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ARTICLE

Effects of Chicken Feet Gelatin and Wheat Fiber Levels on Quality Properties of Semi-dried Chicken Jerky

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Abstract

The aim of this study was to investigate the effect of chicken feet gelatin and wheat fiber levels on the quality characteristics properties of semi-dried chicken jerky. The obtained chicken feet gelatin swollen with hydrochloric solution (0.1 N HCl, pH 1.31±0.02) was dehydrated via freeze-drying. Six formulations of chicken jerky that were prepared, based on the ratio of chicken meat, chicken feet gelatin and wheat fiber, were 100:0:0, 98:0:2, 99:1:0, 97:1:2, 98:2:0 and 96:2:2, respectively. The moisture content of semi-dried chicken jerky containing 2% wheat fiber was higher than that of jerky without the added fiber ($p<0.05$); moreover, an increase in the content of chicken feet gelatin also increased the moisture content. The drying yield of the samples increased with an increase in chicken feet gelatin. In addition, the drying yield of samples containing 2% wheat fiber was higher ($p<0.05$) than those without the added wheat fiber. However, the shear force of the samples significantly decreased with the increase in chicken feet gelatin content. Further, the shear force of the samples containing 2% wheat fiber was higher ($p<0.05$) than those without the added wheat fiber. No significant differences, except for color, were observed in the sensory analysis among the treatments.

Key words: chicken feet, gelatin, fiber, semi-dried jerky

Introduction

Koreans have increased their purchase and consumption of snack foods in the past several years. Food processors want to exploit the consumer demand and increase the availability of snack products. Currently, the food market is overflowing with various types of jerky that are tasty, nutritious, and most importantly convenient. Jerky has been a favorite snack food for many years. Jerky is one of the oldest meat products, treated by salting and drying to reduce water activity. It is prepared by the application of hurdle technology, and includes the use of temperature, water activity, organic acids, and spices during preparation (Leistner, 1987). Jerky has traditionally been prepared with the sliced whole muscle of beef and horse that is cured and dried. However, Choi *et al*. (2008) produced restructured pork jerky by adding meat emulsion to improve its binding ability, and Choi *et al*. (2008) reported the effects of pork/beef levels and casings on the quality properties of semi-dried jerky. In many countries, the consumption of different types of jerky such as beef jerky (Konieczny *et al*., 2007), pork jerky (Choi *et al*., 2008), and turkey jerky (Carr *et al*., 1997) has increased in the past several years because of its easy preparation, convenient, rich nutrient content, and stability without refrigeration. However, whole muscle and ground type jerky prepared from chicken have been little studied.

Chicken meat has been very popular in many countries because it provides excellent animal protein to consumers in developing countries (Jones, 1992). Most processed chicken products are ready-to-cook products such as smoked thigh (Bater *et al*., 1993), chicken nuggets (Ngadi *et al*., 2007), and sausage (Pereira *et al*., 2000). In particular, chicken meat is a good starting material for jerky because poultry meat has high protein and low fat. Recently, the consumer demand for food which is safe, healthy, diverse, and convenient is increasing. Healthy meat foods are those that are good sources of dietary fiber (Choi *et al*., 2009) and gelatin (Johnston-Banks, 1990).

Dietary fiber holds all the characteristics required to be considered an important ingredient in the formulation of functional foods, because of its beneficial effects such as increasing transit, cholesterol, and glycemic levels, chelat-

