

Effects of Dietary Fiber Extracted from Pumpkin (*Cucurbita maxima* Duch.) on the Physico-Chemical and Sensory Characteristics of Reduced-Fat Frankfurters

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Abstract

In this study, we investigated the effects of reducing fat levels from 30% to 25, 20, and 15% by substituting pork fat with water and pumpkin fiber (2%) on the quality of frankfurters compared with control. Decreasing the fat concentration from 30% to 15% significantly increased moisture content, redness of meat batter and frankfurter, cooking loss, and water exudation, and decreased fat content, energy value, pH, and lightness of meat batter and frankfurter, hardness, cohesiveness, gumminess, chewiness, and apparent viscosity. The addition of 2% pumpkin fiber was significantly increased moisture content, yellowness of meat batter and frankfurter, hardness, cohesiveness, gumminess, chewiness, and apparent viscosity, whereas reduced cooking loss and emulsion stability. The treatment of reduced-fat frankfurters formulated with 20 and 25% fat levels and with pumpkin fiber had sensory properties similar to the high-fat control frankfurters. The results demonstrate that when the reduced-fat frankfurter with 2% added pumpkin fiber and water replaces fat levels can be readily made with high quality and acceptable sensory properties.

Keywords: reduced-fat, pumpkin fiber, frankfurters, quality characteristics, sensory properties

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Introduction

Fat content is important to quality characteristics of meat products such as flavor, juiciness, and texture (Jiménez-Colmenero *et al.*, 2010). In addition, the fat content affected meat products by cooking loss, emulsion stability, water holding capacity, and apparent viscosity (Choi *et al.*, 2010), and therefore meat products added fat content have considerable effects on the binding, rheological, and structural properties of emulsion meat products (Choi *et al.*, 2015; Hughes *et al.*, 1997). However, the high fat contents provide high amounts of saturated fatty acids and serum cholesterol (Choi *et al.*, 2008). High animal fat foods are related with various chronic diseases, such as obesity, hypertension, cardiovascular diseases, and coronary heart diseases (Choi *et al.*, 2009). Many consu-

mers have been demanding reduced-fat meat products to improve their health (Choi *et al.*, 2013). As a result, the reduction of the fat content in frankfurters should result in low-fat or reduced-fat meat products. Nevertheless, low-fat and reduced-fat meat products tend to have lower overall quality.

Dietary fiber has been added to different meat products to counter the problems caused by fat reduction (Choi *et al.*, 2008). In general, dietary fiber is a functional material and plays a powerful role in the human diet, and has been ascribed a consistently increasing role in health and well-being (Choi *et al.*, 2009). Furthermore, the sources of added dietary fiber for meat products can improve the physico-chemical properties of meat products, such as cooking loss, water holding capacity, emulsion stability, and viscosity (Choi *et al.*, 2010). Turhan *et al.* (2005) have reported that meat products with added dietary fiber help to improve textural properties and sensory characteristics. Choi *et al.* (2009) observed that the addition of dietary fiber to low-fat or reduced-fat meat products enhances rheological properties and emulsion stability. Thus, the

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addition of dietary fiber to frankfurters as a replacement for animal fat may have a positive effect on consumer health. Dietary fibers are extracted from fruits, cereals, and vegetables. Pumpkin, in particular among vegetable sources of dietary fiber, contains many valuable substances such as protein, starch, vitamins (A, B₁, B₂, and C), minerals (Fe, Ca, Na, K, Mg, and P), and β -carotene required for human health (Choi *et al.*, 2012a; Lee *et al.*, 2010). Pumpkin belongs to the family Cucurbitaceae, which has experienced increased interest in recent years because of its nutritional and health protective effects. Woo *et al.* (2006) studied the quality properties of sponge cake with the addition of dried sweet pumpkin powder. The results of these studies found that the physicochemical properties and sensory characteristics were optimization of sponge cake with 6% pumpkin powder added. Some researchers obtained that bread and cookies with added sweet pumpkin powder (Lee and Joo, 2007). However, no studies have addressed the use of dietary fiber extracted from pumpkin in reduced-fat or low-fat meat products. In addition, the application of dietary fiber sources extracted from pumpkin is limited, because pumpkin has considerable quantities of digested carbohydrate such as starch resulting in the development of retrogradation. For this reason, starch should be removed from pumpkin fiber commercial use, due to research on meat products with the use of pumpkin fiber is limited.

The objective of this work was to evaluate the effects of substituting animal fat with dietary fiber extracted from pumpkin on the physico-chemical and sensory characteristics of reduced-fat frankfurters.

Materials and Methods

Preparation and processing of the pumpkin fiber extract

Dietary fiber was extracted using the modified AOAC enzymatic-gravimetric method (AOAC, 2007). Pumpkin (*Cucurbita maxima Duch.*) was obtained from E-mart, Seoul, Korea. The pumpkin was gelatinized with 0.6% termamyl (heat stable alpha-amylase) at 95°C for 1 h to remove starch, followed by filtration. Then, the residue was washed 3 times with 4 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. Then, the pumpkin fiber (moisture content, 7.82%; fat content, 4.83%; protein content, 12.28%; ash content, 6.67%;

dietary fiber content, 58.34%; *L**-value, 78.81; *a**-value, 1.30; *b**-value, 62.69; pH, 6.74) was placed in polyethylene bags, and vacuum packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea) and stored at 4°C until used for product preparation (Choi *et al.*, 2012b).

