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ARTICLE

Quality Characteristics of Low-salt Chicken Sausage Supplemented with a Winter Mushroom Powder

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Abstract Chicken meat is a low-fat and high-protein food and consumption of chicken meat has been increasing globally. Various food ingredients are widely added for their specific purpose to processed chicken meat. Nonetheless, concerns about the association between high sodium intake and various diseases as well as negative perceptions of artificial additives are increasing. Therefore, in meat products, it is necessary to reduce the amount of salt and to replace artificial additives with natural ingredients. Our aim was to investigate the quality characteristics of low-salt chicken sausages manufactured with the addition of a winter mushroom powder. Sausages was manufactured with sodium pyrophosphate (0.3%) or winter mushroom powder (0%, 0.5% and 1.0%) to ground chicken breast. As a result of addition of the winter mushroom powder to low-salt chicken sausages, pH of the meat batter increased, and the proportion of jelly and melted fat exuded from sausages was reduced. The texture of sausages was softened and lipid oxidation in sausages was inhibited by the winter mushroom powder. This powder did not negatively affect the color and sensory properties of the sausages. According to the results of this study, the winter mushroom powder can serve as a natural ingredient to improve quality of low-salt chicken sausages.

Keywords winter mushroom, chicken sausage, low salt, phosphate

Introduction

Chicken meat is considered a highly nutritious food because it contains relatively high protein and low fat percentages as well as vitamins and minerals (Jung et al., 2015). In addition, it has fewer religious restrictions as compared with pork and beef. The consumption of chicken meat and of the related processed meats has been increasing globally (OECD/FAO, 2017).

Processed chicken meats are generally manufactured with the addition of various food additives for improvement of shelf life and sensorial properties and for convenience. Sodium chloride is an essential ingredient of processed meats because of its multiple roles (Sebranek, 2009). Generally, processed meats contain 7–39 g/kg sodium chloride (Inguglia et al., 2017). Nevertheless, the high concentration of sodium in processed meats is considered a health risk factor because high intake of dietary sodium increases the risks

of various diseases such as hypertension and cardiovascular disease (Chrysant, 2016). Therefore, a reduction in sodium chloride concentration in processed meat products has been necessary and may be increasingly demanded by consumers who choose processed chicken meats because of their high nutritional value (Ruusunen and Puolanne, 2005).

The reduction in sodium chloride concentration in processed meats results in deterioration of various characteristics such as shelf life and flavor intensity (Inguglia et al., 2017). Furthermore, it leads to high cooking loss in processed meats that is caused by lower water-holding capacity and insufficient solubilization of myofibrillar proteins (O'Flynn et al., 2014a). There are various strategies for the reduction of sodium chloride concentration in processed meats: the use of potassium chloride, a flavor enhancer, and/or phosphates (Ruusunen and Puolanne, 2005). The partial replacement of sodium chloride by potassium chloride results in the reduction of sodium content in processed meats with retention of water-holding capacity via the supply of chloride ions that increase the net charge of myofibrillar proteins (Gou et al., 1996). The addition of phosphates, especially alkaline phosphates such as sodium pyrophosphate and sodium tripolyphosphate improves water-holding capacity by increasing pH of processed meats (O'Flynn et al., 2014b). Nevertheless, the addition of potassium chloride negatively influences the flavor and texture of processed meats, and phosphates are an artificial additive that needs to be reduced in amount or replaced by a natural ingredient in processed meats (Gou et al., 1996; Jo et al., 2018; O'Flynn et al., 2014b).

