

Quality Evaluation of Chicken Nugget Formulated with Various Contents of Chicken Skin and Wheat Fiber Mixture

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Abstract

This study aimed to investigate the effects of various mixtures of the chicken skin and wheat fiber on the properties of chicken nuggets. Two skin and fiber mixtures (SFM) were prepared using the following formulations; SFM-1: chicken skin (50%), wheat fiber (20%), and ice (30%); and SFM-2: chicken skin (30%), wheat fiber (20%), and ice (50%). Chicken nugget samples were prepared by adding the following amounts of either SFM-1 or SFM-2: 0%, 2.5%, 5%, 7.5%, and 10%. The water content for samples formulated with SFM-1 or SFM-2 was higher than in the control ($p < 0.05$), and increased with increasing the concentrations of SFM-1 and SFM-2. The addition of SFM-1 and SFM-2 had no significant effect on the pH of the samples. The lightness value of uncooked chicken nuggets was higher than that of cooked chicken nuggets for all the samples tested. Chicken nuggets formulated with SFM-1 and SFM-2 displayed higher cooking yields than the control sample. The hardness of the control sample was also lower than the samples containing SFM-1 and SFM-2. The sensory evaluation showed no significant differences between the control and the samples containing SFM. Therefore, the incorporation of a chicken skin and wheat fiber mixture improved the quality of chicken nuggets.

Key words: chicken, nugget, skin, dietary fiber

Introduction

Chicken nuggets, a chicken products made usually from chicken breast, is a very common type of food, especially in Korea where chicken nuggets are served at large-scale catering. The surface appearance and texture of a nugget are the most significant factors for consumer acceptability. Most nuggets cook rapidly and develop a golden color, crisp texture, and good flavor at frying temperatures between 160 and 190°C. Instrumental measurement of the texture and color can offer a quantified basis for controlling the frying times and temperature for quality control and improvement. In general, a fried food becomes tougher when its frying time increases beyond

an optimum value. The amount of moisture lost during frying generally decreases exponentially with frying time because of mass transfer during the frying process owing to moisture loss and oil absorption. Costa and Oliveira (1999) reported that predicting water loss was critical for modeling and controlling the deep fat frying of potatoes. Interestingly, almost no oil penetrates the food during the frying process; instead, the majority of oil is absorbed by the fried food during the cooling period after it is removed from the fryer (Gamble *et al.*, 1987; Moreira *et al.*, 1995). Fried nuggets often contain a large quantity of oil and fat. However, consumer demand for low-fat and low-calorie products has been increasing, because the consumption of high animal fat content (especially saturated fatty acids and cholesterol) is correlated to an increased incidence of obesity, hypertension, cardiovascular disease, and coronary heart disease (Ozvural and Vural, 2008; Vural and Javidipour, 2002). Consumers prefer low-fat meat products with good flavor (Lin and

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Huang, 2008). The trend toward low-fat and low-calorie food has led the meat products industry to develop or modify traditional food products containing less animal fat (Bloukas and Paneras, 1993; Garcia *et al.*, 2002; Mittal and Barbut, 1994). Consistent with this trend, manufacturers have reduced the fat content of chicken nuggets, typically by using the dietary fiber and chicken skin.

Chicken skin, a by-product of the chicken meat, production process, is a potential water binder and texture-modifying agent for use in reduced-fat meat products. Improving the functionality (solubility) of chicken skin may increase its potential for use in meat products as a less expensive water binder or texture-modifying agent. Mechanical modification (Eilert and Mandigo, 1993), heating (Sadler and Young, 1993), and a combination of factors such as pH, salt, phosphates, and water (Park *et al.*, 2013; Puolanne and Ruusunen, 1981) have been employed to improve collagen solubility in chicken skin. Bonifer *et al.* (1996) reported that the removal of fat from chicken skin using sodium bicarbonate increased the protein content in bologna sausage.

