



Combined Effects of Wheat Sprout and Isolated Soy Protein on Quality Properties of Breakfast Sausage

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Abstract

The objective of this study was to investigate the effects of different concentrations of WSP (wheat sprout powder) and ISP (isolated soy protein) on the quality of breakfast sausage. Treatments were formulated as follows: Control, T1 (2.0% ISP), T2 (1.5% ISP + 0.5% WSP), T3 (1.0% ISP + 1.0% WSP), T4 (0.5% ISP + 1.5% WSP) and T5 (2.0% WSP). The treatments were analyzed for color, pH, cooking loss, emulsion stability, protein solubility, viscosity, texture properties and sensory evaluation. Lightness and redness were reduced and yellowness was increased as increased level of WSP, due to the dark green color of WSP ($p < 0.05$). The pH values of all samples were affected by WSP which has lower pH ($p < 0.05$). The emulsion stability and cooking loss of treatments were improved with increasing level of WSP ($p < 0.05$). The protein solubility, viscosity and overall texture properties of the sausage indicated significant differences in relation to the level of WSP and ISP ($p < 0.05$). The sensory evaluation indicated that the greatest flavor and overall acceptability in sausage was achieved at WSP 1% combination with ISP 1% (T3) ($p < 0.05$). Therefore, these results indicate that breakfast sausage containing 1% WSP and 1% ISP is the optimal formulation, taking into consideration the overall physico-chemical properties and sensory evaluation.

Keywords WSP, ISP, physico-chemical property, sensory evaluation, breakfast sausage

Received August 22, 2016
Revised December 7, 2016
Accepted December 22, 2016

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Introduction

Isolated soy protein (ISP), made up of more than 90% non-meat protein, is commonly used in meat processing industry, especially in the production of emulsion-type sausages, hamburger patties and restructured meat products (Hsu, 2006; Kim *et al.*, 2009; Lee *et al.*, 2003; Rao *et al.*, 1984). ISP has been shown to improve various functional properties, including emulsion stability and water-holding capacity (Choi *et al.*, 2007; Mittal and Osborne, 1985). However, excessive use of ISP has been shown to lower the quality of some meat products, resulting in an undesirable odor in frankfurters (Lecomte *et al.*, 1993). In some countries of Europe, utilizing amounts of ISP has been regally restraint to prevent deterioration of meat products (Park *et al.*, 1998). Furthermore, ISP used in meat industry of Korea highly depends on imported materials for improving yield of commercial meat products (Kim *et al.*, 2009). Therefore, meat processing industries are search-

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ing for alternative to ISP.

Wheat sprout, which is an immature bud that develops prior to germination, is rich in several desirable nutrients (Hänninen *et al.*, 1999). According to RDA (Rural Development Administration, 2009) report, wheat sprout has approximately 29% protein and 37% dietary fiber, and it contains high levels of amino acids, vitamins, and other minerals, including chlorophyll, calcium, folic acid, and iron (Park, 2015). Other studies have investigated the pharmacological potential of wheat sprout, showing it has antioxidant, hypoglycemic, anti-carcinogenic, and anti-inflammatory properties (Cazuola *et al.*, 2004; Eddouks, 2005; Kulkarni *et al.*, 2006; Tudek *et al.*, 1998; Watzl, 2008). Because of these health-promoting characteristics, wheat sprout is currently widely consumed in juice or tablet form (Kulkarni *et al.*, 2006). Recently, several studies concerning physicochemical effects of wheat sprout powdered have been conducted in muffins, cakes, and noodles (Kim *et al.*, 2005; Lee, 2015; Park, 2015). These studies have shown that the addition of wheat sprout can improve the quality characteristics of muffins cakes, and noodles, specifically texture and water retention capacity (Kim *et al.*, 2005; Lee, 2015; Park, 2015).

There have been a lot of studies to utilize ISP and other non-meat ingredient, such as carrageenan or konjac for reduced-fat sausages, wheat fiber singly or combined with ISP in meat batter or frankfurters to substitute ISP (Choi *et al.*, 2002; Choi *et al.*, 2007; Kim *et al.*, 2009; Pietrasik and Duba, 2000). However, no study has examined the use of WSP as an additive in meat products except for one study that only evaluated physicochemical properties, especially focused on the antioxidant activity, in beef patties containing WSP on storage (Ozturk *et al.*, 2014). Thus, there is a need to conduct a study for physicochemical and

quality properties of meat products containing WSP singly or combined with ISP which is one of the quality enhancing additives in meat products.