Frankfurter preparation and processing

Fresh chicken breast meat (broiler, *Muscularis pectoralis major*, 2 wk of age, approximately 1.5-2.0 kg live weight, moisture 74.95%, protein 22.58%, fat 1.09%, ash 1.31%) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor. The reason for using chicken breast meat was due to its relatively low cost of production, low fat content, and high nutritional value. In addition, chicken meats are very popular among consumers and provide an excellent source of animal protein. The chicken meat and pork fat were ground initially through an 8 mm plate, and then secondly ground through a 3 mm plate. The ground tissue was then placed in polyethylene bags, vacuum sealed using a vacuum packaging system (FJ-500XL, Fujee Tech), and stored at 0°C until required for product preparation. Seven different batters (10 kg batches of each meat batters) were produced, and the experimental design and compositions are shown in Table 1. The first meat batter served as the control and was prepared with 30% pork back fat and 20% ice without pumpkin fiber. The following combinations of pork back fat, ice, and pumpkin fiber were used; T1: 25% pork back fat and 25% ice; T2: 25% pork back fat, 23% ice, and 2% pumpkin fiber; T3: 20% pork back fat and 30% ice; T4: 20% pork back fat, 28% ice, and 2% pumpkin fiber; T5: 15% pork back fat and 35% ice; T6: 15% pork back fat, 33% ice, and 2% pumpkin fiber. The pumpkin fiber concentration was as optimized by Choi *et al.* (2012b). Meat was homogenized, ground for 1 min in a silent cutter (Cutter Nr-963009, Hermann Scharfen GmbH & Co, Germany), then chilled in ice water (2°C). NaCl (1.5%) and sodium tripolyphosphate (0.5%) were added to the meat and mixed for 20 s isolated soy protein (1.4%), and pumpkin fiber (2%) were added after 40 sec. Sorbitol (0.7%), black pepper (0.3%), monosodium glutamate (0.01%), onion powder (0.07%), and garlic powder (0.08%) were added after 1 min, and pork back fat was added after 3 min. The batters were homogenized for 5 min. A temperature probe (Kane-May, KM330, UK) was used to monitor the temperature of the emulsion, which was maintained below 10°C throughout batter preparation. After emulsification, the batter was stuffed into 30 mm diameter collagen casings (#240, NIPPI Inc., Japan) and hand-linked at

Table 1. Reduced-fat frankfurter formulation with different fat levels with and without pumpkin fiber

Ingredients	Control	T1	T2	T3	T4	T5	T6
Chicken breast	50	50	50	50	50	50	50
Pork back fat	30	25	25	20	20	15	15
Ice	20	25	23	30	28	35	33
Pumpkin fiber	-	-	2	-	2	-	2
Total	100	100	100	100	100	100	100
NaCl	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sodium tripolyphosphate	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Isolated soy protein	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sorbitol	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black pepper	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Monosodium glutamate	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Onion powder	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Garlic powder	0.08	0.08	0.08	0.08	0.08	0.08	0.08

approximately 30 cm length using a stuffer (Stuffer IS-8, Sirman, Italy). The batters were heat processed in a water bath (model 10-101, Dae Han Co., Korea) until the core temperature reached at 75°C (30 min); then, the cooked batter was cooled in cold water (15°C). This procedure was performed in triplicate for each level of reduced-fat frankfurter, and all analyses were carried out at least in triplicate for each formulation.

Proximate composition

Composition properties of the reduced-fat frankfurters were determined using AOAC (2007) methods. Moisture content (950.46B) was calculated by weight loss after 12 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Korea). Fat content (960.69) was determined by the Soxhlet method with a solvent extraction system (Soxtec Avanti 2050 Auto System, Foss Tecator AB, Sweden), and protein content (981.10) was determined by the Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec 2300 Analyzer Unit, Foss Tecator AB). Ash was determined according to the AOAC method 923.93 (muffle furnace).

Caloric content

Total calorie estimates (kcal) for frankfurters 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).

pH

The pH values of each reduced-fat batter and frankfurter 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 determina-

tions were performed in triplicate.

Color measurements

The color of each reduced-fat batter and frankfurter was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta Ltd., Japan; illuminate C, calibrated with a white plate, $L^* = +97.83$, $a^* = -0.43$, and $b^* = +1.98$). Seven measurements for each of 5 replicates were obtained. Lightness (CIE L^* - value), redness (CIE a^* - value), and yellowness (CIE b^* - value) values were recorded.

Cooking loss

The reduced-fat batter was stuffed into casings (initial weight) and heated at 75°C for 30 min; cooked samples were cooled to room temperature at 21°C for 3 h. After cooling, the cooked batter was weighed, and cooking loss was calculated from the weights.