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ing harmful substances (mutagenic and carcinogenic agents), and stimulating the proliferation of intestinal flora (Heredia *et al*., 2002). In addition, dietary fiber can be used to improve the physicochemical properties of sausages, nuggets, and hamburgers (Akoh, 1998; Crehan *et al*., 2000; Hsu and Chung, 2001; Hughes *et al*., 1997). Gelatin is a gelling protein that has widely been applied in the food and pharmaceutical industries (Johnston-Banks, 1990; Schrieber and Gareis, 2007). In the food industry, gelatin is utilized in confections (mainly to provide chewiness, texture, and foam stabilization), low-fat spreads (to provide stability and texture), baked goods (to provide emulsification, gelling, and stability), and meat products (to provide water-binding). Moreover, it is normally recommended for diabetic patients to enhance protein intake and to reduce carbohydrate intake. Thus, the amount of gelatin used in the food industry worldwide is increasing (Montero and Gómez-Guillén, 2000). In many countries, most commercial gelatin is made from porcine and bovine hide (Binsi *et al*., 2009; Cho *et al*., 2005). However, frequent outbreaks of bovine spongiform encephalopathy (BSE) and foot/mouth disease have been a barrier, and thus the use of new gelatin sources such as poultry skin, feet, and bone has increased to replace mammalian sources (Schrieber and Gareis, 2007). The objective of this study was to evaluate the effects of the levels of wheat fiber and chicken feet gelatin on the quality properties of semi-dried chicken jerky.

Materials and Methods

Materials

Chicken breasts and feet were provided by Maniker F&G Co., Ltd (Yonginsi 388-278, Korea). All subcutaneous fat and visible connective tissue were removed from the chicken breasts. Lean materials were initially ground through an 8 mm plate. They were placed in polyethylene bags, vacuum-packaged using a vacuum-packaging system (FJ-500XL, Fujee Tech, Korea) and stored at -21°C until required for product manufacture. Chicken feet were skinned, washed using tap water, and immediately frozen and stored at -21°C until used. The fiber used was Vitacel® wheat fiber (Rettenmaier and Söhne GmbH, Germany). This fiber consists of 74% cellulose, 26% hemicellulose and <0.5 of lignin; WF400 with 500 μm long particles. All reagents were of analytical grade. All experiments were performed in duplicate with at least three replicates. The results were expressed as mean and standard deviation.

Preparation of gelatins

The extraction procedure is shown in Fig. 1. The cleaned chicken feet were soaked in 10 volumes (v/w) of hydrochloric solution (0.1 N HCl) at 18°C for 24 h to allow swelling. After acid treatment, the feet were neutralized with flowing tap water. For hot-water extraction, they were placed in polyethylene bags, vacuum-packaged using a vacuum-packaging system (FJ-500XL, Fujee Tech, Korea), and then theated at 75°C for 2 h in a boiling water bath. The extracted gelatin was frozen at -70±1°C and dried at -40°C under a pressure of 80×10^{-3} torrs using a freeze-dryer (PVTFD20R, Ilshinlab, Korea). The gelatin was dehydrated until it reached a constant weight (<3% final moisture) for 48 h in the freeze-dryer.

Preparation of semi-dried jerky

The experimental design of semi-dried chicken jerky prepared with fiber and gelatin is shown in Table 1. The manufacturing process of semi-dried jerky is shown in Fig. 2. The jerky curing solution consisted of the following components(in terms of w/w): water (10%), soy sauce (4%), salt (1.5%), red pepper paste (5%), starch syrup

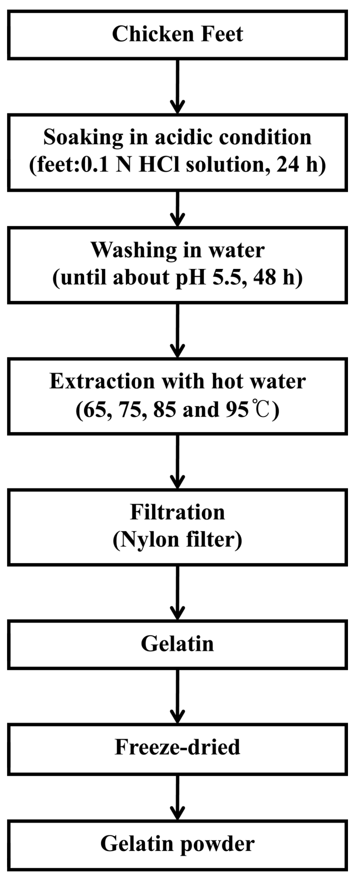

Fig. 1. The diagram of gelatin manufacturing from the chicken feet.

