containing various citrus peel fiber levels. Control, chicken meat emulsion system without citrus peel fiber; T1, chicken meat emulsion system with 1% citrus peel fiber; T2, chicken meat emulsion system with 2% citrus peel fiber; T3, chicken meat emulsion system with 3% citrus peel fiber; T4, chicken meat emulsion system with 4% citrus peel fiber, ▯, sarcoplasmic protein; ▯, myofibrillar protein; ■, total protein. Data were no significant difference among samples means ($p>0.05$). Results are means of at least three experiments.

meat products, because they are an excellent indicator of the functional properties of meat (Young *et al*., 2005).

Cooking loss and emulsion stability of the chicken emulsions in model systems

Table 4 shows the cooking loss from the chicken emulsions in model systems formulated with various levels of citrus peel fiber. The cooking loss from the chicken emulsions in model systems with 2% added citrus peel fiber was the lowest at 5.04%. These results are in agreement with a study indicating that cooking loss of patties is affected by the amount of added dietary fiber (Choi *et al*., 2012). Choi *et al*. (2009) noted that cooking loss decreased significantly with the addition of 1-3% rice bran fiber to meat emulsion systems, but a 4% rice bran fiber treatment did not significantly differ compared to that of the control. For this reason, added too much dietary fiber undermines the water holding capacity and water binding capacity in meat products. Additionally, Lee *et al*. (2008) noted that the reduction in cooking loss with increasing levels of dietary fiber is attributed to reduced cooking loss of the sausage. Sánchez-Zapata *et al*. (2010) showed that meat products with added tiger nut fiber have less cooking loss than that of the control. In fact, this was attributed to high moisture and fat cooking loss. Thus, several researchers have reported that dietary fiber decreases cooking loss by improving moisture and fat binding capacities (Choi *et al*., 2012; Lee *et al*., 2008; Sánchez-Zapata *et al*., 2010). These findings indicate that adding citrus peel fiber results in desirable changes in the cooking characteristics of chicken emulsions in model systems and suggests that meat emulsion in model systems viscosity was possibly improved.

Table 4. Effect of various levels of citrus peel fiber on cooking loss and emulsion stability in chicken emulsions

Treatments[1)]	Cooking loss (%)	Emulsion stability	
		Total expressible fluid separation (mL/g)	Fat separation (mL/g)
Control	8.52±0.24[A]	6.47±0.53[A]	1.46±0.32[A]
T1	6.13±0.18[C]	2.41±0.45[D]	0.97±0.32[C]
T2	5.04±0.51[D]	2.94±0.39[D]	0.99±0.41[C]
T3	6.49±0.82[BC]	3.95±0.41[C]	1.11±0.23[B]
T4	8.17±0.90[AB]	5.33±0.80[B]	1.18±0.24[B]

All values are mean±SD of three replicates

[A-F]Means within a column with different letters are significantly different ($p<0.05$).

[1)]Control, chicken meat emulsion system without citrus peel fiber; T1, chicken meat emulsion system with 1% citrus peel fiber; T2, chicken meat emulsion system with 2% citrus peel fiber; T3, chicken meat emulsion system with 3% citrus peel fiber; T4, chicken meat emulsion system with 4% citrus peel fiber

The chicken meat emulsion in model systems formulated with citrus peel fiber had significant differences in emulsion stability (Table 4). Total expressible fluid separation was lower in the chicken emulsion in model systems with added citrus peel fiber than that of the control ($p<0.05$). Total expressible fluid was the lowest in the treatment containing 1% citrus peel fiber ($p<0.05$). All treatments with added citrus peel fiber had significantly lower fat separation than that of the control ($p<0.05$). According to Choi *et al*. (2010), meat emulsion batter with excess added dietary fiber impairs emulsion stability. These results indicate that meat batters with too much dietary fiber have weakened water and fat binding capacities. As a result, adding 1% citrus peel fiber to the chicken emulsion in model systems provided the greatest emulsion stability among all meat product treatments, which may have been due to the dietary fiber from citrus peel, which has high water holding and binding capacities (Choi *et al*., 2009; Choi *et al*., 2010; Lee *et al*., 2008). Similar results were observed by Wong and Cheung (2000), who reported that dietary fiber improves the quality characteristics of meat products by affecting the matrix structure of meat emulsion systems. These results showed that dietary fiber is a major contributor to water and fat binding in meat emulsion systems. The emulsion stability of meat emulsions is an index that roughly calculates the quality characteristics of the final meat product (Choi *et al*., 2009), and emulsion stability is an indicator of unseparated water and fat retained by meat emulsions (Sarıçoban *et al*., 2008). Thus, some researchers have suggested that the formation of a strong emulsion complex in a stable meat emulsion with no fluid loss is observed because the meat emulsions with dietary fiber had improved emulsion stability and rheological properties (Choi *et al*., 2010; Kim *et al*., 2010; Youssef and Barbut, 2009).