Emulsion stability

The reduced-fat batter samples were analyzed for emulsion stability using the method of Blouka and Honikel (1992) with the following modifications. Pre-weighed graduated glass tubes were filled with batter at the middle of a 15 mesh sieve. The glass tubes were closed and heated for 30 min in a boiling water bath to a core temperature of 75°C. After cooling to approximately 4°C to facilitate fat and water layer separation, the water and fat separated in the bottom of each graduated glass tube were measured and calculated.

Water exudation (mL/g) = [the water layer (mL) / weight of raw meat batter (g)] × 100

Fat exudation (mL/g) = [the fat layer (mL) / weight of

raw meat batter (g)] \times 100

Apparent viscosity

The reduced-fat batter viscosity was measured in triplicate with a rotational viscometer (Hakke Viscotester 550, Thermo Electron Corp., 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 for 30 s under a constant shear rate (s^{-1}) before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time ($18^{\circ}C$) of viscosity testing was also recorded.

Texture profile analysis

The texture profile analysis (TPA) was conducted using the method of Choi *et al.* (2010) at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., Surrey, England). The reduced-fat batter was stuffed into casings followed by heating ($75^{\circ}C$ for 30 min), and the cooked samples were cooled to room temperature at $21 \pm 1^{\circ}C$ for 30 h. The samples were allowed to equilibrate to room temperature. Samples were taken from the central portion of each frankfurter. The texture analysis conditions were as follows: pre-test speed, 2.0 mm/s; post-test speed, 5.0 mm/s; maximum load, 2.0 kg; head speed, 2.0 mm/s; distance, 8.0 mm; force, 5.0 g. TPA values were calculated by graphing force and time plots. Values for hardness (N), springiness, cohesiveness, gumminess (N), and chewiness (N) were determined as described by Bourne (1978).

Sensory evaluation

The sensory evaluations were performed in triplicate on each sample by a sensory panelist. A selected 12-member panel consisting of researchers from the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea was used to evaluate the frankfurters. The selection of panelists was performed according to sensory evaluation procedure (Lawless and Heymann, 1999). Each reduced-fat frankfurter was evaluated in terms of color, flavor, juiciness, tenderness, and overall acceptability. Reduced-fat frankfurters were cooked to a center temperature of $75 \pm 1^{\circ}C$, cooled to $21 \pm 1^{\circ}C$, cut into quarters (diameter \times length: 30 \times 40 mm), and served randomly to the panelists. Each sample was coded with a randomly selected 3-digit number. Sensory evaluations were performed under fluorescent lighting. Panelists were instructed to cleanse their palates with water between samples. The color (1 = extremely undesirable, 10 = extre-

mely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the cooked samples were evaluated, using a 10-point descriptive scale. This analysis was conducted using the hedonic test described by Bergara-Almeida and da Silva (2002).

Statistical analysis

All tests were conducted at least 3 times for each experimental condition, and mean values are reported. An analysis of variance was performed on all the variables measured using the general linear model procedure of the SAS statistical package (2008). Duncan's multiple range tests ($p < 0.05$) was used to determine the differences among treatments.

Results and Discussion

Proximate composition and caloric content

The proximate compositions of the reduced-fat frankfurters formulated with various fat levels and with/without pumpkin fiber are shown in Table 2. The moisture content of the samples with reduced-fat frankfurters was higher than that in the controls, as decreasing fat levels treatments were higher moisture content ($p < 0.05$). For the reason, due to the reduced-fat treated samples had fat content replaced by more water added and less fat (Table 1). Also, the moisture content of the reduced-fat frankfurters samples added pumpkin fiber was higher than the treated-samples without pumpkin fiber ($p < 0.05$). Crehan *et al.* (2000) indicated that the reduced-fat frankfurters had higher moisture content than the high-fat control due to the higher initial moisture content, and incorporation of maltodextrin into the formulations affect the moisture content of the reduced-fat frankfurters. Similar trends in moisture content were reported in a study by Hughes *et al.* (1997) when different fat levels and adding oat fiber and carrageenan were added to reduced-fat frankfurters. The reduced-fat frankfurters had a protein content ranging from 13.05 to 13.56%, which was slightly higher than the high-fat control (12.98%) due to probably the higher moisture losses during processing; however, this did not differ significantly among all the treatments ($p > 0.05$). The protein content is slightly increased due to the reduction in the relative moisture content. These results agree with those reported by Choi *et al.* (2010), who found protein content in reduced-fat frankfurters was not significantly

Table 2. Effects of proximate composition of reduced-fat frankfurters formulations with varying amounts of added fat with and without pumpkin fiber

Parameters	Control ^A	T1	T2	T3	T4	T5	T6
Moisture (%)	53.57±0.47 ^e	56.30±0.89 ^f	58.15±0.31 ^e	62.15±0.38 ^d	64.02±0.53 ^c	66.88±0.53 ^b	68.55±0.85 ^a
Protein (%)	12.98±0.46	13.56±0.50	13.26±0.44	13.45±0.26	13.13±0.71	13.38±0.44	13.05±0.60
Fat (%)	30.21±0.63 ^a	26.19±0.69 ^b	25.77±1.29 ^b	20.13±0.97 ^c	19.93±1.14 ^c	14.61±0.51 ^d	13.93±0.51 ^d
Ash (%)	2.28±0.05 ^c	2.30±0.04 ^c	2.44±0.05 ^b	2.32±0.07 ^c	2.51±0.06 ^{ab}	2.46±0.09 ^b	2.55±0.08 ^a
Energy value (kcal/100g)	336.61±6.14 ^a	301.64±5.23 ^{bc}	296.15±4.23 ^c	251.76±4.38 ^d	243.45±4.87 ^e	205.13±4.01 ^f	195.13±5.21 ^g

All values are mean±standard deviation of three replicates.