Therefore, in this study, we have investigated quality characteristics of breakfast sausages with WSP singly or combined with ISP for replacement of ISP and being the basic study for applying the combination of WSP and ISP to improve quality characteristics in meat products.

Materials and Methods

Preparation and breakfast sausage processing

Fresh pork ham (Landrace × Yorkshire × Duroc; approximately 110 kg, *M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus*) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor at 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from the fresh muscle. Lean meat and back fat were initially ground through 8 mm plate using a meat grinder (PM-70, Mainca, Spain). The ground tissue was then placed in polyethylene bags, vacuum-packaged using a vacuum packaging system and stored at 0°C until required for product manufacturing. Six different ratios of isolated soy protein (ISP; moisture: 5.6%; fat: 0.2%; protein: 86.43%; ash: 3.86%; L*-value: 88.70; a*-value: -0.54; b*-value: 14.42; pH: 7.52) and wheat sprout powder (WSP; moisture: 2.48%; fat: 5.47%; protein: 30.36%; ash: 0.95%; dietary fiber: 39.87; L*-value: 59.46; a*-value: -6.12; b*-value: 23.43; pH: 5.82) were applied in breakfast sausages, and the experimental design of breakfast sausages are given Table 1. The first breakfast sausage served as control, with 1.5% NaCl and without ISP and WSP. The following treatments with ISP and/or WSP were used; T1: 2% ISP, T2:

Table 1. Formulations of breakfast sausage with different ratio of WSP and ISP

Ingredients (units: %)	Treatments ¹⁾					
	Control	T1	T2	T3	T4	T5
Pork meat	50	50	50	50	50	50
Ice	25	25	25	25	25	25
Back fat	25	25	25	25	25	25
Total	100	100	100	100	100	100
Sodium chloride (NaCl)	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
ISP	-	2.0	1.5	1.0	0.5	-
WSP	-	-	0.5	1.0	1.5	2.0

¹⁾Treatments: Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

1.5% ISP + 0.5% WSP, T3: 1.0% ISP + 1.0% WSP, T4: 0.5% ISP + 1.5% WSP, T5: 2% WSP. The lean materials were homogenized and ground for 1 min 30 s in a silent cutter (Cutter Nr-963009, Hermann Scharfen GmbH & Co., Germany). Pork back fat, NaCl, sodium tripolyphosphate (0.5%) and each different ratio of ISP and WSP were added to the meat and mixed for 1 min 30 s. The meat batters were homogenized for 3 min. The final temperature was below 10°C. After emulsification, the batters were shoved into collagen casings (#240, NIPPI Inc., Japan; approximate diameter of 25 mm) using a stuffer (Stuffer IS-8, Sirman, Italy). The meat batters were cooked to 80°C for 30 min in a chamber (Model MAXi3501, Kerres, Germany), and then the cooked sausages were cooled (21°C) for 3 h. Then, the cooled sausages were used for analyzing physicochemical, textural and sensory properties in triplicated.

Proximate composition

Compositional properties of breakfast sausages were performed using AOAC (2007). Moisture content (950.46B) was measured 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 205 Auto System, Foss Tecator AB, Sweden). Protein content (981.10) was determined by Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Sweden). Ash was determined according to AOAC method 920.153 (muffle furnace).

pH

Each 5 g of raw batter and cooked breakfast sausage was homogenized in a homogenizer (Ultra-Turrax T25, Janke and Kunkel Staufen, Germany) with 20 mL distilled water. The pH of those homogenates were determined with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). All determinations were performed in triplicate.

Color evaluation

The color of raw batters and cooked breakfast sausages were measured using a colorimeter (Minolta Chroma meter CR-210, Japan; illuminate C, calibrated with white plate, $L^* = +97.83$, $a^* = -0.43$, $b^* = +1.98$). Six measurements were obtained in each of five replicated. CIE L^* (lightness), CIE a^* (redness), and CIE b^* (yellowness) values were recorded.