Apparent viscosity of the chicken emulsions in model systems

Fig. 2 shows the apparent viscosity values of the chicken emulsions in model systems formulated with various levels of citrus peel fiber. The treatments with added citrus peel fiber significantly affected the viscosity of the chicken emulsions in model systems. The control and all treatments with added citrus peel fiber revealed decreased apparent viscosity values with an increase in rotation time. The apparent viscosity values were higher in the chicken emulsions in model systems formulated with citrus peel fiber than those in the control, and the highest values were obtained in the 4% added citrus peel fiber samples ($p<0.05$). Similar results were observed by Choi *et al*. (2009) in meat emulsions systems with added rice bran fiber, and by Aktas and Genccelep (2006) in frankfurters with added high-dietary fiber. According to Sarıçoban *et al*. (2008), various levels of dietary fiber from lemon albedo significantly affect the apparent viscosity of meat emulsion batters. They reported that the high apparent viscosity in meat emulsion systems is not easily broken. Some researchers have indicated that an increase in emulsion viscosity is related with an increase in emulsion stability due to the water binding capacity of a meat emulsion (Choi *et al*., 2009; Kim *et al*., 2010; Lee *et al*., 2008). Additionally, increasing apparent viscosity generally reduces cooking loss and emulsion stability. Thus, meat products with added dietary fiber have improved viscosity, which helps improve physicochemical properties such as cooking loss and emulsion stability.

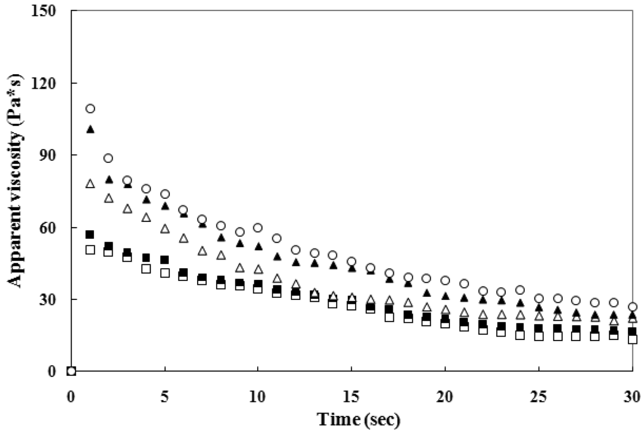

Fig. 2. Change in apparent viscosity of chicken meat emulsion systems containing various amounts of citrus peel fiber stirred for 30 sec. Control (□), chicken meat emulsion system without citrus peel fiber; T1 (■), chicken meat emulsion system with 1% citrus peel fiber; T2 (△), chicken meat emulsion system with 2% citrus peel fiber; T3 (▲), chicken meat emulsion system with 3% citrus peel fiber; T4 (○), chicken meat emulsion system with 4% citrus peel fiber. Results are means of at least three experiments.

Conclusion

The results of this study indicate that citrus peel fiber significantly affected the physicochemical characteristics of chicken emulsions in model systems. Thus, citrus peel fiber could be an excellent source of dietary fiber that can be used as a functional ingredient in chicken emulsions in model systems. The added dietary fiber extracted from citrus peel positively affected cooking loss, emulsion stability, and apparent viscosity. The best results were obtained with chicken emulsions in model systems containing 2% dietary fiber extracted from citrus peel.

Acknowledgements

This research was supported (608001-05-2-SB310) by the Rural Development Administration (Republic of Korea). The authors were also partially supported by the Brain Korean 21 (BK 21) Project from Ministry of Education and Human Resources Development (Republic of Korea).