Table 1. The semi-dried chicken jerky prepare with chicken feet gelatin and wheat fiber

Ingredients		Treatments (%)					
	Gelatin	0		1		2	
	Fiber	0	2	0	2	0	2
Chicken breast (%)		100	98	99	97	98	96
Chicken feet gelatin (5)		0	0	1	1	2	2
Wheat fiber (%)		0	2	0	2	0	2
Total		100	100	100	100	100	100

(4.2%), sugar (2%), D-sorbitol (6%), pepper (0.2%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2), sodium nitrate (0.007%), sodium citrate (0.01%), potassium sorbate (0.1%), sodium erythorbate (0.03%), soup stock powder (0.1%) and teriyaki seasoning (0.1%). The frozen ground chicken breast was thawed at 4°C overnight, cured by tumbling with curing solution, and stuffed into cellulose casing (Φ - 18 mm). Each preparation was cut in to 15 cm-lengths. Samples were dried in the following steps: 55°C (30 min) → 60°C (150 min) → 73°C (90 min) → 75°C (10 min), in a chamber (1600EL, Kerres GmbH, Germany). After cooling at 20°C, cellulose casing was removed from the samples.

Analytical methods

Compositional properties

The compositional properties of the semi-dried jerky

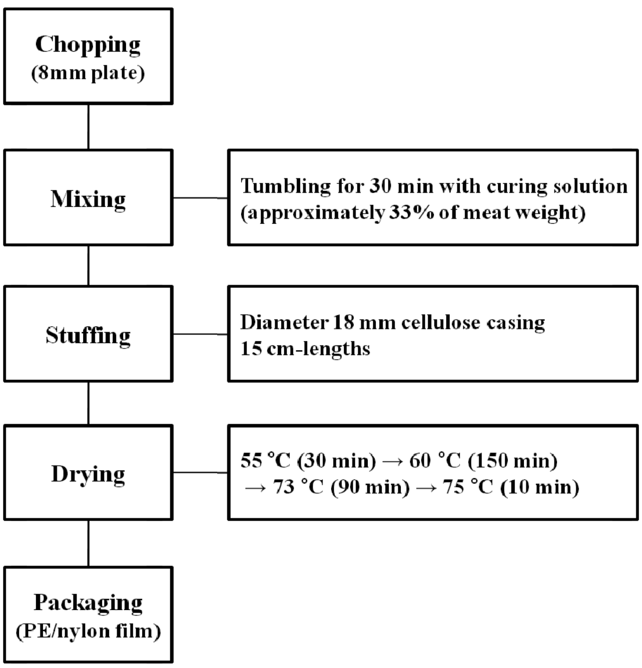

Fig. 2. The diagram of semi-dried chicken jerky manufacturing.

were analyzed using methods published by the Association of Official Analytical Chemists (AOAC, 2000). 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 the Soxhlet method with a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Sweden) and protein content was determined by the 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.

Processing yields

Processing yield was determined by calculating the weight change in the jerky before and after drying as follows:

Processing yield (%)
= (Jerky weight after drying/
Cured meat weight before drying) × 100

pH and water activity

The pH of each sample was determined using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). pH values were measured by blending a 5 g sample with 20 mL distilled water for 60 s in a homogenizer (Ultra-Turrax T25, Janke & Kunkel, Germany). For water activity testing, samples were minced into pieces approximately 1 mm × 1 mm × 1 mm in size. The water activity of each sample was determined in duplicate with a hygrometer (BT-RS1, Rotronic ag., Switzerland).

Shear force measurement

Shear force values were determined with a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2i, Stable Micro System Ltd., UK). Test speeds were set at 2 mm/s. Data on shear force values were collected and analyzed to obtain the maximum force (kg) required to shear through each sample.