Cooking loss

Each raw batter was stuffed into a collagen casing and cooked at 80°C for 30 min. Cooking loss was determined by calculating the weight differences before and after heating as following equation.

$$\text{Cooking loss (\%)} = \frac{[(\text{weight of raw batter (g)} - \text{weight of cooked breakfast sausage (g)}) / \text{weight of raw batter (g)}] \times 100}$$

Emulsion stability

The meat batters of emulsion systems were analyzed for emulsion stability using the method of Blouka and Honikel (1992) with the following modifications. At the middle of a 15 mesh sieve, pre-weighed graduated glass tubes were packed with meat batter. The glass tubes were enveloped and heated in a boiling water bath to a core temperature of $75 \pm 1^\circ\text{C}$ for 30 min. After cooling to approximately $4 \pm 1^\circ\text{C}$ to facilitate fat and water layer separation, the total expressible fluid and fat separated in the bottom of graduated glass tube were measured calculated (Choi *et al.*, 2007).

$$\text{Water released (\%)} = \frac{[\text{the water layer (mL)} / \text{weight of raw meat batter (g)}] \times 100}$$

$$\text{Fat released (\%)} = \frac{[\text{the fat layer (mL)} / \text{weight of raw meat batter (g)}] \times 100}$$

Protein solubility

Protein solubility was measured using the modification of method of Joo *et al.* (1999). The sarcoplasmic protein solubility was determined by dissolving 2 g of raw meat emulsion in 20 mL of ice-cold 25 mM potassium phosphate buffer (pH 7.2). Then, the samples and buffer were homogenized on ice, (Model AM-7, Nihonseiki Kaisha Ltd., Japan) and were left to position on a shaker at 4°C overnight. Each mixture was centrifuged at 6,000 g for 15 min, and the supernatant protein concentrations determined using the Biuret method (Gornall *et al.*, 1949). The total protein solubility was determined by homogenizing 2 g of meat batter emulsion in 20 mL of ice-cold 1.1 mol/L potassium iodide in 100 mol/L phosphate buffer (pH 7.2). The procedures for homogenization, shaking, centrifugation, and protein determination were as described above. Myofibrillar protein solubility was obtained by calculating the difference between total and sarcoplasmic protein solubilities.

Texture profile analysis (TPA)

Texture profile analysis (TPA) was followed by the method of Choi *et al.* (2010). Texture measurements in the form of texture profile analysis were performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems, England). Breakfast sausage samples were taken from the central portion of each sausage with sized 2.5×2.0 cm (diameter \times length). Prior to TPA, samples were allowed to be cooled to room temperature (20°C, 3 h). The conditions of texture analysis were as follows: pre-test speed 2.0 mm/s, post-test speed 4.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 10.0 mm, force 5 g. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (*N*), springiness, cohesiveness, gumminess (*N*), and chewiness (*N*) were determined as described (Bourne, 1978).

Apparent viscosity

Apparent viscosity of meat batter was measured with a rotational viscometer (HAKKE Viscotester® 500, Thermo Elctron Corporation, Germany) set at 10 rpm in triplicated. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with meat batter and allowed to rotate under a constant share rate at 1/s for 30 s before each reading was taken. Apparent viscosity values in cp were determined. The temperature of each sample at the time (18±1°C) of viscosity testing was also recorded (Shand, 2000).

Sensory evaluation

Each breakfast sausage was evaluated in terms of color, flavor, texture, juiciness, and overall acceptability. The trained sensory panel consisted of 10 researchers from the department of food sciences and biotechnology of animal resources at Konkuk University in Korea. Breakfast sausages were cooked a center temperature of 75°C, and the

cooked samples were cooled to room temperature at 21°C, cut into quarters by 1 cm length and served randomly to the panelists. Sensory evaluations were performed by the panelists under fluorescent lighting. Panelists were instructed to cleanse their palates between samples using water. The color (1=extremely undesirable, 10=extremely desirable), appearance (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), salty taste (1=much too weak, 10=much to intense), and overall acceptability (1=extremely undesirable, 10=extremely desirable) of the cooked samples were evaluated using a 10 point descriptive scale, using hedonic test (Bergara-Almeida and da Silva, 2002).

Statistical analysis

All tests were done three times for each experimental condition, and mean values were reported. The statistical analysis of all data was performed by SPSS Ver. 20.0 (SPSS Inc., USA). The one-way ANOVA (one-way analysis of variance) and Duncan's multiple range tests were used to find the differences among treatments ($p < 0.05$).