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

^AControl, frankfurter with 30% fat without pumpkin fiber; T1, frankfurter with 25% fat without pumpkin fiber; T2, frankfurter with 25% fat with 2% pumpkin fiber; T3, frankfurter with 20% fat without pumpkin fiber; T4, frankfurter with 20% fat with 2% pumpkin fiber; T5, frankfurter with 15% fat without pumpkin fiber; T6, frankfurter with 15% fat with 2% pumpkin fiber.

different between the high-fat controls and the reduced-fat frankfurter treatments with rice bran fiber. The fat content was higher in the high-fat control than the treatments formulated with reduced-fat and pumpkin fiber added ($p<0.05$). The overall fat content of the reduced-fat frankfurters were close to the targeted values of 15%, 20%, and 25% fat; the addition of pumpkin fiber did not affect the fat content of the reduced-fat frankfurters ($p>0.05$). Previously, this research has been reported on various low-fat or reduced-fat meat products (Choi *et al.*, 2009; Hughes *et al.*, 1998). The ash content was slightly higher tendency in as reducing fat treatments. The ash content was higher in samples containing pumpkin fiber than that in the treatment without pumpkin fiber ($p<0.05$), due to ash content of pumpkin fiber being 6.67%.

The differences in energy value of reduced-fat frankfurters formulated at various fat levels and with/without pumpkin fiber were significantly different (Table 2). The highest energy value was in the high-fat control (336.61 kcal/100 g) with 30% animal fat compared to the other reduced-fat treatments. The energy value of reduced-fat frankfurter tended to decrease by reducing animal fat content ($p<0.05$), and at the same fat levels added treated samples were lower treatment with pumpkin fiber than treatment without pumpkin fiber ($p<0.05$). Choi *et al.* (2010) reported similar results for replacing pork back fat with vegetable oil and rice bran fiber of reduced-fat frankfurters. The results obtained energy values of meat products affected by added total fat content levels. According to Turhan *et al.* (2005), the energy values of the meat products was affected by fat content, because fats have an energy value of 9 kcal/g, which is more than twice that supplied by proteins (4.02 kcal/g) of digested carbohydrates (3.87 kcal/g). Similar results were reported by Choi *et al.* (2012a) for the addition of dietary fiber from *Lami-*

naria japonica to reduced-fat pork patties, and by Turhan *et al.* (2005) for the addition of dietary fiber from hazelnut pellicle to beef burgers.

pH and color

The pH, L^* -values (lightness), a^* -values (redness), and b^* -values (yellowness) for reduced-fat meat batter and frankfurters with various concentrations of fat and with/without pumpkin fiber are shown in Table 3. The pH of the meat batter and frankfurter trended to decrease slightly by decreasing added pork fat level, the pH of the meat batter and frankfurter increased by adding pumpkin fiber. These results may have been affected by the fat levels and pumpkin fiber (pH, 6.74) added. Normally, the more the fat content increase, the pH is increased (Choi *et al.*, 2009). According to Grigelmo-Miguel *et al.* (1999), fat reduction influence the pH that found that the pH values of low-fat high-dietary fiber frankfurters were significantly different at different fat levels. Similar results obtained that reduced-fat emulsion sausage with rice fiber (Choi *et al.*, 2010). Furthermore, Choi *et al.* (2012a) found that the pH of frankfurters increased significantly by increasing the pumpkin fiber levels. Similar results were reported for the effect of pumpkin flour on the pH of foods (Lee *et al.*, 2010).

The reduced-fat meat batters and frankfurters formulated with different amounts of added fat concentrations and with/without pumpkin fiber had significant differences in lightness, redness, and yellowness (Table 3). The highest lightness values of meat batters and frankfurters were obtained in the control ($p<0.05$), as the treatments with reducing added fat content level and with added pumpkin fiber had decreased lightness ($p<0.05$). Crehan *et al.* (2000) obtained that similar results, as the reducing the fat content from 30 to 5% caused a significant decrease in the lightness of the frankfurters. Choi *et al.* (2012a) rep-

Table 3. Effects of pH and color of reduced-fat meat batters and reduced-fat frankfurters formulations with varying fat levels with and without pumpkin fiber