Percent metmyoglobin

The metmyoglobin concentration of semi-dried jerky was assessed using a modification of the procedures describeds by Kryzwicki (1979). Briefly, samples were blended with 5 volumes of cold 0.04 M phosphate buffer at pH 6.8 for 10 s in a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Japan). After standing at 1°C for 24 h, the mixtures were centrifuged at 3500×g at 4°C for 30 min. The supernatant was further clarified by filtration through a Whatman No. 1 filter paper. The absorbance of the filtrate was measured at 525, 572, and 700 nm using a spectrophotometer (Optizen III, Mecasys, Korea). Percent metmyoglobin content was calculated using the following formula:

$$\text{Metmyoglobin (\%)} = [1.395 - (A_{572} - A_{700})/(A_{525} - A_{700})] \times 100$$

Where A_λ = Absorbance at λ nm

Microbiological evaluations

To measure the microbial quality of the samples, duplicate packs from each treatment were taken, and 10 g samples of the meat were aseptically transferred into individual sterile stomacher bags. Following this, 90 mL of sterile 0.1% peptone water (Difco Laboratories, USA) was added to each sample and the contents were macerated for 2 min in a stomacher. A decimal serial dilution in 0.1% peptone water was prepared. The presence of mesophilic microorganisms was determined using Plate Count Agar (PCA, Difco) at 35°C for 48 h. Microbial colonies were counted and expressed as colony forming units (CFU) per gram.

Rehydration

Samples for rehydration were cut into pieces approximately 1 mm×1 mm×1 mm in size. Samples were placed in glass beakers containing 5 volumes of distilled water. Rehydration was conducted at 30±1°C for 10, 20, and 30 min. the extent of rehydration was determined by calculating the weight change in the sample before and after rehydration.

Sensory evaluations

Semi-dried jerky processed with various chicken levels were subjected to sensory evaluations. The samples were served to 12 experienced panel members. Panelists were presented with randomly coded samples. The color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the samples were evaluated using a 10-point descriptive scale. Panelists were required to cleanse their palate with water among samples (Keeton, 1983).

Statistical analysis

Analyses of variance were performed on all the measured variables using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Inst., 2010). The Duncan's multiple range test ($p<0.05$) was used to determine the significant differences among samples.

Results and discussion

Approximate composition of semi-dried chicken jerky

Table 2 shows the proximate analysis of semi-dried chicken jerky prepared with various chicken feet gelatin/ wheat fiber levels. The moisture content of semi-dried chicken jerky containing 2% wheat fiber was higher than that of samples without added fiber ($p<0.05$), and increasing the chicken feet gelatin content also resulted in increased moisture content; this is because these samples contained wheat fiber, which had higher water retention and improved emulsion stability (Choi *et al.*, 2009), and chicken gelatin, which absorbed the added water during gel formation (Osburn and Mandiso, 1998). Addition of wheat fiber also significantly reduced fat content by increasing moisture content. Choi *et al.* (2008) reported that moisture content has a conclusive effect on the stabil-

Table 2. Proximate analysis of semi-dried jerky prepared with chicken feet gelatin and wheat fiber

Traits		Treatments (%)					
	Gelatin	0		1		2	
	Fiber	0	2	0	2	0	2
Moisture (%)		37.45±0.34^d	38.28±0.29^c	38.34±0.10^c	39.38±0.11^b	39.39±0.35^b	40.28±0.13^a
Protein (%)		40.27±0.06^c	38.71±0.25^e	41.60±0.18^b	39.77±0.28^d	42.35±0.11^a	40.45±0.21^c
Fat (%)		8.90±0.09^a	8.87±0.34^a	8.76±0.25^a	8.31±0.23^{bc}	8.60±0.11^{ab}	8.22±0.09^c
Ash (%)		5.43±0.06^a	5.04±0.12^{bc}	5.05±0.03^b	4.90±0.10^c	5.01±0.00^{bc}	4.46±0.15^d
Moisture-to-protein ratio (MPR)		0.93	0.99	0.92	0.99	0.93	1.00