Results and Discussion

Proximate composition

The proximate composition of breakfast sausage with various ratio of WSP and WSP is shown in Table 2. The highest moisture contents were observed in the T5 treatment compared to the other treatments ($p < 0.05$). Chung and An (2015) found a similar increase in moisture content in muffins that were formulated with up to 6%. According to RDA (2009), there were high contents of fiber (37 g of 100 g) in wheat sprout that could be a critical role in water-holding capacity. The protein content in the control were lower than the other treatments ($p < 0.05$). Accord-

Table 2. The proximate composition of breakfast sausage with different ratio of WSP and ISP

	Control	T1	T2	T3	T4	T5
Moisture (%)	61.12±0.81 ^f	62.16±0.58 ^c	62.56±0.76 ^d	63.47±0.42 ^c	63.97±0.23 ^b	64.68±0.34 ^a
Protein (%)	12.27±1.72 ^c	13.86±0.70 ^b	14.30±0.97 ^a	14.27±0.98 ^a	14.40±1.22 ^a	14.15±1.04 ^a
Fat (%)	21.49±0.55	21.16±0.79	21.58±0.79	21.00±0.87	21.78±1.10	21.50±0.32
Ash (%)	1.87±0.13	1.92±0.23	1.96±0.13	1.86±0.22	1.99±0.10	1.91±0.03

All values are mean \pm standard deviation of three replicates (n=9).

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

¹⁾Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

ding to RDA (2009), high content of protein (proximately 29%) exist in wheat sprout. Therefore, treatments formulated with WSP and ISP resulted higher protein content as compared to the control. The fat and ash contents were not significantly different at all treatments ($p>0.05$). This is because the added fat contents were same, and WSP and ISP would not affect the ash content (Choi *et al.*, 2015).

pH and color evaluation

Table 3 shows the pH, lightness (L^* -value), redness (a^* -value), and yellowness (b^* -value) values of uncooked and cooked breakfast sausages. The pH of uncooked sausages ranged from 6.10 to 6.20, and that of cooked sausages ranged from 6.25 to 6.33. The T1 treatment had the highest pH for both uncooked and cooked ($p<0.05$) due to the high pH (7.52) of ISP. According to Chin (1999), the addition of ISP makes the pH of final product be increased. Frankfurters made with ISP also had high pH level than those not manufactured with ISP (Decker *et al.*, 1986). From treatment T1 to T5, the pH decreased in both uncooked and cooked breakfast sausages, as the amount of ISP decreased and the amount of WSP increased ($p<0.05$). These results also agreed with that reported by Chung and An (2015), who showed that the pH of muffins decreased with increasing amounts of WSP. Also, the pH value of cookies with added WSP had shown to be less than that of cookies without added WSP (An, 2015). These similar outcomes are likely due to the low pH (5.63) of wheat sprout.

The addition of ISP and WSP affected the color attributes (L^* , a^* , and b^* -value) of breakfast sausages. The T1 treatment had higher than all treatments in lightness value ($p<0.05$), due to the addition of ISP. Cho *et al.* (1990) found that the addition of ISP to sausages resulted

increase in lightness because of the brightness of ISP as compared to meat protein. The T5 treatment had the lowest value of lightness, redness and the highest in yellowness ($p<0.05$). According to Chung and An (2015), the lightness and redness of muffins were decreased and the yellowness was increased as WSP level increased in muffins. These effects were also reported in cookies with added WSP (An, 2015). However, Ozturk *et al.* (2014) found beef patties manufactured with WSP had lower lightness and higher redness and yellowness than the control. These differences in redness between this previous study and our study might be due to a different kind of wheat sprout used in beef patties.