Parameters	Control ^A	T1	T2	T3	T4	T5	T6
pH	6.42±0.08 ^a	6.39±0.12 ^{ab}	6.40±0.10 ^{ab}	6.37±0.08 ^b	6.39±0.11 ^{ab}	6.33±0.07 ^c	6.37±0.11 ^b
Meat batter	<i>L</i> *-value	80.14±0.15 ^a	79.02±0.32 ^{ab}	77.05±0.23 ^b	76.54±0.15 ^b	75.31±0.33 ^{bc}	73.24±0.35 ^c
	<i>a</i> *-value	3.22±0.13 ^d	3.43±0.17 ^d	2.07±0.15 ^e	4.91±0.14 ^c	3.18±0.16 ^d	6.88±0.18 ^a
	<i>b</i> *-value	9.97±0.17 ^f	10.18±0.20 ^e	30.94±0.70 ^c	10.21±0.11 ^e	32.40±0.56 ^b	11.64±0.30 ^d
Frankfurter	pH	6.54±0.12 ^a	6.49±0.09 ^{ab}	6.52±0.05 ^a	6.46±0.07 ^{ab}	6.48±0.11 ^{ab}	6.41±0.08 ^b
	<i>L</i> *-value	78.83±0.32 ^a	77.07±0.16 ^{ab}	75.62±0.26 ^b	74.09±0.12 ^b	72.11±0.19 ^{bc}	71.93±0.17 ^c
	<i>a</i> *-value	1.02±0.18 ^{cd}	1.13±0.12 ^c	0.21±0.05 ^f	1.24±0.03 ^b	0.53±0.07 ^e	1.58±0.08 ^a
<i>b</i> *-value	11.56±0.30 ^b	10.86±0.38 ^b	32.08±0.33 ^a	11.04±0.75 ^b	33.15±0.48 ^a	10.32±0.66 ^b	32.09±0.20 ^a

All values are mean±standard deviation of three replicates.

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

^AControl, frankfurter with 30% fat without pumpkin fiber; T1, frankfurter with 25% fat without pumpkin fiber; T2, frankfurter with 25% fat with 2% pumpkin fiber; T3, frankfurter with 20% fat without pumpkin fiber; T4, frankfurter with 20% fat with 2% pumpkin fiber; T5, frankfurter with 15% fat without pumpkin fiber; T6, frankfurter with 15% fat with 2% pumpkin fiber.

orted that the lightness of the meat batters and frankfurters decreased significantly by increasing pumpkin fiber because the pumpkin fiber was a specific yellowish color that was likely transferred to the tested samples causing modification of the batters and frankfurters. The redness and yellowness values of the meat batters and frankfurters increased treatment with decreasing fat contents levels ($p<0.05$). In addition, the redness values of the meat batters and frankfurters decreased and the yellowness of the meat batters and frankfurters increased with increasing amount of pumpkin fiber ($p<0.05$), due to the color of pumpkin. Similar results of increased redness and yellowness with increasing pumpkin levels were reported by Choi *et al.* (2012b) for meat batters and frankfurters with pumpkin fiber were added to the pumpkin fiber. These results were also in agreement with those of Crehan *et al.* (2000) who reported the redness values increased significantly with decrease in fat content. Hughes *et al.* (1997) found that reducing the fat level decreased the lightness and yellowness and increased the redness of frankfurters. Hughes *et al.* (1998) reported that the lightness values decreased and the redness values increased as treatments with added reducing fat content levels in frankfurters, although yellowness was not significantly affected by fat content levels.

Cooking loss and emulsion stability

The cooking loss and emulsion stability of reduced-fat frankfurters formulations with varying amounts of added fat concentrations and with or without pumpkin fiber are provided in Table 4. The results of this analysis observed that the cooking loss increased when fat content was reduced in frankfurters ($p<0.05$), due to fat replacers work best at reduced fat levels when added water is high. These

results supported the findings of Hughes *et al.* (1998). In this study, they examined fat level, tapioca starch and whey protein on frankfurters formulated with 5% and 12% fat contents. Hughes *et al.* (1997) observed that similar results, as the cooking loss of frankfurters were increased which decreased fat concentrations added, and apparent that frankfurters with added carrageenan and oat fiber shown to decrease cooking loss. According to Crehan *et al.* (2000), reducing the fat concentrations of the frankfurters from 30% to 5% caused a significant increase in cooking loss, because meat products of lower fat concentrations and fat replaced added more water increased. And as the treatments with increasing added pumpkin fiber were decreased cooking loss ($p<0.05$). Choi *et al.* (2012b) reported that frankfurters with pumpkin fiber had less cooking loss compared to that in the treatments without pumpkin fiber. Turhan *et al.* (2005) indicated that beef burgers of cooking loss decreased with more dietary fiber from hazelnut pellicle addition. In general, previous studies using dietary fiber extracted from natural sources resulted in meat products with less cooking loss that is the result of a release in fat and moisture contents (Choi *et al.*, 2013).

