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# Application of winter mushroom powder as an alternative to phosphates in emulsion-type sausages

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ABSTRACT

This research evaluated the utilization of winter mushrooms as a replacement for phosphate in emulsion-type sausages. Winter mushroom powder (WMP) was added to the sausages at 0, 0.5, 1.0, 1.5, and 2.0% (w/w), and phosphate was added at 0.3% as a positive control. The WMP additions above 1.0% increased the pH of meat batter and efficiently inhibited the exudation of fat from the sausages ($p < 0.05$). Lipid oxidation of sausages was inhibited by the addition of WMP ($p < 0.05$). On the other hand, the addition of phosphate and WMP provided different instrumental texture properties. However, no adverse effects were observed with respect to the color and sensory properties of the sausages containing WMP, except for that containing 2.0% WMP. Therefore, this research indicates that WMP can effectively replace phosphate in meat products, and that the most effective addition level may be 1.0% WMP.

## 1. Introduction

Meat products have significant roles in the human diet because they contain various nutrients such as proteins, lipids, vitamins, and minerals. Various ingredients and additives are used to improve the quality and shelf life of meat products. Phosphates are a widely used additive for manufacturing meat products (Sebranek, 2009). In meat processing, one of the most beneficial functions of phosphates, especially alkaline phosphates, is the improvement of water holding capacity by raising the pH of meat batter. This results in improved cooking yield, texture, and eating quality, including improved tenderness and juiciness (Aberle, Forrest, Gerrard, & Mills, 2001; Sebranek, 2009). Other beneficial effects include (1) stabilization of emulsions and the texture of meat products by increasing the extraction of salt-soluble proteins based on increasing ion strengths and charges; and (2) reduction of lipid oxidation via their metal chelating activity, which subsequently inhibits off-flavor development (Aberle et al., 2001; Sebranek, 2009). However, phosphates are a chemical synthetic analogue. Recent research has revealed that consumers tend to choose natural sources of functional ingredients rather than chemical synthetic additives, and that they will pay significant premiums of 200% or more for natural ingredients (Carocho, Morales, & Ferreira, 2015; Sebranek & Bacus, 2007). Moreover, the meat processing industry has already taken steps to find suitable alternatives to synthetic additives, such as nitrites and ascorbic acids, to meet consumer demands (Jo, Lee, Lim, Hwang, & Jung, 2018; Jung et al., 2017). Thus, there is a requirement to find natural ingredients for the replacement of phosphates (E450).

Mushrooms, which originate from the natural environment, have been widely cultivated and consumed by humans since ancient times as a part of normal diet and as a delicacy because of their unique taste and flavor (Mattila, Suonpaa, & Piironen, 2000). Winter mushrooms (*Flammulina velutipes*) are widely distributed and are among the most popularly consumed mushrooms in South Korea, China, and Japan (Dong et al., 2017). Winter mushrooms have high levels of nutrients (protein, polysaccharides, fiber, and vitamins) and several biological benefits, such as antioxidant, antitumor, and antiinflammation properties, regardless of the extraction methods or active components (Dong et al., 2017; Kim & Kim, 2010; Leung, Fung, & Choy, 1997; Oh & Lee, 2010; Zhang et al., 2013). Moreover, some studies have shown that mushrooms can increase the pH of meat (Bao, Ushio, & Ohshima, 2008) and other food products (Ko & Kim, 2007) when used as a food additive for inhibiting the discoloration of meat via their antioxidant effects and improving their sensory and physicochemical properties. Considering both the antioxidant activities of winter mushrooms and the increase in pH of the meat products, we hypothesized that they could replace phosphates in meat products. Therefore, the aim of this study was to

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evaluate the potential use of winter mushrooms as an alternative to phosphates in emulsion-type sausages by testing various quality parameters including the pH of the meat batter, lipid oxidation, texture, and the sensory properties.

## 2. Materials and methods

### 2.1. Preparation of winter mushroom powder

Winter mushrooms (*Flammulina velutipes*) were purchased from a local market and washed using tap water. Winter mushrooms were lyophilized (Ilshin Co., Seoul, Korea) and pulverized using a bowl cutter (C4VV, Sirman, Curtarolo, Italy). Total phenolic content of WMP was estimated by the Folin-Ciocalteu method (Subramanian, Padmanaban, & Sarma, 1965).

### 2.2. Manufacture of emulsion-type sausages and sample collections

Winter mushrooms (*Flammulina velutipes*) were purchased from a local market and washed using tap water. Winter mushrooms were lyophilized (Ilshin Co., Seoul, Korea) and pulverized using a bowl cutter (C4VV, Sirman, Curtarolo, Italy).

Hind-leg pork and fat (after 24–36 h postmortem) were purchased from a local market (Daejeon, South Korea). Excessive visible fat and connective tissue were removed from the pork, and then ground by using a meat grinder (M-12S; Hankook Fugee Industries Co., Ltd., Hwaseong, Korea) with a 6-mm plate. Ground pork (1.6 kg) was mixed with back fat (0.4 kg), ice (0.4 kg), sodium chloride (1.5%), L-ascorbic acid (0.02%), and sodium nitrite (0.01%) in a silent cutter (12VV, Sirman, Curtarolo, Italy). Sodium pyrophosphate or different level of winter mushroom powder (WMP) were added depending on the formula for each of the six treatments: 1) Phosphate: sausages manufactured with 0.3% sodium pyrophosphate, 2) WMP 0: sausages manufactured without sodium pyrophosphate or WMP, 3) WMP 0.5: sausages manufactured with 0.5% WMP, 4) WMP 1.0: sausages manufactured with 1.0% WMP, 5) WMP 1.5: sausages manufactured with 1.5% WMP, and 6) WMP 2.0: sausages manufactured with 2.0% WMP (Table 1). The meat batters of 6 treatments were manufactured in each batch and 3 independent batches were prepared at different times on the same day. Eighteen meat batters (6 treatment × 3 batches) were stored in a refrigerator at 4 °C 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 °C. 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 °C. Ten sausages (10 cans) were manufactured from each treatment/batch. Three sausages from each treatment/batch were randomly collected and total nine sausages (3 sausages × 3 batches) of each treatment were used for quality analysis. The remaining sausages were used for sensory analysis. After storing the sausages for one day in a refrigerator at 4 °C, the proportion of jelly and melted fat, instrumental color, and texture properties of the sausages were measured with three replicates per treatment. Samples were collected in test tubes for lipid oxidation and stored at −70 °C until analysis.