Cooking loss and emulsion stability

Cooking loss in breakfast sausages with WSP and ISP is shown in Fig. 1. The cooking loss of the control was higher than that of the other treatments ($p<0.05$). The addition of WSP in combination with ISP significantly reduced the cooking loss of breakfast sausage as compared to those only formulated with ISP ($p<0.05$). According to Park *et al.* (1995), the emulsion-type sausages with ISP had the reduced loss of moisture content, due to high water holding capacity of ISP. Also, Cooking loss of frankfurter-type sausages containing ISP has also been shown to be lower than those without ISP (Kim *et al.*, 2009). Furthermore, the addition of WSP to cookies, muffins, and sponge cakes significantly increased the moisture content of the finished products (An, 2015; Lee, 2015; Park, 2015). This was likely due to high level of dietary fiber (37%) in wheat sprout that allows it to absorb an increase volume of water (RDA, 2009). Therefore, these results indicated that wheat sprout, which had a greater water-holding capacity, effectively reduced cook-

Table 3. pH and color parameters of breakfast sausage with different ratio of WSP and ISP

Parameters		Control ¹⁾	T1	T2	T3	T4	T5
Uncooked	pH	6.18±0.01 ^c	6.24±0.01 ^a	6.19±0.01 ^b	6.15±0.01 ^d	6.13±0.01 ^c	6.10±0.01 ^f
	L^* -value	73.07±0.70 ^b	75.18±0.98 ^a	69.54±1.07 ^c	61.43±0.96 ^d	61.01±1.44 ^d	59.38±1.07 ^e
	a^* -value	13.05±0.76 ^a	12.03±0.62 ^b	2.58±0.22 ^c	-0.23±0.38 ^d	-2.24±0.22 ^e	-3.87±0.13 ^f
	b^* -value	14.46±0.78 ^e	14.75±0.39 ^c	20.20±0.55 ^d	23.11±0.88 ^c	25.62±0.12 ^b	27.03±0.48 ^a
Cooked	pH	6.38±0.01 ^c	6.40±0.01 ^a	6.36±0.01 ^b	6.36±0.01 ^d	6.35±0.01 ^e	6.35±0.01 ^f
	L^* -value	76.76±0.55 ^a	76.60±0.76 ^a	71.73±0.30 ^b	68.21±3.14 ^c	65.34±0.91 ^d	64.15±0.30 ^d
	a^* -value	3.80±0.16 ^a	3.85±0.15 ^a	-1.38±0.10 ^b	-3.67±0.20 ^c	-5.13±0.10 ^d	-6.07±0.16 ^e
	b^* -value	10.51±0.13 ^f	11.40±0.20 ^e	16.59±0.41 ^d	20.26±0.13 ^c	22.12±0.36 ^b	23.70±0.37 ^a

All values are mean ± standard deviation of three replicates (n=9).

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

¹⁾Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

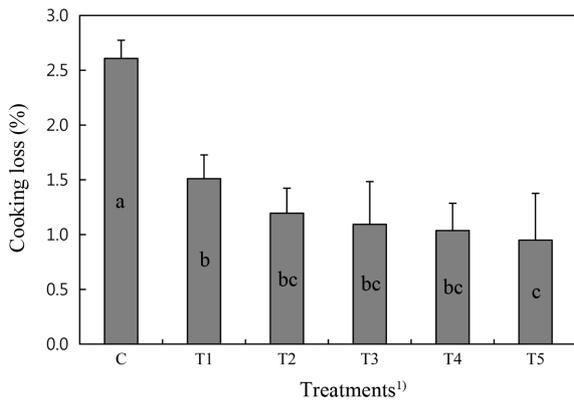


Fig. 1. Effects of WSP and ISP on cooking loss of breakfast sausages. ¹⁾Treatments: Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4, breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP. ^{a-c} Means in the treatments with different letters are significantly different ($p < 0.05$).

ing loss in breakfast sausage.

The emulsion stability of breakfast sausages containing WSP and ISP was shown in Table 4. In our current study, the water and fat separation tended to similar to the cooking loss results. The amount of fat released was similar for all the treatments with added ISP or WSP, though it was significantly different from the control ($p < 0.05$). However, there was a significant difference in the water released ($p < 0.05$). The control was higher in water fluid separation by 7.19% than the other treatments, on the other hand, the T5 treatment showed the lowest water separation by 2.53% ($p < 0.05$). According to Warriss *et al.* (1999), the higher pH in meat product, the more water holding capacity, the meat product has. Therefore, the unique physicochemical properties of ISP may result in enhanced emulsion stability in meat products (Choi *et al.*, 2007; Kim *et al.*, 2009; Sariçoban *et al.*, 2008). Muffins, cookies, and

sponge cakes with added WSP showed lower pH compared with those without WSP. However, these have greater water-holding capacity than controls without WSP (An, 2015; Lee, 2015; Park, 2015), due to their higher dietary fiber content (RDA, 2009). Some studies showed similar results that high dietary contents had effect on enhancing emulsion stability (Choi *et al.*, 2007b; Choi *et al.*, 2009; Fernandez-Gines *et al.*, 2004; Turhan *et al.*, 2005). This physicochemical capacity of WSP would reduce water separation in breakfast sausages. Therefore, an increase in the ratio of WSP had a greater influence on the emulsion stability of breakfast sausage than ISP.