The winter mushroom (*Flammulina velutipes*) is a popular edible mushroom and is widely cultivated in many Asian countries. Various studies have shown that the winter mushroom has several biological functions such as anticancer and anti-inflammatory effects (Leung et al., 1997; Ng et al., 2006). This mushroom contains various nutrients such as proteins, vitamins, minerals, polysaccharides, and fiber (Breene, 1990). Dietary fiber, which is generally lacking in meat, has a therapeutic effect on some human diseases such as colon cancer, obesity, and cardiovascular diseases (Thebaudin et al., 1997). Therefore, addition of dietary fibers into processed meats has been considered a good strategy for enhancing the nutritional value of processed meats (Verma et al., 2010). Various studies have revealed the water-binding effect of dietary fiber in processed meats (Verma et al., 2010). Furthermore, the increase of pH in pork meat batter with the addition of winter mushroom powder was recently reported (Choe et al., 2018). The winter mushroom contains various flavor precursors such as free amino acids and nucleotides, which are the compounds responsible for the sweet and umami flavors of mushrooms (Ito et al., 2017).

We hypothesized that winter mushroom powder (WMP) will act as an enhancer of water-holding capacity and of the flavor of low-salt chicken sausages. Therefore, the aim of this study was to evaluate the quality characteristics of low-salt chicken sausages manufactured with the addition of WMP.

Materials and Methods

Preparation of WMP

Winter mushrooms (*Flammulina velutipes*) were purchased at a local market and washed with tap water. Winter mushrooms were lyophilized (Bondiro, Ilshin Co., Seoul, Korea) and pulverized using a bowl cutter (C4VV, Sirman, Curtarolo, Italy). Proximate composition and dietary fiber content of WMP was analyzed according to the AOAC method (2010). Total phenolic content of WMP was estimated by the Folin-Ciocalteu method (Subramanian et al., 1965). Proximate composition, dietary fiber content, and total phenolic content of WMP were shown in Table 1.

Preparation of low-salt chicken sausages

The low-salt food according to regulations should contain less than 140 mg of sodium in reference to the amount

Table 1. Proximate composition, dietary fiber content, and total phenolic content of WMP

Variables	Winter mushroom powder
Proximate composition (%)	
Moisture	8.13±0.15[1)]
Crude protein	18.42±0.13
Crude fat	2.94±0.23
Crude ash	6.33±0.37
Crude fiber	7.81±0.06
Nitrogen free extract	56.37±0.17
Dietary fiber (%)	
Soluble dietary fiber	6.59±0.32
Insoluble dietary fiber	37.90±0.34
Antioxidant potential	
Total phenolic compounds (g GAE/kg)	3.20±0.02

[1)] Mean±SD (n=3).
WMP, winter mushroom powder; GAE, gallic acid equivalent.

customarily consumed (US FDA, 2016). The reference amount customarily consumed in poultry sausage products is 55 g and the sodium content of chicken breast meat (skinless) is 450 mg/kg (USDA FSIS, 2016; USDA, 2017). Therefore, the amount of added sodium chloride was chosen to be 3 g/kg for this study.

Skinless breasts of chickens were purchased at a local market (Daejeon, Korea) and then ground up in a meat grinder (M-12S, Hankook Fugee Industries Co., Ltd., Hwaseong, Korea) with a 6 mm plate. The meat batter of each treatment was prepared by mixing with the ground chicken breast (2.0 kg), ice (0.4 kg), sodium chloride (3 g/kg), and sodium pyrophosphate (3g/kg) or WMP in silent cutter (12VV, Sirman, Curtarolo, Italy) depending on the formula for each of the four treatments: 1) positive control, sausages manufactured with 3 g/kg sodium pyrophosphate, 2) WMP 0 (negative control): sausages manufactured without sodium pyrophosphate or WMP, 3) WMP 0.5: sausages manufactured with 5 g/kg of WMP, and 4) WMP 1.0: sausages manufactured with 10 g/kg of WMP. The meat batters of 4 treatments were manufactured in each batch and 3 independent batches were prepared at different times on the same day. Twelve meat batters (4 treatments×3 batches) were stored in a refrigerator at 4℃ for 12 h prior to manufacturing the sausages. The meat batter (200 g) was packed into a steel can (95 mm×50 mm×50 mm) and then sealed using an automatic closing machine (DWC-160, Duckwoo Machinery Co., Korea). The cans were heated for 1 h in a water bath at 85℃. After the heating process, the cans were cooled in tap water for 30 min. The cans were then dried and placed in a refrigerator at 4℃. Ten sausages were prepared for each treatment per batch. Three sausages of each treatment/batch were randomly selected and used for quality analysis, and the remaining sausages were subjected to a sensory analysis. After storage of the sausages for 1 day in a refrigerator at 4℃, the proportion of jelly and melted fat, instrumental color, and texture properties of the sausages were measured. Samples were collected in test tubes for lipid and protein oxidation assays and stored in a freezer at −70℃ until analysis.