The emulsion stability of reduced-fat frankfurters with various concentrations of fat and with or without pumpkin fiber is shown in Table 4. The reduced-fat meat batters with 15% fat without pumpkin fiber treatment (T5) had the highest water exudation ($p<0.05$), and water exudation of reduced-fat meat batter prepared without pumpkin fiber was significantly higher than that in treatments with pumpkin fiber ($p<0.05$). Furthermore, the water exudation of reduced-fat meat batters increased significantly by decreasing fat concentrations ($p<0.05$). For these reasons, treatments were added to replace the fat content with

Table 4. Effects of cooking loss and emulsion stability of reduced-fat frankfurters formulations with varying fat levels with and without pumpkin fiber

Parameters	Control ^A	T1	T2	T3	T4	T5	T6
Cooking loss (%)	6.87±0.57 ^c	12.64±0.89 ^c	7.31±0.31 ^c	14.57±0.78 ^b	9.13±0.53 ^d	16.87±1.35 ^a	9.95±0.98 ^d
Emulsion stability							
Water exudation (mL/g)	3.50±0.72 ^{de}	6.23±0.58 ^c	3.09±1.08 ^e	8.28±0.88 ^b	4.26±1.01 ^d	13.75±1.82 ^a	6.46±0.91 ^c
Fat exudation (mL/g)	1.39±0.12 ^c	2.31±0.19 ^a	1.37±0.18 ^c	1.97±0.22 ^{ab}	1.34±0.21 ^c	1.57±0.17 ^b	1.36±0.15 ^c

All values are mean±standard deviation of three replicates.

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

^AControl, frankfurter with 30% fat without pumpkin fiber; T1, frankfurter with 25% fat without pumpkin fiber; T2, frankfurter with 25% fat with 2% pumpkin fiber; T3, frankfurter with 20% fat without pumpkin fiber; T4, frankfurter with 20% fat with 2% pumpkin fiber; T5, frankfurter with 15% fat without pumpkin fiber; T6, frankfurter with 15% fat with 2% pumpkin fiber.

water content. Fat exudation of reduced-fat meat batter formulated without pumpkin fiber was significantly higher than that in treatments with pumpkin fiber ($p<0.05$), and there was no significant difference between control and all reduced-fat treatments with pumpkin fiber treatment groups ($p>0.05$). Hughes *et al.* (1998) observed that was increased in total expressible fluid in frankfurter meat batters as decreased fat concentration, which agreed with the present. Hughes *et al.* (1997) showed increased emulsion stability when fat content was reduced from 30 to 5% fat. Similar results were reported by Choi *et al.* (2013) for a reduced-fat frankfurter with dietary fiber extracted from *makgeolli* lees. The likely reason for this result is the well-known ability of dietary fiber to bind water and strongly water holding capacity and thus emulsion stability was reinforced. Similar trends in emulsion stability were observed in studies by many researchers on the addition of dietary fiber extracted from various natural sources, because of its water and fat-binding properties. Normally, the emulsion stability of meat batter is an indicator of water exudation and fat exudation retained by meat protein that estimates the quality characteristics of a meat product (Choi *et al.*, 2010). As a result, the ability to control cooking loss and emulsion stability is influenced by added fat and moisture concentration, and ingredient such as sources of dietary fiber.

Apparent viscosity

The apparent viscosity of the reduced-fat meat batters with various concentrations of fat and with/without pumpkin fiber are shown in Fig. 1. Apparent viscosity values of control and including all treatments in which pork back fat was replaced with water and pumpkin fiber were decreased thixotropically with rotation time. Similar results were obtained by Choi *et al.* (2013) who reported that reduced-fat frankfurters adding dietary fiber to meat emulsion results in a significantly decreased viscosity with an

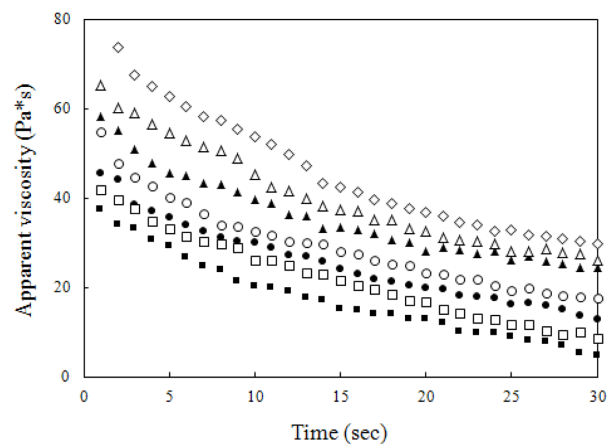


Fig. 1. Change of apparent viscosity on meat batter containing various fat levels with and without pumpkin fiber stirred for 30 s. Control (\diamond): frankfurter with 30% fat without pumpkin fiber, T1 (\blacktriangle): frankfurter with 25% fat without pumpkin fiber, T2 (\triangle): frankfurter with 25% fat with 2% pumpkin fiber, T3 (\bullet): frankfurter with 20% fat without pumpkin fiber, T4 (\circ): frankfurter with 20% fat with 2% pumpkin fiber, T5 (\blacksquare): frankfurter with 15% fat without pumpkin fiber, T6 (\square): frankfurter with 15% fat with 2% pumpkin fiber.