Protein solubility

The solubility of total, sarcoplasmic, and myofibrillar proteins in meat batters formulated with WSP and ISP are presented in Fig. 2. Protein solubility is an important factor in emulsion formation. Generally, myofibrillar and sarcoplasmic protein solubility have the largest effect on the physicochemical and quality properties of processed meat products (Sayre and Briskey, 1963). The solubility of total, sarcoplasmic, and myofibrillar proteins in meat batter was the lowest in the control ($p < 0.05$). The T5 treatment had the lowest total and myofibrillar protein solubility compared to other treatments, except for the control ($p < 0.05$). These results were consistent with previous study indicating that the addition of ISP to a meat emulsion would increase salt-soluble proteins (Lee *et al.*, 2003). Lin and Mei (2000) showed that the introduction of ISP increased the concentration of salt-soluble protein in raw and cooked meat batter. This might be a result of the interaction between soy protein and actomyosin, resulting in higher solubility of myofibrillar protein in both uncooked and cooked meat (Haga and Ohasi, 1984; Lin and Ito, 1985). Even as the proportions of ISP and WSP were changed, the total and myofibrillar protein solubility did not significantly change. Therefore, the higher levels of

Table 4. Effects of WSP and ISP on emulsion stability of breakfast sausages

Parameters	Control ¹⁾	T1	T2	T3	T4	T5
<i>Emulsion stability</i>						
Total released (%)	8.12±1.57 ^a	4.82±1.11 ^b	4.25±0.69 ^{bc}	3.12±0.83 ^c	3.98±0.60 ^{bc}	3.06±1.04 ^c
Water released (%)	7.19±1.47 ^a	4.72±0.89 ^b	3.79±0.46 ^{bc}	2.50±0.58 ^c	3.45±0.46 ^{bc}	2.53±0.90 ^c
Fat released (%)	0.93±0.10 ^a	0.55±0.22 ^b	0.55±0.23 ^b	0.62±0.25 ^b	0.53±0.14 ^b	0.53±0.14 ^b

All values are mean ± standard deviation of three replicates (n=9).

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

¹⁾Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4, breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

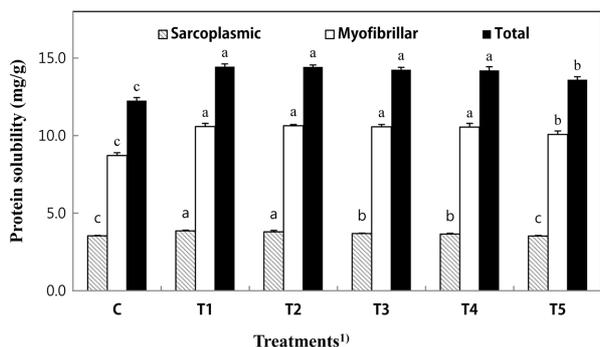


Fig. 2. Effects of WSP and ISP on protein solubility of breakfast sausages. ¹⁾Treatments: Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP. ^{a-c}Means in the treatments with different letters are significantly different ($p < 0.05$).

protein solubility could be attributed to addition of ISP, and to some degree of the protein content of WSP.

Texture profile analysis (TPA)

Texture profile analysis was affected by the different ratio of WSP and ISP. The effects of these additives on breakfast sausages were shown in Table 5. The control had lower values in general texture properties than the other treatments ($p < 0.05$). Kim *et al.* (2009) showed the addition of ISP increases the hardness of frankfurters, and Claus and Hunt (1991) found that the introduction of 2% ISP to bologna enhances its texture properties. However, WSP had more significant effect than ISP in our study. According to Park (2015), increasing the amount of WSP would improve hardness, cohesiveness, chewiness, and springiness in muffins. Similar results have been reported in other studies examining the quality characteristics of muffins

(Chung and An, 2015). Lee (2015) reported sponge cakes with added WSP had higher hardness, gumminess, and chewiness values as compared to those without WSP. Our results indicated that added WSP improved overall texture properties as compared to breakfast sausages without WSP and those with added ISP only. Furthermore, the T3 treatment, containing 1% ISP and 1% WSP, was the optimal formulation to reduce cooking loss, and improved protein solubility and emulsion stability.