pH of the meat batter

Three samples were collected from each meat batter for pH measurements, and the pH was measured before the manufacture of sausages. A meat batter sample (1 g) was homogenized with 9 mL of distilled water using a homogenizer

(T25 basic, IKA GmbH & Co. KG, Germany). The homogenates were filtered through Whatman No. 4 filter paper (Whatman, Maidstone, England) after centrifugation at 2,090×g for 15 min (Union 32R, Hanil Co., Ltd., Incheon, Korea). pH of the filtrate was measured with a pH meter (SevenEasy, Mettler-Toledo Intl Inc., Schwerzenbach, Switzerland).

The proportion of jelly and melted fat exuded from sausages

The canned sausages were opened, and the sausages were removed from the can and placed on a cutting board. The sausages were weighed after removal of the jelly and melted fat exuded from the sausages. The results were expressed as a percentage of the net weight of the packed meat batter.

Color of sausages

CIE lightness (L*), redness (a*), and yellowness (b*) of the sausages were measured on a spectrophotometer with the illuminant D_{65} (CM-3500d, Konica Minolta Inc., Tokyo, Japan). Measurements were taken perpendicularly to the cut surface of a sausage with a 30 mm diameter of illumination area at two different locations per sample. The results were analyzed in the SpectraMagic software (Spectramagic^{TM} NX, Konica Minolta Inc., Tokyo, Japan).

Instrumental texture properties of sausages

The textural properties of the sausages were analyzed by means of the two-bite system involving a Texture Analyzer (Model A-XT2, Stable Micro Systems Ltd., UK) with a compression probe (70 mm diameter) attachment. Each sausage (2×2×1.5 cm) underwent two cycles of 70% compression at a test speed of 2 mm/s. The textural characteristics of sausage were expressed as hardness, springiness, cohesiveness, gumminess, and chewiness.

Lipid oxidation in sausages

Lipid oxidation in sausages was monitored with the 2-thiobarbituric-acid–reactive substances (TBARS) value. This procedure was conducted according to the method described by Kim et al. (2016). Each sausage sample (3 g) was homogenized with 9 mL of distilled deionized water and 50 μL of 2,6-di-tert-butyl-4-methylphenol in ethanol (72 g/L) using a homogenizer (T25 basic, IKA GmbH & Co. KG, Germany) at 16,000 rpm for 1 min. The homogenates (1 mL) were transferred to a test tube, and 2 mL of a TBA-TCA solution (20 mM *2*-thiobarbitric acid in trichloroacetic acid at 150 g/L was added to the test tube. The tubes were then heated (90°C) in a boiling water bath for 30 min, cooled, and centrifuged at 2,090×g for 15 min. Absorbance of the supernatants was measured at 532 nm on a spectrophotometer (DU530, Beckman Instruments Inc., Fullerton, CA, USA). The TBARS value of each sample was expressed in [malondialdehyde (MDA) mg] kg^{-1} of sausages**.** 1,1,3,3-tetraethoxypropane served as the MDA standard.