All values are mean±SD of three replicates.
$^{a-e}$Means within a row with different letters are significantly different ($p < 0.05$).

ity of intermediate-moisture (IM) foods which, have moisture contents of 20-40% (Jose *et al*., 1994). A moisture content of approximately 36-38% satisfied the requirements for the sensory characteristics of the jerky (Miller *et al*., 1988). The protein content of semi-dried chicken jerky was significantly increased by increasing the chicken feet gelatin content, and the protein content of samples containing 2% wheat fiber was lower ($p<0.05$) than that of samples without added wheat fiber. Jerky-type products that are made from whole-muscle type jerky and restructured type jerky are considered microbiologically safe if the moisture-to-protein ratio (MPR) does not exceed 0.75 (USDA, 1996). As shown in Table 2, the mean MPR values of the jerky preparations ranged from 1.00 to 0.92. Treatment with 1% chicken feet gelatin and 0% wheat fiber resulted in the lowest MPR value of all the treatments, and approximated a safe MPR value. Both the fat and ash contents of semi-dried chicken jerky containing 2% wheat fiber were lower than those without added fiber, and an increase in chicken feet gelatin levels also caused a decrease in ash content. This was similar to the trend noted in reduced fat meat products (Eilert *et al*., 1993).

pH, water activity, metmyoglobin, rehydration, and total microbiological properties of semi-dried chicken jerky

The pH, water activity, metmyoglobin, rehydration, and total microbiological properties of semi-dried chicken jerky prepared with various chicken feet gelatin and wheat fiber levels are shown in Table 3. The pH values of semi-dried chicken jerky significantly decreased with increasing chicken feet gelatin content. Choi *et al*. (2008) reported that the pH value of pork/beef level semi-dried jerky was between 5.73 and 5.76. Further, Han *et al*. (2011) reported that the average pH for semi-dried chicken jerky was in the broad range of 6.09-6.17, which is very close to our results. In this study, the water activity of semi-dried jerky was within the range of 0.83-0.84 (Table 3). There were no clear differences in water activity among samples with varying chicken feet gelatin and wheat fiber levels ($p>0.05$). Other scientists have reported that chicken jerky had lower water activity than samples containing konjac, egg albumin, and isolated soy protein (Han *et al*., 2011). Many researchers have suggested that jerky must have stable water activity to avoid changes in quality during storage (Yamaguchi *et al*., 1986). The percent metmyoglobin content of semi-dried chicken jerky significantly decreased with increasing chicken feet gelatin, and that of samples containing 2% wheat fiber was lower than of those without added wheat fiber ($p<0.05$). In general, sodium chloride (Huffman *et al*., 1981), temperature (Sherwin and Labuza, 2003), lipid oxidation (Faustman and Cassens, 1990), and manufacturing processes are known to affect discoloration. Choi *et al*. (2008) found that the percent metmyogolbin content of semi-dried jerky prepared with pork/beef levels gradually decreased as the beef content increased. The percent rehydration of chicken jerky generally ranged from 107.36% to 150.61%. Our experimental results indicate that semi-dried jerky prepared with various chicken feet gelatin and wheat fiber levels did not exhibit alterations in percent rehydration. Overall, the total microbial counts of jerky were low, within the range of 4 Log CFU/g to 5 Log CFU/g. The jerky inhibited microbial growth due to its low water activity (Gould and Christian, 1988). No significant differences were detected between the various jerky preparations ($p>0.05$). Restructured jerky was suggested to be a greater threat than sliced jerky prepared using whole muscle due to contamination with pathogens during the grinding process (Faith *et al*.1998). Furthermore, previous studies have reported that *Salmonella* and *Listeria monocytogenes* were observed at lower counts in sliced products than in restructured jerky (Harrison *et al.*,