Apparent viscosity

The addition of WSP and ISP obviously affected the apparent viscosity of meat batters (Fig. 3). Though all samples exhibited a decreased apparent viscosity of the meat batter as the rotation time increased, the apparent viscosity of the T5 treatment was higher than the other treatments ($p < 0.05$). However, the apparent viscosity of breakfast sausages containing WSP and ISP increased as the proportion of WSP increased ($p < 0.05$). This result might be the effect of ISP on meat emulsion system to increase water binding capacity (Choi *et al.*, 2007; Joseph, 1987; Raokosky, 1970). According to Lee (2015), the apparent viscosity of sponge cakes formulated with WSP showed higher than that of the control. Shand (2000) indicated that an increase in viscosity of emulsion resulted in an increase in emulsion stability. Furthermore, it has been reported there is a strong correlation between emulsion viscosity and emulsion stability in meat batters (Turgut *et al.*, 1981; Zorba *et al.*, 1993). Our results showed the T5 treatment had the highest viscosity in all treatments with different ratio of ISP and WSP, similar to our emulsion stability results.

Sensory evaluation

An evaluation of the sensory traits of breakfast sausages containing WSP and ISP is shown in Table 6. Color, flavor, texture, and juiciness were evaluated in order to

Table 5. Effects of WSP and ISP on texture profile analysis (TPA) of breakfast sausages

Parameters	Control ¹⁾	T1	T2	T3	T4	T5
Hardness (N)	2.90±0.29 ^b	3.11±0.23 ^{ab}	3.13±0.35 ^{ab}	3.15±0.15 ^{ab}	3.22±0.07 ^a	3.20±0.13 ^a
Springiness	0.96±0.01 ^b	0.98±0.01 ^a	0.98±0.02 ^a	0.99±0.01 ^a	0.99±0.01 ^a	0.99±0.01 ^a
Cohesiveness	0.41±0.01 ^c	0.42±0.03 ^{bc}	0.43±0.02 ^{abc}	0.44±0.01 ^{ab}	0.45±0.01 ^{ab}	0.45±0.02 ^a
Gumminess (N)	1.19±0.15 ^b	1.32±0.16 ^{ab}	1.40±0.17 ^{ab}	1.39±0.09 ^a	1.44±0.05 ^a	1.42±0.08 ^a
Chewiness (N)	1.10±0.11 ^b	1.32±0.15 ^{ab}	1.37±0.19 ^a	1.37±0.09 ^a	1.42±0.05 ^a	1.40±0.08 ^a

All values are mean ± standard deviation of three replicates (n=9).

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

¹⁾Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage with 2.0% WSP.

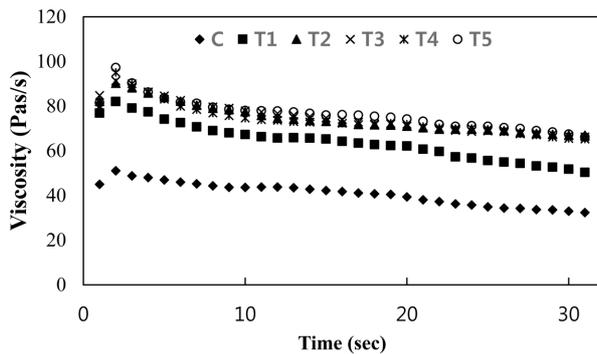


Fig. 3. Effects of WSP and ISP on apparent viscosity of breakfast sausages. ¹⁾Treatments: Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