Protein oxidation in sausages

Protein oxidation, as measured by the total carbonyl content, was evaluated by derivatization with dinitrophenylhydrazine (DNPH) according to the method described by Armenteros et al (2016). Samples (1 g) were homogenized in a 1:10 (w/v) ratio in 20 mM sodium phosphate buffer containing 0.6 M NaCl (pH 6.5) in a homogenizer for 30 s. Two equal aliquots of 0.2 mL each were taken from the homogenates and added into 2 mL Eppendorf tubes. Proteins were precipitated by the addition of 1 mL of cold trichloroacetic acid (100 g/L), with subsequent centrifugation for 5 min at 10,000×g for 10 min

(HM-150IV, Hanil Co., Ltd., Incheon, Korea). One pellet was treated with 1 mL of 2 M HCl (protein concentration measurement), and the other with an equal volume of 2,4-dinitrophenyl hydrazine (DNPH) at 2 g/L in 2 M HCl (carbonyl concentration measurement). Both samples were incubated for 1 h at room temperature. Afterwards, the samples were precipitated with 1 mL of cold trichloroacetic acid (100 g/L) and washed twice with 1 mL of an ethanol:ethyl acetate mixture (1:1, v/v) in order to remove excess DNPH. The pellets were then dissolved in 1.5 mL of 20 mM sodium phosphate buffer (pH 6.5) containing 6 M guanidine hydrochloric acid, stirred, and centrifuged for at 10,000×g for 10 min (HM-150IV) to remove insoluble fragments. Protein concentration was calculated from the absorption at 280 nm, with bovine serum albumin as a standard. The carbonyl content was expressed as nmol/mg of protein using an absorption coefficient of 21.0 nM^{-1} cm^{-1} at 370 nm for protein hydrazones.

Sensory evaluation

Sausages were stored in a refrigerator at 4℃ for 3 days before sensory evaluation. Sensory evaluation of the sausages was implemented as a group of 20 panelists. Sausages from three batches were combined and cut regularly. The sausages were reheated at 180℃ for 3 min in an electric steam oven (EON-C305CSM, Tong Yang Magic Co., Korea) and were served to the panelists on white glass plates. The scoring of each sample was done on a single sheet with a 9-point hedonic scale (1=strongly dislike, 9=strongly like). The color, flavor, taste, texture, and overall acceptability were then scored.

Statistical analysis

The data from this study were analyzed by the PROC GLM procedure in a randomized complete block design (batch as a block). The experimental unit was a sausage. For analysis of the data from the sensory evaluation, The PROC MIXED procedure was used, and the panel was included as a random effect. Specific comparisons were performed by Tukey's multiple-range test when the main effect was significant. Results are reported as least-square mean values and standard error of the least-square means. Statistical significance was assumed at $p<0.05$. The SAS software (version 9.3, SAS Institute Inc., Cary, NC, USA) was used for statistical analyses.

Results and Discussion

pH of the meat batter and the proportion of fat exuded from sausages

The pH level of the meat batter was the highest in the positive control group owing to the addition of sodium pyrophosphate, an alkaline phosphate (Fig. 1). In the treatment groups involving added WMP, pH of the meat batter significantly increased with the increasing WMP content ($p<0.05$). This result may be due to the relatively high concentration of basic amino acids such as histidine and arginine among the amino acids of the winter mushroom (Ito et al., 2017).

pH of meat batter is an important factor that affects quality of meat products, and alkaline phosphate increases pH of the meat batter (O'Flynn et al., 2014b). As pH of meat batter increases, the negative charge of the myofibrillar protein increases and repulsive forces between proteins increase (Hamm, 1996). As a result, interfilament spacing, which can be collecting moisture, increases, thus enhancing water-holding capacity and inhibiting fat separation in meat products (Hamm, 1996). Nonetheless, there was no significant difference in the proportion of exuded fat from sausages between groups positive control and WMP 0 even though pH was high in the positive control group (Fig. 1, $p>0.05$). The fat separation in meat products is affected not only by pH but also by the emulsion stability of meat batter. The latter parameter is dependent on