Table 3. Comparison on physicochemical properties and total microbial counts of semidried jerky prepared with chicken feet gelatin and wheat fiber

Traits		Treatments (%)					
	Gelatin	0		1		2	
	Fiber	0	2	0	2	0	2
pH		6.08±0.01[a]	6.09±0.02[a]	6.06±0.03[b]	6.05±0.03[b]	6.02±0.02[c]	5.99±0.01[d]
Water activity		0.84±0.01	0.84±0.01	0.83±0.01	0.84±0.01	0.83±0.01	0.83±0.01
Metmyoglobin (%)		96.27±0.55[a]	95.24±0.87[b]	94.51±0.81[bc]	94.06±0.65[c]	93.71±0.74[cd]	93.01±1.03[d]
Rehydration (%)		107.36±11.59	131.21±1.85	130.93±0.88	146.20±3.74	135.38±4.43	150.61±0.05
Total microbial count (Log CFU/g)		4.86±0.03	4.97±0.03	4.85±0.04	4.99±0.01	4.94±0.02	4.97±0.03

All values are mean±SD of three replicates.

[a-d]Means within a row with different letters are significantly different ($p<0.05$).

1997).

Drying yield and shear force of semi-dried chicken jerky

The drying yields of semi-dried jerky prepared with various chicken feet gelatin and wheat fiber levels are shown in Fig. 3. The processing yields of jerky had values in the range of 47-50%, regardless of chicken feet gelatin and wheat fiber levels. The drying yield of semi-dried chicken jerky increased with increasing chicken feet gelatin levels, and the drying yield of jerky containing 2% wheat fiber was higher ($p<0.05$) than that of jerky without added wheat fiber. Han *et al*. (2011) reported similar results with the drying yield of pork jerky containing humectant. Eilert and Mandigo (1993) reported that smokehouse processing yields were highest with a 20% beef connective tissue content, which resulted in high collagen content in meat products. The addition of fiber, such as rice bran fiber (Choi *et al*., 2009), fruit fiber (Garcia *et al*., 2002), and carrot fiber (Eim *et al*., 2008) to meat products increased the drying yield and improved water holding capacity and fat-binding properties. In general, texture, color, and taste are important factor in consumer preference. Fig. 4. presents a comparison of the shear force of semi-dried jerky prepared with various levels of chicken feet gelatin and wheat fiber. The shear force of semi-dried chicken jerky significantly decreased with increasing chicken feet gelatin content and that of samples containing 2% wheat fiber was higher ($p<0.05$) than of those without added wheat fiber. Shear force is the force needed to change the form of food, and is correlated with water activity, moisture content, cooking yield, and muscle fiber composition. Similar studies have

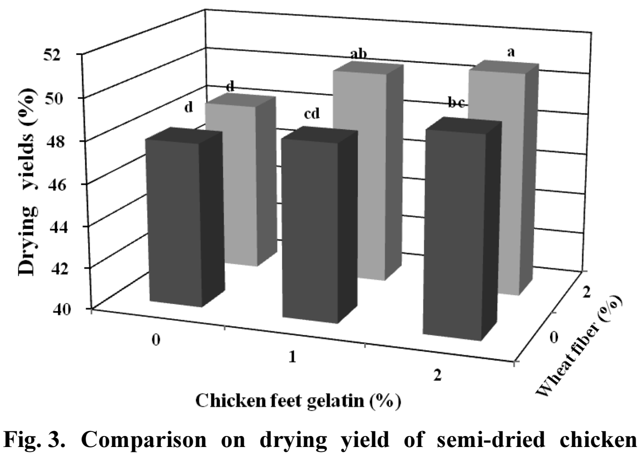

Fig. 3. Comparison on drying yield of semi-dried chicken jerky prepared with chicken feet gelatin and wheat fiber levels. [a-d]Means values with different letters among the treatment are significantly different ($p<0.05$).