increase in rotation time. As reducing fat concentration added, meat batters showed a tendency to decrease the apparent viscosity. The reason for this is that replaced animal fat, which is highly viscous with added water. These studies can be has agreed in previous studies (Choi *et al.*, 2009; Choi *et al.*, 2013). Griegelmo-Miguel *et al.* (1999) demonstrated that the viscosity of batters made of pork fat decreased with the substitution of fat by water. In addition, the apparent viscosity of the meat batters that the same fat concentration added treatments was significantly higher for treatments formulated with pumpkin fiber than treatment without pumpkin fiber ($p<0.05$). Similar trend results have been observed for the effect of pumpkin fiber on the apparent viscosity of meat batters (Choi *et al.*

al., 2012b). These results observed that the control samples had the lowest viscosity, whereas the treatments samples added to more pumpkin fiber had higher viscosity values. Some researcher obtained that dietary fiber provides higher water holding capacity and water binding capacity, these resulted improved viscosity (Choi *et al.*, 2009). In addition, some studies have reported that the apparent viscosity of meat batter is vital linked emulsion stability, that is the mean, high viscosity of emulsion meat batter in not easily broken by emulsion stability (Choi *et al.*, 2013). Therefore, apparent viscosity values can be considerable effect on the qualities of meat product.

Texture profile analysis

The textural properties of the reduced-fat frankfurters formulated with various fat levels and with/without pumpkin fiber given in Table 5. The results indicated that different fat concentrations and with or without pumpkin fiber significantly affected the textural properties of reduced-fat frankfurters. The hardness, cohesiveness, gumminess, and chewiness of the samples with frankfurters were the highest in the control, as decreasing fat concentrations treatments with no pumpkin fiber added were significantly lower hardness, cohesiveness, gumminess, and chewiness ($p < 0.05$). The same fat concentrations added treatments samples, the hardness of treatments with pumpkin fiber samples were higher than treatment without pumpkin fiber ($p < 0.05$). The springiness of the frankfurters samples tended to decrease slightly by decreasing fat concentration. The springiness of the same fat concentrations added treatments was higher for treatments formulated with pumpkin fiber than treatment without pumpkin fiber, but there was no statistically significant difference ($p > 0.05$). This result agrees with Hughes *et al.* (1998) who studied the effects of fat level, tapioca starch, and whey protein on reduced-fat frankfurters. There is reported that reducing the fat level from 12% to 5% significantly decreased

cohesiveness and gumminess of the frankfurters. However, hardness and chewiness of 12% fat treatments were higher than 5% fat treatments, but there were no significant differences between. Crehan *et al.* (2000) reported that effect between fat level and added maltodextrin for hardness, gumminess, and chewiness of the reduced-fat frankfurters, and they reported fat reduction from 30% to 12% or 5% cause a significant increase in springiness of the resulting frankfurters. According to Cofrades *et al.* (1997), high-fat frankfurters were harder than low-fat frankfurters, due to the fact that the hardness of frankfurters is dependent on the fat concentration and the amount of fat replaced with water. Grigelmo-Miguel *et al.* (1999) found that decreasing fat concentration or increasing added water produced lower hardness only 17% peach dietary fiber treatments among the frankfurter treatments. On the other hand, when frankfurters were formulated with a higher 29% peach dietary fiber concentration significantly decreased hardness, springiness, cohesiveness, gumminess, chewiness from 15% to 10% fat content and from 20% to 15% fat content. Choi *et al.* (2012a) reported that hardness of control meat patty treatments at regular-fat (20%) was higher than low-fat treatments with dietary fiber from *Laminaria japonica*, but similar resulted control and low-fat treatment with 5% dietary fiber. These results may be due to added dietary fiber from natural sources. Choi *et al.* (2010) showed similar results when the studying the effect of replacing pork back fat with vegetable oils and rice bran fiber on the quality of reduced-fat frankfurters. Therefore, some studies have observed that low-fat or reduced-fat meat products with added dietary fiber extracted from natural sources have improved textural properties (Choi *et al.*, 2013). The dietary fiber was improved meat products by forming an insoluble 3-dimensional network capable of modifying the rheological properties of meat emulsion batters. That is, with added dietary fiber have resulted in water binding ability and swelling prop-

Table 5. Effects of textural properties of reduced-fat frankfurters formulations with varying fat levels with and without pumpkin fiber

Parameters	Control ^A	T1	T2	T3	T4	T5	T6
Hardness (N)	3.33±0.20 ^a	2.74±0.29 ^c	3.14±0.27 ^b	2.55±0.31 ^d	2.65±0.34 ^c	2.25±0.28 ^c	2.45±0.19 ^d
Springiness	0.96±0.02 ^a	0.95±0.03 ^{ab}	0.96±0.04 ^a	0.94±0.02 ^{ab}	0.95±0.04 ^{ab}	0.93±0.06 ^b	0.94±0.06 ^{ab}
Cohesiveness	0.63±0.05 ^a	0.55±0.02 ^{bc}	0.57±0.02 ^b	0.53±0.03 ^c	0.56±0.04 ^b	0.50±0.02 ^e	0.53±0.02 ^c
Gumminess (N)	1.96±0.27 ^a	1.47±0.18 ^{bc}	1.57±0.19 ^b	1.37±0.17 ^c	1.47±0.18 ^{bc}	1.08±0.13 ^e	1.27±0.17 ^d
Chewiness (N)	1.87±0.29 ^a	1.44±0.24 ^{bc}	1.57±0.19 ^b	1.37±0.28 ^c	1.47±0.17 ^{bc}	1.19±0.18 ^e	1.28±0.16 ^d

All values are mean±standard deviation of three replicates.