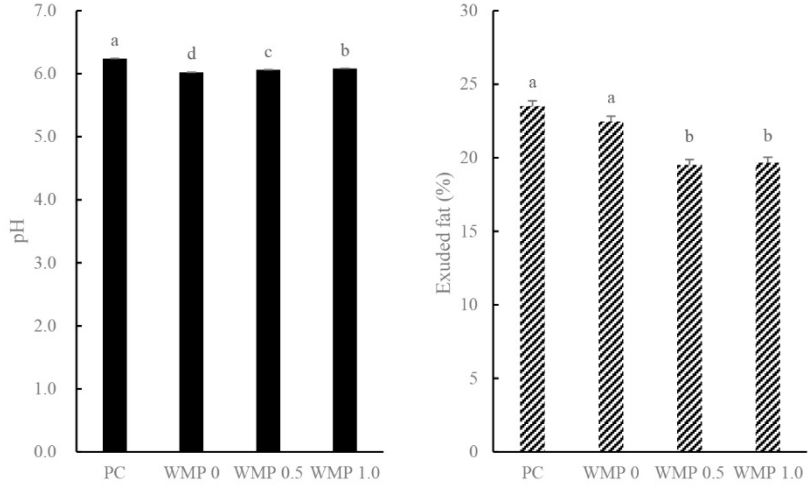

Fig. 1. pH and exuded fat of low-salt chicken sausages with WMP. [a–d] Different letters represent significant differences ($p<0.05$). WMP, winter mushroom powder; PC, sausages manufactured with 3 g/kg sodium pyrophosphate; WMP 0, sausages manufactured without sodium pyrophosphate or WMP; WMP 0.5, sausages manufactured with 5 g/kg of WMP; WMP 1.0, sausages manufactured with 10 g/kg of WMP.

solubility of salt-soluble proteins such as myosin and actin, which are myofibrillar proteins (Smith et al., 1973). The salt-soluble protein extracted by means of salt and phosphate added to the meat batter forms a layer around the fat surface to emulsify meat batter (Smith et al., 1973). Therefore, the extraction of a salt-soluble protein is an important factor increasing emulsion stability. Some studies have indicated that the minimum sodium chloride concentration of 1.2% is required for effective activation of proteins, and a low concentration of sodium chloride leads to lower protein solubility (Cofrades et al., 2008; Kameník et al., 2017). In the present study, the salt amount added in all treatment groups was 0.3%. Therefore, the emulsion stability was low due to the low extractable amount of salt-soluble proteins in the meat batter. For this reason, even though sodium pyrophosphate was added, the fat separation in the positive control group was not inhibited.

In treatment groups WMP 0.5 and WMP 1.0, the proportion of exuded jelly and melted fat from sausages was significantly lower than that in the positive and negative control groups ($p<0.05$), and there was no significant influence of the amount of WMP added ($p>0.05$). WMP increased the pH of the meat batter, but the inhibition of the separation of jelly and melted fat in groups WMP 0.5 and WMP 1.0 may be related to the dietary fiber contained in WMP rather than to the effect of the pH increase. The dietary fiber content of WMP was 44.49% (Table 1). Dietary fiber has hydration properties and fat absorption capacity (Thebaudin et al., 1997). As a result, dietary fiber can increase emulsion stability and reduce fat and water loss in meat products owing to the binding capacity of dietary fiber for water and fat (Thebaudin et al., 1997). Previous studies have shown that the dietary fiber increases emulsion stability and the cooking yield in meat products by reducing the loss of water and fat during cooking (Cofrades et al., 2008; Thebaudin et al., 1997). Therefore, WMP can decrease the proportion of exuded fat from low-salt chicken sausages.

Color of sausages

According to the comparison of the color between the negative control and treatment groups involving WMP, the L* value significantly decreased with increasing WMP content (Table 2, $p<0.05$). There was no significant difference in the a* value and b* value of treatment groups involving WMP as compared with those of the negative control ($p>0.05$). A similar result was obtained with fish meat paste containing the winter mushroom (Koo et al., 2001). There was no significant difference in

Table 2. Color (CIE L*, a*, and b*) of low-salt chicken sausages with WMP

Variables	L* value	a* value	b* value
PC	83.58[b]	1.62[b]	11.79[a]
WMP 0	84.40[a]	1.64[ab]	11.34[b]
WMP 0.5	83.96[ab]	1.78[ab]	11.38[b]
WMP 1.0	83.52[b]	1.85[a]	11.67[ab]
SEM[1)]	0.172	0.059	0.079