Dietary fibers have been added to a range of meat products to improve the functional and rheological properties of the meat products (Choe *et al.*, 2013; Choi *et al.*, 2009). Kim *et al.* (2012) reported the addition of wheat fiber to semi-dried jerky to enhance its quality characteristics such as texture and drying yield. In addition, several studies have shown that dietary fiber can be used to improve the physicochemical properties of jerky, sausages, meat balls, and hamburgers (Choe *et al.*, 2013; Crehan *et al.*, 2000; Hughes *et al.*, 1997; Jiménez-Colmenero, 1996; Kim *et al.*, 2012; Mansour and Khalil, 1999; Nuria *et al.*, 1999; Thebaudin *et al.*, 1997). This study was conducted to assess the effect of chicken skin and wheat fiber mixtures (SFM) as a replacement for chicken skin on the quality properties of a chicken nugget, including proximate composition, cooking yield, pH, color, texture profile, and sensory evaluation.

Materials and Methods

Materials

The chicken breast and skin were provided by Maniker F&G Co., Ltd (Yongin, Korea). The subcutaneous fat and visible connective tissue were completely removed from the chicken breast and skin. The chicken breast and skin (2-3 kg) was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL, Jujee Tech, Korea), and stored at -21°C until required for

product preparation. The fiber used was wheat fiber Vita-cel® (J. Rettenmaier & 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 the experiments were performed in duplicate with at least three replicates. The results were expressed as the mean and standard deviation.

Preparation of chicken skin and fiber mixture

Suitable amounts of the chicken skin were tempered at 4°C for 4 h prior to preparing the chicken skin and fiber mixture. Two skin and fiber mixtures (SFM) were prepared with the following formulations: SFM-1: chicken skin (50%), wheat fiber (20%), and 30% ice (30%); and SFM-2: chicken skin (30%), wheat fiber (20%), and ice (50%). Two batches of SFM-1 and SFM-2 were prepared for each treatment. For each batch of the chicken skin, wheat fiber and ice were emulsified using a silent cutter (Nr-963009, Germany). Immediately after cutting, the SFM samples were stored in dark at 4°C until required for product manufacture.

Chicken nugget preparation and processing

Suitable amounts of the chicken breast and chicken skin were tempered at 4°C for 24 h prior to nugget batter preparation. The chicken breast and skin were initially ground through an 8 mm plate. Nine different nugget batters (each 5 kg) were produced; the experimental design and compositions are shown in Table 1. The binder chicken breast was homogenized and ground for 1 min in a silent cutter (Nr-963009, Germany), followed by cooling it in an iced water (2°C), 0.5% NaCl and 0.3% sodium tripolyphosphate were added to the binder chicken breast and mixed for 1 min. The chicken skin and SFM were added after 3 min, and the batter was homogenized for 6 min. A temperature probe (Kane-May, KM330, Germany) was used to monitor the emulsion temperature, which was maintained below 10°C during batter preparation. The chicken breast was then added to the chicken emulsion and mixed for 5 min. Spherical chicken nugget samples, each weighing 50 g, were then prepared. The frying oil was maintained at ±2°C of the set temperature (180°C) using a programmable temperature controller (Eutech Instrument Pte Ltd., Singapore). Fresh soy oil was preheated at 180°C for 30 min prior to normal frying and it was then used to fry the chicken nuggets for 5 min. After frying, the samples were immediately removed from the oil and blotted gently with dry tissue papers to remove

Table 1. Chicken nugget formulation with various chicken skin and wheat fiber mixture

Ingredients	CON	Treatment								
		SFM-1 ¹⁾				SFM-2 ²⁾				
		2.5%	5%	7.5%	10%	2.5%	5%	7.5%	10%	
Chicken breast (%)	70	70	70	70	70	70	70	70	70	
Binder chicken breast (%)	17	17	17	17	17	17	17	17	17	
Main	Chicken skin (%)	10	7.5	5	2.5	-	15	10	5	-
	SFM-1 (%)	-	2.5	5	7.5	10	-	-	-	-
	SFM-2 (%)	-	-	-	-	-	2.5	5	7.5	10
	Ice (%)	3	3	3	3	3	3	3	3	3
Additive	NaCl (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Sodium tripolyphosphate (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3.