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

^AControl, frankfurter with 30% fat without pumpkin fiber; T1, frankfurter with 25% fat without pumpkin fiber; T2, frankfurter with 25% fat with 2% pumpkin fiber; T3, frankfurter with 20% fat without pumpkin fiber; T4, frankfurter with 20% fat with 2% pumpkin fiber; T5, frankfurter with 15% fat without pumpkin fiber; T6, frankfurter with 15% fat with 2% pumpkin fiber.

erties (Turhan *et al.*, 2005).

Sensory properties

Table 6 shows the results of sensory evaluation for the addition of various fat concentrations and with/without pumpkin fiber in reduced-fat frankfurters. The control samples had the highest all sensory parameters ($p < 0.05$). The color, flavor, tenderness, juiciness, and overall acceptability scores of frankfurters showed a tendency to decrease by reducing added pork fat levels, treatments with pumpkin fiber added was higher sensory scores than treatments without pumpkin fiber ($p < 0.05$). Reduced-fat frankfurters containing 25% and 20% fat concentration, and 2% pumpkin fiber treatment (T2 and T4) generated sensory properties scores similar to high fat (30%) control. Similar results were obtained by Hughes *et al.* (1997), who examined the decreasing the fat level from 30% to 5% significantly alters the overall acceptability of frankfurters, and the addition of either oat fiber or carrageenan to the low-fat frankfurters did not significantly affect the overall acceptability. Crehan *et al.* (2000) reported that reduction the fat level from 30% to 5% resulted in frankfurters with decreased overall acceptability. Grigelmo-Miguel *et al.* (1999) showed that all the frankfurters with peach dietary fiber were considered acceptable with the exception of those with 5% fat, although the acceptability decreased as fat concentration decreased. Choi *et al.* (2012b) reported that frankfurter containing 2-3% pumpkin fiber had higher sensory scores for tenderness, juiciness, and overall acceptability when compared to controls. Furthermore, Choi *et al.* (2010) observed that flavor, tenderness, juiciness, and overall acceptability scores were similar for the high-fat (30% fat) control and reduced-fat (20% fat) treatments with 2% rice bran fiber added. The observed results determine that added dietary fiber had beneficial and positive effects on the sensory properties of reduced-

fat meat products. Thus, added fat levels and fat replacers, as dietary fiber affected the sensory characteristics of meat products.

Conclusion

The results of this investigation showed that reducing fat levels from 30% to 15% and adding 2% dietary fiber extracted from pumpkin fiber and more water had a vital effect on the quality characteristics of reduced-fat frankfurters. Pumpkin fiber is an excellent source of dietary fiber, and reduced-fat frankfurters are granted beneficial for technology. Especially, the pumpkin fiber improves the following qualities frankfurter: physicochemical, cooking loss, emulsion stability, apparent viscosity, and textural properties. Reduced-fat frankfurters had lower energy values than the high-fat (30% fat) control frankfurter. The reduced-fat frankfurters made with 20% and 25% fat concentration reductions supplemented with 2% pumpkin fiber had sensory properties similar to the high-fat control frankfurters. Therefore, incorporating pumpkin fiber and water into the formulation successfully reduced fat in the frankfurters.

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Table 6. Effects of sensory characteristics of reduced-fat frankfurters formulations with varying fat levels with and without pumpkin fiber

Parameters	Control ^A	T1	T2	T3	T4	T5	T6
Color	8.24±0.52 ^a	7.98±0.48 ^b	8.05±0.61 ^{ab}	7.74±0.43 ^b	7.95±0.47 ^{ab}	6.91±0.44 ^c	7.23±0.51 ^b
Flavor	8.69±0.63 ^a	7.52±0.85 ^{bc}	8.01±0.64 ^{ab}	7.32±0.81 ^{bc}	7.91±0.58 ^{ab}	7.82±0.63 ^b	7.82±0.63 ^b
Tenderness	8.11±0.48 ^a	7.92±0.63 ^{ab}	8.13±0.67 ^a	7.23±0.82 ^b	7.79±0.88 ^{ab}	6.81±0.38 ^c	7.19±0.57 ^b
Juiciness	7.68±0.34 ^a	7.58±0.44 ^{ab}	7.75±0.35 ^a	7.48±0.49 ^b	7.59±0.57 ^{ab}	6.21±0.24 ^d	6.91±0.24 ^d
Overall acceptability	7.88±0.67 ^a	7.20±0.53 ^b	7.90±0.71 ^a	7.14±0.56 ^c	7.83±0.72 ^{ab}	6.78±0.43 ^d	7.15±0.51 ^c

All values are mean±standard deviation of three replicates.

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

^AControl, frankfurter with 30% fat without pumpkin fiber; T1, frankfurter with 25% fat without pumpkin fiber; T2, frankfurter with 25% fat with 2% pumpkin fiber; T3, frankfurter with 20% fat without pumpkin fiber; T4, frankfurter with 20% fat with 2% pumpkin fiber; T5, frankfurter with 15% fat without pumpkin fiber; T6, frankfurter with 15% fat with 2% pumpkin fiber.

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