[1)] Standard error of the least square mean (n=12).
[a,b] Different letters within the same column represent significant differences ($p<0.05$).
WMP, winter mushroom powder; PC, sausages manufactured with 3 g/kg sodium pyrophosphate; WMP 0, sausages manufactured without sodium pyrophosphate or WMP; WMP 0.5, sausages manufactured with 5 g/kg of WMP; WMP 1.0, sausages manufactured with 10 g/kg of WMP.

the L* value and b* value between groups positive control and WMP 1.0 ($p>0.05$), and the a* value of the positive control group was significantly lower than that of group WMP 1.0. Generally, the high pH in meat results in the high a* value by increasing the water-holding capacity (Qiao et al., 2001). However, the amount of jelly and melted fat exuded from sausages of positive control was higher than that of WMP 1.0 although the pH of meat batter was high in positive control than WMP 1.0. Therefore, the WMP 1.0 showed the highest a* value among treatments with its low level of jelly and melted fat exuded from sausages.

There was a significant difference between treatment groups in the results on sausage color, but there were few numerical differences. Various studies indicate that natural sources can change the color of the meat product because of their characteristic color; this situation may have a negative effect on the acceptability by consumers (Cofrades et al., 2008; Verma et al., 2010). Nevertheless, WMP did not have a strong effect on sausage color in this study because the color of WMP is white.

Instrumental texture properties of sausages

Hardness of the positive control was not significantly different from that of the negative control (Table 3, $p>0.05$). On the other hand, springiness, cohesiveness, gumminess, and chewiness of the positive control were significantly lower than those of the negative control ($p<0.05$). The addition of phosphate to meat products results in the increase of hardness, springiness, chumminess, and chewiness by reducing the exudation of jelly and melted fat from meat products (Choe et al., 2018). However, the water holding capacity of positive control was not improved due to the low salt concentration added to sausages

Table 3. Textural properties of low-salt chicken sausages with WMP

Variables	Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness
PC	73.93[ab]	0.68[b]	0.26[b]	19.38[b]	13.23[b]
WMP 0	75.98[a]	0.74[a]	0.30[a]	22.38[a]	16.64[a]
WMP 0.5	76.30[a]	0.74[a]	0.28[ab]	21.23[ab]	15.72[a]
WMP 1.0	68.48[b]	0.67[b]	0.28[ab]	19.34[b]	13.04[b]
SEM[1)]	1.850	0.011	0.006	0.557	0.536

[1)] Standard error of the least square mean (n=12).
[a,b] Different letters within the same column represent significant differences ($p<0.05$).
WMP, winter mushroom powder; PC, sausages manufactured with 3 g/kg sodium pyrophosphate; WMP 0, sausages manufactured without sodium pyrophosphate or WMP; WMP 0.5, sausages manufactured with 5 g/kg of WMP; WMP 1.0, sausages manufactured with 10 g/kg of WMP.

and the proportion of jelly and melted fat exuded from sausages was higher in positive control than negative control although there was no significance in the present study. As a result, the hardness of positive control tended to be low and other texture properties were lower than those of negative control.

Sausages of group WMP 0.5 showed no significant differences in hardness, springiness, cohesiveness, and gumminess from the positive control, and chewiness was significantly higher than that in the positive control ($p<0.05$). Hardness, springiness, and chewiness significantly decreased with the increasing amount of WMP added ($p<0.05$). This result may mean the effect of dietary fiber present in WMP. Some studies have revealed that the addition of dietary fiber to low-fat meat products decreases hardness because dietary fiber may disturb the protein–protein or protein–water gel network (Han and Bertram, 2017). There was no significant difference in textural properties between groups WMP 1.0 and positive control ($p>0.05$).