References

1. Ajila, C. M., Leelavathi, K., and Prasada Rao, U. J. S. (2008) Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *J. Cereal Sci*. **48**, 319-326.
2. Aktas, N. and Genccelep, H. (2006) Effect of starch type and its modifications on physicochemical properties of bologna-type sausage produced with sheep tail fat. *Meat Sci*. **74**, 404-408.
3. AOAC (2007) Official methods of analysis. AOAC International. 18th ed. 950.46, 920.153, 928.08, 960.39. Association of Official Analytical Chemists, Washington, DC.
4. Astiasaran, I., Villanueva, R., and Bello, J. (1990) Analysis of proteolysis and protein insolubility during the manufacture of some varieties of dry sausage. *Meat Sci*. **28**, 111-117.
5. Bloukas, I. and Honikel, K. O. (1992) The influence of addi-

tives on the oxidation of pork back fat and its effect on water and fat binding in finely comminuted batters. *Meat Sci*. **32**, 31-43.
6. Calvo, M. M., Garcia, M. L., and Selgas, M. D. (2008) Dry fermented sausages enriched with lycopene from tomato peel. *Meat Sci*. **80**, 167-172.
7. 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 physico-chemical and sensory characteristics of reduced-fat pork patties. *Meat Sci*. **91**, 1-7.
8. 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.
9. Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., and Kim, C. J. (2009) Characteristics of low-fat meat emulsion systems with pork fat replaced by vegetable oils and rice bran fiber. *Meat Sci*. **82**, 266-271.
10. Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Kim, H. W., Lee, J. W., Chung, H. J., and Kim, C. J. (2010) Optimization of replacing pork back fat with grape seed oil and rice bran fiber for reduced-fat meat emulsion systems. *Meat Sci*. **84**, 212-218.
11. Choi, Y. S., Choi, J. H., Han, D. J., Kim, H. Y., Lee, M. A., Lee, E. S., Jeong, J. Y., Paik, H. D., and Kim, C. J. (2008) Effects of rice bran fiber on quality of low-fat *Tteokgalbi*. *Food Sci. Biotechnol*. **17**, 959-964.
12. Eim, V. S., Simal, S., Rosselló, C., and Femenia, A. (2008) Effects of addition of carrot dietary fibre on the ripening process of a dry fermented sausage (*sobrassada*). *Meat Sci*. **80**, 173-182.
13. Fernández-Ginés, J. M., Fernandez-López, J., Sayas-Barberá, E., Sendra, E., and Pérez-Álvarez, J. A. (2004) Lemon albedo as a new source of dietary fiber: Application to bologna sausages. *Meat Sci*. **67**, 7-13.
14. 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.
15. Grigelmo-Miguel, N. and Martin-Belloso, O. (1999) Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. *LWT-Food Sci. Technol*. **32**, 503-508.
16. Jiménez-Colmenero, F., Serrano, A., Ayo, J., Solas, M. T., Cofrades, S., and Carballo, J. (2003) Physicochemical and sensory characteristics of restructured beef steak with added walnuts. *Meat Sci*. **65**, 1391-1397.
17. Joo, S. T., Kauffman, R. G., Kim, B. C., and Park, G. B. (1999) The relationship of sarcoplasmic and myofibrillar protein solubility to colour and water-holding capacity in porcine longissimus muscle. *Meat Sci*. **52**, 291-297.
18. Kang, H. J., Chawla, S. P., Jo, C., Kwon, J. H., and Byun, N. W. (2006) Studies on the development of functional powder from citrus peel. *Biores. Technol*. **97**, 614-620.
19. Kim, C. W. and Song, E. (2010) Qualtiy characteristics of *Gamgyul-Injeulmi* with citrus mandarin powder during storage. *Korean J. Food Nutr*. **23**, 247-257.
20. Kim, H. Y., Lee, E. S., Jeong, J. Y., Choi, J. H., Choi, Y. S., Han, D. J., Lee, M. A., Kim, S. Y., and Kim, C. J. (2010) Effect of bamboo salt on the physicochemical properties of meat emulsion systems. *Meat Sci*. **86**, 960-965.
21. Kim, N. Y., Yu, A. R., Min, J. Y., and Han, M. J. (2011) Fermentation characteristics of *Ginpi* wine with different levels of added *Ginpi*. *Korean J. Food Culture* **26**, 178-183.