²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

the excess oil from their surfaces. The samples were allowed to cool to room temperature before further tests were conducted.

Compositional properties

The compositional properties of the chicken nuggets were analyzed using AOAC (2000). The moisture content was determined by weight loss after drying the nuggets for 12 h at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Korea). The fat content was determined by the Soxhlet method using a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Sweden) and the protein content was determined by the Kjeldahl method using an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Sweden). The ash content was determined by the AOAC method 923.03.

pH

First, a 5 g sample of the prepared chicken nugget was ground and homogenized with distilled water (20 mL) for 1 min (Ultra-Turrax® T25, Janke & Kunkel, Germany), and the pH was measured using a pH meter (Model 340, Mettler-Toledo GmbH Analytical, Switzerland). All determinations were performed in triplicate, and the results are expressed as the mean and standard deviation.

Color evaluation

Color measurements were taken using a colorimeter (Chroma meter CR-210, Minolta, Japan; illuminate C, calibrated using white standard plate $L^*=97.83$, $a^*=-0.43$, $b^*=+1.98$), with a measuring area of 8 mm diameter. Color evaluation (CIE L^* , a^* , and b^*) was measured on the surface of the chicken nugget samples with results taken in triplicate for each sample and the results are

expressed as the mean and standard deviation.

Cooking yield

The chicken nugget (initial weight) was fried at 180 ± 2 °C for 5 min, during which time, the core temperature of the samples reached 80 ± 1 °C. The fried samples were allowed to cool for 1 h, weighed (frying weight), and the percentage cooking yield calculated from the weights.

$$\text{Cooking yield (\%)} = \left(\frac{\text{frying weight}}{\text{initial weight}} \right) \times 100$$

Texture profile analysis (TPA)

The texture profile analysis (TPA) of each sample was performed in duplicate. The textural properties for each sample were measured using a cylinder probe (ϕ 50 mm diameter), set attached to a Texture Analyzer (TA-XT2i, Stable Micro System Ltd., UK). The test conditions were as follows: stroke, 2 kg; test speed, 2.0 mm/s; distance, 8 mm. The texture profile analysis (TPA) parameters, namely hardness [peak force on first compression (kg)], springiness [ratio of the sample recovered after the first compression], cohesiveness [ratio of active work done under the second force-displacement curve to that done under the first compression curve], gumminess [hardness (kg) \times cohesiveness], and chewiness [hardness \times cohesiveness \times springiness (kg)] were calculated.

Sensory evaluation

Twelve panelists were selected from a group of 15 potential panelists using basic taste identification tests. Each chicken nugget was evaluated in terms of color, flavor, juiciness, tenderness, and overall acceptability. The samples were served to 12 experienced panel members. The panelists were presented with randomly coded sam-

ples. 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. The panelists were also required to cleanse their palates with water between tasting the samples (Keeton, 1983).

Statistical analysis

An analysis of variance was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Inst., 2008). The Duncan's multiple range test with $\alpha=0.05\%$ was used.

Results and Discussion

Approximate composition of chicken nugget

The approximate composition of a chicken nugget formulated with various chicken skin and wheat fiber mixture (SFM) levels (2.5%, 5%, 7.5%, and 10%) is shown in Table 2. The water content of chicken nuggets formulated with SFM-1 and SFM-2 was higher than that of the control ($p<0.05$), and increased with an increase in the SFM-1 and SFM-2 concentration. This was attributed to the presence of the wheat fiber and chicken skin mixture in the samples (SFM-1 and SFM-2); this result might be associated with the high water holding capacity and low fat absorption properties of wheat fiber (Choi *et al.*, 2009; Osburn and Mandiso, 1998). Choe *et al.* (2013) and Lee *et al.* (2008) reported that fiber and skin gelatin resulted in a high water holding capacity. Our results were similar to those obtained by An *et al.* (2010) for semi-dried pork