determine overall acceptability. There was no significant difference in the juiciness for each treatment, and ISP did not significantly improve the color sensory trait as compared to the control ($p>0.05$). Kim *et al.* (2009) also found ISP had no effect on the color sensory trait in frankfurters. Color and flavor trait scores decreased as WSP concentration increased; however, this negative impact on the flavor score was only significantly different for the T4 and T5 treatments ($p<0.05$). Chung and An (2015) showed that the addition of WSP to muffins could have a positive impact on the color and flavor sensory traits, as compared to the control, owing to WSP's color and flavor being similar to green tea. It was important to note that the use of WSP in excess of 5% has been shown to have an undesirable effect on the sensory properties of muffins (Park, 2015). However, Ozturk *et al.* (2014) reported a decrease in appearance, taste, odor, and overall acceptability as the WSP concentration was increased in beef patties. These

results would be due to unfamiliarity with the green color and unique flavor of wheat sprout. Furthermore, the T3 treatment formulation (1% WSP and 1% ISP) does not significantly affect flavor trait or overall acceptability ($p>0.05$). In our texture trait assessment, the control had the lowest score ($p<0.05$) and while the addition of 2% WSP had a slight negative impact on texture properties, this was not significantly different ($p>0.05$). Therefore, the lowest overall acceptability score was determined in the breakfast sausage formulated with 2% WSP ($p<0.05$). Several studies have shown the sensorial properties of meat products are negatively impacted as the concentration of vegetable additives increases. For example, the sensory parameters of beef patties have been shown to decrease with increased flaxseed content (Bilek and Turhan, 2009). Furthermore, Turhan *et al.* (2005) indicated that beef burgers with increasing hazelnut pellicle content results in decreased overall acceptability. Therefore, while the addition of WSP to breakfast sausages enhances texture properties, the green tea-like color and flavor characteristics of wheat sprout have undesirable effects on the color and flavor of breakfast sausages. Taking all of these properties into consideration, our results showed that the texture, color, flavor, and overall acceptability of breakfast sausages were not significantly affected as long as the concentrations of WSP and ISP were at or below 1%.

Conclusions

The results of this study indicated that WSP can be added at some part of ISP to enhance the quality characteristic of meat products despite of its poor flavor. The combination of WSP and ISP had generally improved not only the quality properties but also physicochemical properties of breakfast sausages. Cooking loss, emulsion stability, protein solubility, viscosity, texture properties were

Table 6. Effects of WSP and ISP on sensory properties of breakfast sausages

Parameters	Control ¹⁾	T1	T2	T3	T4	T5
Color	7.43±0.53 ^a	7.43±0.53 ^a	6.00±0.58 ^b	6.86±0.69 ^{ab}	6.71±1.25 ^{ab}	6.70±1.25 ^{ab}
Flavor	7.33±0.52 ^a	7.00±0.82 ^{ab}	7.17±1.17 ^{ab}	7.17±1.17 ^{ab}	6.00±0.63 ^{bc}	5.50±0.84 ^c
Texture	6.71±1.11 ^b	7.29±0.49 ^{ab}	7.57±0.53 ^{ab}	7.71±0.49 ^a	7.86±0.69 ^a	7.14±0.90 ^{ab}
Juiciness	7.14±0.90	7.14±0.69	7.14±0.69	7.14±1.21	7.14±1.21	7.14±1.21
Overall acceptability	7.29±0.49 ^{ab}	7.14±0.98 ^a	7.00±0.82 ^a	6.71±0.53 ^{ab}	6.00±0.98 ^{bc}	5.57±0.79 ^c

All values are mean ± standard deviation of three replicates (n=9).

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

¹⁾Control, breakfast sausage formulated without ISP and WSP; T1, breakfast sausage formulated with 2.0% ISP; T2, breakfast sausage formulated with 1.5% ISP and 0.5% WSP; T3, breakfast sausage formulated with 1.0% ISP and 1.0% WSP; T4 breakfast sausage formulated with 0.5% ISP and 1.5% WSP; T5, breakfast sausage formulated with 2.0% WSP.

all improved as the amount of WSP increased. Furthermore, the addition of up to 1% WSP and 1% ISP did not have a negative impact on overall sensory attributes. Therefore, our results indicate that breakfast sausage formulated with 1% WSP and 1% ISP is the optimal combination to improve physicochemical properties and overall acceptability.

Acknowledgements

This research was supported High Value-added Food Technology Development Program (2017-314068-3) by the Ministry of Agriculture, Food and Rural Affairs (Republic of Korea).

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