Chicken breast muscle mainly consists of fast glycolytic fibers (typeIIb fibers); therefore, the texture of meat is dry and firm because the diameter of muscle fiber is substantial, and concentration of fat is low (Choe, 2018). Generally, fat is added to improve the texture of meat products. However, the consumer demand for healthier meat products has increased recently due to the concern about the association between high fat intake and various diseases such as obesity, diabetes, and cardiovascular disease (Han and Bertram, 2017; Verma et al., 2010). In addition, chicken breast has the nutritional characteristic of low fat and high protein percentages; as a result, adding fat to chicken breast sausage may not be beneficial. However, reducing the fat content results in a rubbery dry texture of meat products. To solve this problem, a dietary fiber source such as peach dietary fiber, apple pulp, carboxymethyl cellulose sodium salt, or pectin have been added to low-fat meat products in various studies, and the hardness of meat products decreased (Han and Bertram, 2017; Verma et al., 2010). Addition of dietary fiber to meat products can yield a soft texture while reducing fat content. WMP used in this study contained dietary fiber at a level of 44.49% (Table 1). Therefore, the use of WMP enables the manufacture of soft chicken breast sausages without adversely affecting nutritional characteristics of the chicken breast. Furthermore, the nutritional attributes of sausage can be improved by supplementation with dietary fiber that is lacking in the meat product with WMP.

Lipid and protein oxidation in sausages

Lipid oxidation is one of indicators of quality deterioration in meat products. Free radicals generated during the processing of meat products oxidize fatty acids, especially polyunsaturated fatty acids through a radical chain reaction (Min and Ahn, 2005). Lipid oxidation leads to the development of an off-flavor, rancid odor, to a decrease in shelf life, loss of nutrient value, and formation of toxic compounds in meat products (Falowo et al., 2014). Therefore, it is important to control lipid oxidation in meat products.

Concentration of MDA, a secondary product of lipid oxidation, in low-salt chicken sausages was significantly lower in the positive control than in the negative control group (Fig. 2, $p<0.05$). This result is due to the phosphate added to the positive control. Myoglobin, which is a heme protein in meat, is denatured during the heating process, and next, nonheme iron is released from the heme of myoglobin (Jung et al., 2012). Nonheme iron generates the hydroxyl radical, one of well-known free radicals, via the Fenton reaction, which promotes lipid oxidation in meat products (Falowo et al., 2014). One study has shown that phosphate can inhibit lipid oxidation through metal ion chelation (Lee et al., 1998). The MDA content of WMP 0.5 and WMP 1.0 sausages was significantly lower than that in the positive control and negative control ($p<0.05$). This is the result of inhibition of lipid oxidation by antioxidants such as polyphenol in the winter mushroom. The phenolic content of WMP was 3.20 g of gallic acid equivalents per kilogram (Table 1). Some studies have shown that mushrooms have antioxidant activities and contain antioxidant substances such as phenolic compounds and ergothioneine (Bao et al., 2008;