jerky made using kimchi powder which contains high concentrations of dietary fiber. The protein content was not significantly different between the control and the SFM-1 and SFM-2 containing samples. The fat content in samples formulated with SFM-1 and SFM-2 was lower than that found in the control sample ($p<0.05$). The addition of an SFM reduced the fat content by increasing the water content of the chicken nugget. A similar trend was previously reported previously for various types of meat products made with dietary fiber or skin gelatin, such as frankfurters (Choe *et al.*, 2013; Choi *et al.*, 2009), breakfast sausages (Lee *et al.* 2008), jerky (Hughes *et al.*, 1997; Kim *et al.*, 2012), and bologna sausage (Osburn and Mandiso, 1998). The ash content in the samples formulated with SFM-1 and SFM-2 was higher than that in the control ($p<0.05$), because wheat fiber contains ash (Choi *et al.*, 2011). Choe *et al.* (2009) and Lee *et al.* (2008) observed that the ash content of liver and breakfast sausages increased with an increase in *kimchi* powder concentration.

pH value and color evaluations of chicken nugget

The pH, lightness (L^*), redness (a^*), and yellowness (b^*) values of chicken nuggets formulated with various amounts of SFM (2.5%, 5%, 7.5%, and 10%) are shown in Table 3. The pH of an uncooked nugget ranged from 6.30 to 6.38, whereas that of a cooked nugget ranged from 6.48 to 6.51. The addition of SFM-1 and SFM-2 had no significant effect on the pH of the cooked chicken nugget samples. Yoo *et al.* (2007) reported that the pH was not significantly altered for comminuted sausages with various fat levels and fat replacers. The pH of the uncooked chicken nugget was lower than that of the cooked chicken nugget in all the samples. Kim *et al.*

Table 2. Proximate composition of chicken nugget formulation with various chicken skin and wheat fiber mixture

Properties	CON	Treatment							
		SFM-1 ¹⁾				SFM-2 ²⁾			
		2.5%	5%	7.5%	10%	2.5%	5%	7.5%	10%
Water content (%)	61.95±0.67 ^f	62.54±0.58 ^{ef}	63.41±0.48 ^d	64.48±0.57 ^c	64.26±0.24 ^c	63.07±0.93 ^{de}	64.61±0.31 ^c	65.29±0.14 ^b	66.06±0.02 ^a
Protein content (%)	27.36±0.47 ^a	27.17±0.16 ^{ab}	27.36±0.32 ^a	26.41±0.06 ^{bc}	25.44±0.06 ^d	27.16±1.63 ^{ab}	26.41±0.03 ^{bc}	26.29±0.25 ^c	25.13±0.28 ^d
Fat content (%)	11.61±0.13 ^a	10.81±0.02 ^b	9.57±0.12 ^c	8.77±0.05 ^d	7.61±0.23 ^f	8.46±0.27 ^e	7.57±0.17 ^f	7.33±0.20 ^f	6.40±0.61 ^g
Ash content (%)	1.82±0.07 ^d	1.89±0.01 ^c	1.97±0.04 ^b	1.99±0.01 ^b	2.06±0.05 ^a	1.89±0.07 ^c	1.94±0.01 ^{bc}	1.94±0.07 ^{bc}	1.99±0.01 ^b

All values are mean ± standard deviation of three replicates.

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

¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3.

²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

Table 3. pH value and CIE L, a, b value of chicken nugget formulation with various chicken skin and wheat fiber mixture