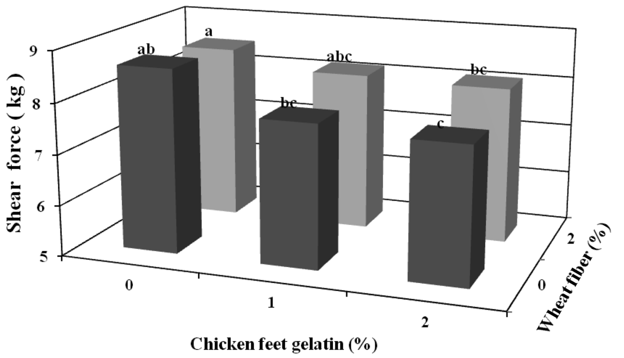

Fig. 4. Comparison on shear force of semi-dried chicken jerky prepared with chicken feet gelatin and wheat fiber levels. [a-c]Means values with different letters among the treatment are significantly different ($p<0.05$).

reported that jerky manufactured with rice bran fiber (Choi *et al*., 2009); paprika and Japanese apricot extracts (Oh *et al*., 2007); and pear, pineapple, and kiwi extracts (Yang, 2006) exhibited decreased tenderness. Kim and Lee (1988) found that hardness decreased as the lean meat to pork skin gelatin gel substitution ratio increased, and gelatin extracted at high temperature showed lower hardness than that extracted at low temperature. The jerky in this study was of the semi-dried type and was produced using ground chicken, so it had a lower shear force value than sliced whole muscle jerky products or low-moisture jerky products.

Sensory properties of semi-dried chicken jerky

The sensory properties of semi-dried chicken jerky prepared with various chicken feet gelatin and wheat fiber levels are shown in Table 4. The texture is the most important factor determining the sensory attributes, buying decisions, and market share of meat products such as jerky (Choi *et al*., 2008; Guerrero *et al*., 1999). The color score of semi-dried chicken jerky slightly decreased with increasing chicken feet gelatin content, and that of samples containing 2% wheat fiber was lower than of those without added wheat fiber. On the other hand, the tenderness of semi-dried chicken jerky slightly increased with increasing chicken feet gelatin content, and that of samples containing 2% wheat fiber was rather lower than of those without added wheat fiber. The observed flavor, tenderness, juiciness, and overall acceptability scores were between 7.73 and 8.93 points ($p>0.05$). The tenderness of jerky containing 2% wheat fiber was rather lower than that of jerky without added wheat fiber, and the result was consistent with that revealed by instrumental analysis. Few differences ($p>0.05$) were detected in the juiciness and overall acceptability of all jerky prepara-

Table 4. Comparison on sensory properties of semi-dried jerky prepared with chicken feet gelatin and wheat fiber

Traits	Treatments (%)						
	Gelatin	0		1		2	
	Fiber	0	2	0	2	0	2
Color		8.93±0.46[a]	8.20±1.01[b]	8.47±0.83[ab]	8.07±0.59[b]	8.60±0.51[ab]	8.07±0.70[b]
Flavor		8.33±0.82	8.20±0.77	8.27±0.70	8.13±0.74	8.13±0.64	8.13±0.74
Tenderness		8.00±1.00	7.80±1.01	8.27±0.88	7.80±1.08	8.40±0.51	8.20±0.41
Juiciness		8.13±0.92	7.87±0.83	7.93±0.80	7.73±1.03	7.80±0.86	7.80±0.94
Overall acceptability		8.33±0.72	7.93±0.70	8.20±0.68	7.87±0.64	7.93±0.96	7.87±0.64

All values are mean±SD of three replicates.
[a-b]Means within a row with different letters are significantly different (p< 0.05).

tions. Since the jerky used in the present study was ground and restructured, it appeared that the panel preferred semi-dried jerky with an instrumentally low shear force and high tenderness.

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