22. Kurita, S., Fujiwara, T., and Yamazaki, E. (2008) Characterization of the pectin extracted from citrus peel in the presence of citric acid. *Carbohydr. Polymers* 74, 725-730.
23. Lee, M. A., Han, D. J., Jeong, J. Y., Choi, J. H., Choi, Y. S., Kim, H. Y., Paik, H. D., and Kim, C. J. (2008) Effect of *kimchi* powder level and drying methods on quality characteristics of breakfast sausage. *Meat Sci*. **80**, 708-714.
24. Lee, M. G. (1999) Computation of residue limit of organophosphorus pesticides in functional foods from citrus fruit peels. *Korean J. Environ. Agric*. **18**, 349-354.
25. Lee, S. C., Prosky, L., and Devries, J. W. (1992) Determination of total, soluble, and insoluble dietary fiber in foods. Enzymatic-gravimetric method, MES-TRIS buffer: collaborative study. *J. Assoc. Off. Anal. Chem. Int*. **75**, 395-416.
26. Sánchez-Zapata, E., Muñoz, C. M., Fuentes, E., Fernández-López, J., Sendra, E., Sayas, E., Navarro, C., and Pérez-Alvarez, J. A. (2010) Effect of tiger nut fibre on quality characteristics of pork burger. *Meat Sci*. **85**, 70-76.
27. Sarıçoban, C., Özalp, B., Yilmaz, M. T., Özen, G., Karakaya, M., and Akbulut, M. (2008) Characteristics of meat emulsion systems as influenced by different levels of lemon albedo. *Meat Sci*. **80**, 599-606.
28. SAS (2008) SAS/STAT Software for PC. Release 9.2, SAS Institute Inc., Cary, NC, USA.
29. Sayre, R. N. and Briskey, E. J. (1963) Protein solubility as influenced by physiological conditions in the muscle. *J. Food Sci*. **28**, 675-679.
30. Shand, P. J. (2000) Textural, water holding, and sensory properties of low-fat pork bologna with normail and waxy starch hull-less barley. *J. Food Sci*. **65**, 101-107.
31. Turhan, S., Sagir, I., and Ustun, N. S. (2005) Utilization of hazelnut pellicle in low-fat beef burgers. *Meat Sci*. **71**, 312-316.
32. Vergara-Valencia, N., Granados-Pérez, E., Agama-Acevedo, E., Tovar, J., Ruales, J., and Bello-Pérez, L. A. (2007) Fibre concentrate from mango fruit: characterization, associated antioxidant capacity and application as a bakery product ingredient. *LWT-Food Sci. Technol*. **40**, 722-729.
33. Viuda-Martos, M., Ruiz-Navajas, Y., Fernandez-Lopez, J., and Perez-Alvarez, J. A. (2010) Effect of adding citrus fibre washing water and rosemary essential oil on the quality characteristics of a bologna sausage. *LWT-Food Sci. Technol*. **43**, 958-963.
34. Wang, Y. C., Chuang, Y. C., and Hsu, H. W. (2008) The flavonoid, carotenoid and pectin content in peels of citrus cultivated in Taiwan. *Food Chem*. **106**, 277-284.
35. Wong, K. H. and Cheung, P. C. K. (2000) Nutritional evaluation of some subtropical red and green seaweeds. Proximate composition, amino acid profiles and some physic-chemical

properties. *Food Chem*. **71**, 475-482.

36. Yang, H. S., Choi, S. G., Jeon, J. T., Park, G. B., and Joo, S. T. (2007) Textural and sensory properties of low fat pork sausages with added hydrated oatmeal and tofu as texture-modifying agent. *Meat Sci*. **75**, 283-289.
37. Yang, Y. T., Kim, M. S., Hyun, K. H., Kim, Y. C., and Koh, J. S. (2008) Chemical constituents and flavonoids in citrus pressed cake. *Korean J. Food Preserv*. **15**, 94-98.
38. Yilmaz, I. (2004) Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. *Meat Sci*. **67**, 245-249.
39. Young, O. A., Zhang, S. X., Farouk, M. M., and Podmore, C. (2005) Effect of pH adjustment with phosphates on attributes and functionalities of normal and high pH beef. *Meat Sci*. **70**, 133-139.
40. Youssef, M. K. and Barbut, S. (2009) Effects of protein level ad fat/oil on emulsion stability, texture, microstructure and color of meat batters. *Meat Sci*. **82**, 228-233.

(Received 2012.6.22/Revised 2012.9.17/Accepted 2012.10.11)