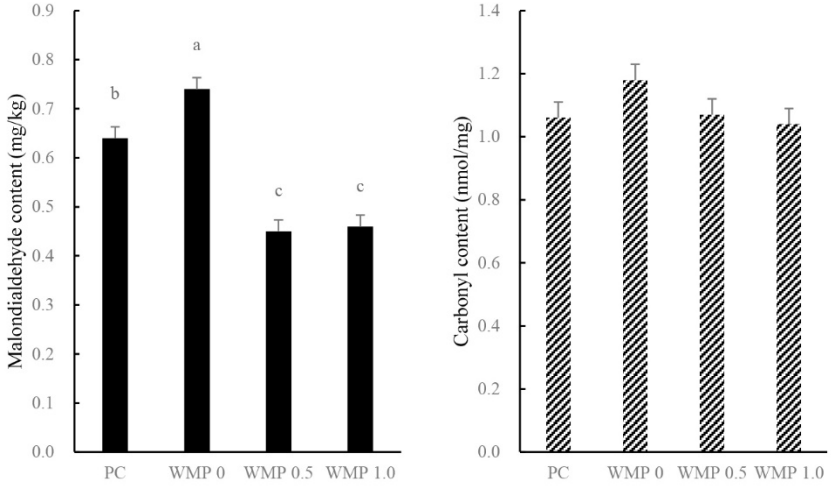

Fig. 2. Malondialdehyde (mg/kg) and carbonyl content (nmol/mg of protein) of low-salt chicken sausages with WMP. [a–c] Different letters represent significant differences ($p<0.05$). WMP, winter mushroom powder; PC, sausages manufactured with 3 g/kg sodium pyrophosphate; WMP 0, sausages manufactured without sodium pyrophosphate or WMP; WMP 0.5, sausages manufactured with 5 g/kg of WMP; WMP 1.0, sausages manufactured with 10 g/kg of WMP.

Breene, 1990). Winter mushroom also contains phenolic compounds and ergothioneine, and a winter mushroom extract was reported to effectively inhibit lipid oxidation (Bao et al., 2008). Phenolic compounds can chelate metal ions and scavenge free radicals, and ergothioneine inhibits formation of the hydroxyl radical from the Fenton reaction of hydrogen peroxide and scavenges hydroxyl radicals (Cai et al., 2014; Rice-Evans et al., 1997). These properties of the antioxidant can inhibit lipid oxidation in meat products.

In meat products, not only lipid oxidation but also protein oxidation occurs via a free radical chain reaction. Protein oxidation by free radicals leads to a loss of meat protein functionality and causes quality deterioration by reducing water-holding capacity and texture-forming ability of meat products (Lund et al., 2011). Carbonyl content (reflecting products of protein oxidation) of the positive control sausages and of sausages containing WMP tended to be lower than that in the negative control, but there was no significant difference among the treatment groups (Fig. 2, $p>0.05$).

Sensory evaluation

The scores of color, flavor, taste, texture, and overall acceptability of low-salt chicken sausages were not significantly different among the treatment groups (Table 4, $p>0.05$). Mushrooms are a health food because they contain a variety of nutrients and physiologically active substances. Furthermore, mushrooms contain volatile compounds such as 1-octen-3-ol, and water-soluble taste constituents such as 5′-nucleotides and free amino acids that contribute to the umami taste. Mushrooms have a unique and subtle flavor and are employed as food-flavoring materials (Ulziijargal and Mau, 2011). However, in this study, there was no enhancing effect on the sensory properties of chicken sausages after addition of WMP. One study has revealed that natural source has a negative effect on sensory properties of meat products owing to the strong taste and flavor of natural source (Verma et al., 2010). Nevertheless, WMP has no negative effects on the sensory properties of chicken sausages.

Conclusion

In this study, low-salt chicken sausages were manufactured with WMP. WMP increases pH of meat batter and reduces the

Table 4. Sensory evaluation of low-salt chicken sausages with WMP

Variables	Color	Flavor	Taste	Texture	Overall acceptability
PC	5.30	6.56	6.48	6.11	6.44
WMP 0	5.26	6.00	6.04	6.00	5.96
WMP 0.5	5.30	5.93	5.96	6.44	6.11
WMP 1.0	5.22	5.48	5.41	6.15	5.59
SEM[1)]	0.221	0.293	0.305	0.326	0.306

Sensory scale: 1, strongly dislike; 9, strongly like.
[1)] Standard error of the least square mean (n=4).
WMP, winter mushroom powder; PC, sausages manufactured with 3 g/kg sodium pyrophosphate; WMP 0, sausages manufactured without sodium pyrophosphate or WMP; WMP 0.5, sausages manufactured with 5 g/kg of WMP; WMP 1.0, sausages manufactured with 10 g/kg of WMP.

proportion of the jelly and melted fat exuded from sausages. In addition, hardness of sausages decreased, and resistance to lipid oxidation increased with the addition of WMP. This supplementation of sausages did not negatively affect the color and sensory quality of sausages. Furthermore, there is another positive effect: dietary fiber contained in WMP increases the nutritional quality because dietary fiber is lacking in the meat product. Therefore, WMP can serve as natural ingredient for improving quality of low-salt chicken sausages.

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