Properties	CON	Treatment								
		SFM-1 ¹⁾				SFM-2 ²⁾				
		2.5%	5%	7.5%	10%	2.5%	5%	7.5%	10%	
Uncooked	pH	6.36±0.02 ^a	6.37±0.02 ^a	6.37±0.02 ^a	6.38±0.03 ^a	6.38±0.03 ^a	6.30±0.02 ^b	6.30±0.01 ^b	6.30±0.03 ^b	6.31±0.02 ^b
	L*-value	78.52±1.05 ^a	76.22±1.95 ^b	74.65±1.06 ^{bc}	74.57±0.61 ^{bc}	73.98±0.78 ^c	70.53±1.03 ^d	66.12±1.06 ^f	68.59±3.01 ^e	66.26±2.92 ^f
	a*-value	4.11±0.41 ^{abc}	4.55±0.58 ^a	4.07±0.33 ^{abc}	4.29±0.57 ^{ab}	4.15±0.33 ^{abc}	2.98±0.29 ^d	3.75±0.46 ^{bc}	3.56±1.00 ^c	3.64±0.44 ^c
	b*-value	15.10±1.47 ^a	15.96±0.86 ^a	15.14±0.83 ^a	15.26±1.15 ^a	16.00±0.29 ^a	12.48±0.81 ^{bc}	11.35±1.38 ^c	12.84±1.14 ^b	11.83±1.16 ^{bc}
Cooked	pH	6.51±0.03	6.49±0.02	6.47±0.02	6.50±0.03	6.48±0.02	6.51±0.03	6.49±0.02	6.48±0.02	6.50±0.01
	L*-value	73.87±0.83 ^a	71.07±1.05 ^{bc}	71.91±1.02 ^b	71.64±1.39 ^{bc}	70.75±1.89 ^{bc}	69.96±1.64 ^{cd}	70.06±1.67 ^{cd}	68.32±2.20 ^d	68.35±1.61 ^d
	a*-value	4.50±0.84 ^d	4.74±0.74 ^d	4.75±0.59 ^d	4.99±0.61 ^{cd}	5.68±0.88 ^{bc}	6.15±0.43 ^b	6.19±0.60 ^b	7.54±1.00 ^a	7.53±0.38 ^a
	b*-value	35.48±1.02 ^d	36.56±1.36 ^{cd}	36.04±1.33 ^d	36.66±1.06 ^{cd}	37.61±2.28 ^c	41.98±0.61 ^b	43.05±0.84 ^{ab}	43.89±0.70 ^a	43.98±1.15 ^a

All values are mean ± standard deviation of three replicates.

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

¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3.

²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

(2010) reported that the pH of cooked meat batter was higher than that of uncooked meat batters formulated with various bamboo salts. Several studies have reported that the pH of meat batter increases during cooking because of the release of imidazolium, the basic R group, from the amino acid histidine upon heating (Choi *et al.*, 2009; Choe *et al.*, 2013; Kim *et al.*, 2010).

The lightness value of the uncooked chicken nugget was higher than that of the cooked chicken nugget in all the samples. Also, the addition of SFM-1 and SFM-2 resulted in decreased lightness values of the cooked chicken nugget. Ngadi *et al.* (2007) found that the lightness value of fried chicken nuggets decreased on increasing of the frying time. Additionally, Ramirez *et al.* (2004) reported differences in the lightness of pork loin chops fried in olive oil, sunflower oil, butter, and pig lard. The highest lightness value for cooked chicken nuggets was observed for the control, and reducing the amount of

chicken skin decreased the lightness of the cooked chicken nugget. The addition of SFM-1 and SFM-2 resulted in increased redness and yellowness values of the cooked chicken nugget. Ngadi *et al.* (2007) reported that the redness and yellowness value increased with the frying time and the degree of oil hydrogenation. However, redness in fried food products such as fried chicken and chicken nugget is not desirable (Krokida *et al.*, 2001).

Cooking yield of chicken nugget

The cooking yield of chicken nugget formulated with various amounts of SFM (2.5%, 5%, 7.5%, and 10%) is shown in Fig. 1. Chicken nuggets containing SFM-1 and SFM-2 displayed a higher cooking yield (ranging from 83.90 to 85.31 and 83.09 to 84.59, respectively) than the control. A similar observation was reported by Choe *et al.* (2013) with frankfurters containing a pork skin and wheat fiber mixture. This was attributed to a reduction in oil

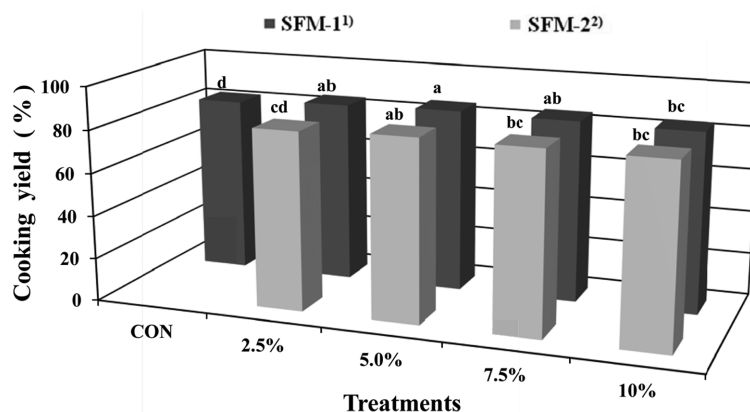


Fig. 1. Cooking yield of chicken nugget formulation with various chicken skin and wheat fiber mixture. ^{a-d}Means values with different letters among the treatment are significantly different ($p < 0.05$). ¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3. ²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

absorption and increase in moisture retention by the SFM during the frying process. The wheat fiber contained in SFM reduced oil absorption and increased moisture absorption in frying food; this is due to hydrogen bonding between water molecules and wheat fiber which inhibit the displacement of water by oil for frying (Fizman and Salvador, 2003). Eilert and Mandigo (1993) reported that the cooking yield of meat products containing beef connective tissue were higher than that of the control because of a high collagen and gelatin content in the beef connective tissue. In addition, Ang (1993) reported increased moisture content and decreased fat content in fried batter coating upon the addition of cellulose powder. Similar trends in cooking yield were observed in studies involving the addition of dietary fibers or gelatin to meat products such as jerky (Kim *et al.*, 2012), low-fat meat emulsion (Choi *et al.*, 2009), and breakfast sausage (Lee *et al.*, 2008). Previous studies have reported that various types of dietary fiber (alone or in combination) and gelatin could be used to increase the cooking yield and improve the texture of meat products (Choi *et al.*, 2009; Kim *et al.*, 2012; Turhan *et al.*, 2005).

Textural properties and sensory evaluation of chicken nugget

The textural properties of chicken nuggets formulated with various amounts of SFM (2.5%, 5%, 7.5%, and 10%) are listed in Table 4. TPA analysis is important to examine the textural properties upon protein denaturation after the cooking process. The hardness of the control was lower than that of the samples containing SFM-1 and SFM-2 and because of increased wheat fiber content. This result may be due to increase in added level of wheat fiber within SFM. Additionally, the reduced fat content could affect decrease in hardness of chicken nugget. Similar results were observed by Choe *et al.* (2013), who

showed that increasing the level of pork skin and wheat fiber mixture increased the hardness value of frankfurters. Vural *et al.* (2004) showed that the addition of sugar beet fiber increased the hardness values of various meat batters. Saldler and Young (1993) observed that the hardness value decreased for cooked emulsion sausages containing pre-heated beef tendons. The springiness in chicken nuggets supplemented with SFM-1 and SFM-2 ranged from 0.89 to 0.95. The cohesiveness, gumminess, and chewiness values were the highest for chicken nugget containing 10% SFM-2. The cohesiveness of nuggets containing fat levels below 12-14% was lower because the fat was replaced mainly by water. Similar effects have been reported for changes in the content of fat, salt, pH, fiber, and gelatin on the textural properties of low-fat sausages (Choe *et al.*, 2013; Matulis *et al.*, 1995).

The sensory evaluation results of chicken nugget formulated with various amounts of SFM (2.5%, 5%, 7.5%, and 10%) are listed in Table 5. The color, flavor, tenderness, juiciness, and overall acceptability scores of the control were only slightly higher than those of others samples, but there were no significant differences among all the samples containing SFM-1 and SFM-2. These results agree with those reported by Choe *et al.* (2013), who noted significantly higher scores in frankfurter sausage on the addition of pork skin and wheat fiber mixture. In addition, Kim *et al.* (2012) showed that flavor, tenderness, juiciness, and overall acceptability score were not significantly observed jerky containing chicken feet and wheat fiber. The overall acceptability score of the chicken nugget with SFM ranged between 7.94 and 8.63. This score was slightly decreased with increasing the levels of SFM-1 and SFM-2. Therefore, the addition of SFM-1 and SFM-2 did not deteriorate the sensory properties.

In conclusion, the use of a chicken skin and wheat fiber mixture (SFM) as a chicken skin substitute improved the

Table 4. Texture properties of chicken nugget formulation with various chicken skin and wheat fiber mixture

Properties	CON	Treatment							
		SFM-1 ¹⁾				SFM-2 ²⁾			
		2.5%	5%	7.5%	10%	2.5%	5%	7.5%	10%
Hardness (kg)	1.46±0.11 ^d	1.49±0.09 ^d	1.54±0.09 ^{cd}	1.79±0.10 ^b	1.99±0.18 ^a	1.46±0.11 ^d	1.53±0.11 ^{cd}	1.63±0.09 ^c	1.75±0.12 ^b
Cohesiveness	0.41±0.07 ^{ab}	0.43±0.03 ^{ab}	0.43±0.03 ^{ab}	0.42±0.03 ^{ab}	0.40±0.02 ^b	0.42±0.07 ^{ab}	0.43±0.05 ^{ab}	0.41±0.06 ^{ab}	0.45±0.03 ^a
Gumminess (kg)	0.59±0.07 ^c	0.64±0.07 ^{bc}	0.66±0.07 ^{bc}	0.74±0.05 ^a	0.80±0.08 ^a	0.60±0.09 ^c	0.65±0.08 ^{bc}	0.67±0.07 ^b	0.78±0.09 ^a
Springiness	0.91±0.06 ^{bc}	0.89±0.04 ^{cd}	0.89±0.05 ^{cd}	0.86±0.03 ^d	0.85±0.05 ^d	0.95±0.06 ^a	0.96±0.04 ^a	0.95±0.04 ^a	0.93±0.07 ^{ab}
Chewiness (kg)	0.54±0.08 ^d	0.57±0.06 ^{cd}	0.58±0.07 ^{cd}	0.64±0.04 ^{bc}	0.68±0.07 ^{ab}	0.57±0.10 ^{cd}	0.62±0.09 ^{bc}	0.64±0.09 ^{bc}	0.73±0.10 ^a

All values are mean ± standard deviation of three replicates.

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

¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3.

²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

Table 5. Sensory evaluation of chicken nugget formulation with various chicken skin and wheat fiber mixture

Properties	CON	Treatment							
		SFM-1 ¹⁾				SFM-2 ²⁾			
		2.5%	5%	7.5%	10%	2.5%	5%	7.5%	10%
Color	9.25±0.46	9.13±0.35	9.13±0.35	9.13±0.64	9.25±0.46	9.38±0.52	9.13±0.64	9.25±0.46	9.25±0.46
Flavor	9.00±0.53	9.13±0.35	9.13±0.35	9.13±0.35	9.13±0.35	9.13±0.83	9.13±0.83	8.75±0.89	9.00±0.76
Tenderness	8.38±0.52	8.38±0.52	8.00±0.53	8.00±0.53	7.75±1.04	8.25±0.71	7.63±0.74	8.13±0.83	8.13±1.13
Juiciness	8.25±0.71	8.25±0.71	8.00±0.53	8.13±0.64	7.75±1.04	8.13±0.64	7.88±0.64	8.06±1.15	8.13±1.25
Overall acceptability	8.44±1.12	8.50±0.53	8.25±0.46	8.38±0.52	7.94±0.94	8.63±0.92	8.38±0.52	8.44±0.73	8.44±1.05

All values are mean ± standard deviation of three replicates.

¹⁾Formulation ratio of skin and fiber mixture-1 is chicken skin: wheat fiber: ice = 5: 2: 3.

²⁾Formulation ratio of skin and fiber mixture-2 is chicken skin: wheat fiber: ice = 3: 2: 5.

physicochemical properties of the chicken nugget. The SFM has a greater water holding capacity. Therefore, the incorporation of an SFM improved cooking yield and texture profile and decreased fat contents of chicken nugget. Thus, SFM can replace the chicken skin replacer in the chicken nugget industry.

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