**Table 1**
Formulations (%) for manufacturing emulsion-type sausages.

| | Phosphate | Winter mushroom powder (%, w/w) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 0.5 | 1.0 | 1.5 | 2.0 |
| Ingredients | | | | | | |
| Pork hind leg meat | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| Pork fat | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |
| Ice | 20 | 20 | 20 | 20 | 20 | 20 |
| Additives | | | | | | |
| Sodium chloride | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| L-ascorbic acid | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Sodium nitrite | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| SPP[a] | 0.3 | – | – | – | – | – |
| WMP[b] | – | – | 0.5 | 1.0 | 1.5 | 2.0 |

[a] Sodium pyrophosphate.
[b] Winter mushroom powder.

2.3. 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 2090 ×*g* for 15 min (Union 32R, Hanil Co., Ltd., Incheon, Korea). The pH of the filtrate was measured using a pH meter (SevenEasy, Mettler-Toledo Intl Inc., Schwerzenbach, Switzerland).

### 2.3. 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 removing the jelly and melted fat that exuded from the sausages. The results were expressed as a percentage in relation to the net weight of the packed meat batter.

### 2.4. Lipid oxidation

Lipid oxidation of sausages was estimated by detecting malondialdehyde (MDA). This procedure was conducted according to the method described by Jung, Nam, and Jo (2016). For this analysis, MDA was extracted from the samples with acetonitrile as follows. A 3 g sample was homogenized with 6 mL of distilled deionized water and 50 μL of 7.2% 2,6-Di-tert-butyl-4-methylphenol in ethanol using a homogenizer (T-25 Basic) at 1130 ×*g* for 1 min. Next, 500 μL of the homogenate was transferred into an Eppendorf tube, and 100 μL of a 6 M NaOH solution (final concentration: 1 M) was added for alkaline hydrolysis of the protein-bound MDA. The tubes were incubated in a water bath at 60 °C for 45 min. After cooling in ice for 5 min, 1 mL of acetonitrile was added to the tube, and the mixture was vigorously vortexed. The tube was centrifuged at 13,000 ×*g* for 10 min (HM-150IV, Hanil Co., Ltd., Incheon, Korea). The upper clear phase of the supernatant contained the MDA extract. As an MDA standard, a 1,1,3,3-tetraethoxypropane solution (3.2 mM) was diluted with distilled deionized water to 0.1, 0.2, 0.4, 0.8, or 1.6 μM. Subsequently, 1 mL of the MDA extract, standard, or distilled deionized water (blank) was passed through a 0.2 μm polyvinylidene fluoride syringe filter (Whatman), and the filtrate was collected into a vial. The MDA concentration was then analyzed by HPLC (ACME 9000, Young Lin Instruments Co., Ltd., Daejeon, Korea) using an Atlantis T3 C18 RP column (4.6 × 250 mm, 5 μm particles) with a mobile phase consisting of 30 mM $K_2HPO_4$ (pH adjusted to 6.2 with $H_3PO_4$). The isocratic flow rate of the mobile phase was 1.2 mL/min, and the injection volume was 50 μL. The column temperature was maintained at 35 °C and the UV/VIS detector was set to a wavelength of 254 nm. The concentration of MDA in each sample was expressed as mg of MDA/kg of sausage.

### 2.5. Instrumental color measurements

The color of each sausage was measured using a colorimeter (CM-3500d, Minolta, Japan). Measurements were taken perpendicular to the surface of the sausage with a 30 mm diameter illumination area at two different locations per sample. The results were analyzed using the SpectraMagic software (Minolta, Japan) and were expressed CIE

lightness (L*), redness (a*), and yellowness (b*). Additionally, the color difference ($\Delta E$) with respect to sausages containing no phosphate and WMP was calculated using following equation.,

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

Where $L_1^*$, $a_1^*$, and $b_1^*$ were the values of WMP 0 and $L_2^*$, $a_2^*$, and $b_2^*$ were the values of treatment that was compared to WMP 0.

### 2.6. Instrumental texture properties

The texture properties of the sausages were analyzed by the two-bite system using a Texture Analyzer (Model A-XT2, Stable Micro Systems Ltd., UK) with a compression probe (70-mm diameter) attachment. The sausage (20 × 20 × 15 mm) underwent two cycles of 70% compression with a test speed of 2 mm/s. The texture characteristics of the sausage were expressed as the hardness, springiness, cohesiveness, gumminess, and chewiness.

### 2.7. Sensory evaluation

Sausages were stored in a refrigerator at 4 °C for 3 days before sensory evaluation. Sensory evaluation of the sausages was implemented using a group of twenty consumer panels. The sensory properties of sausages from six treatments were evaluated twice in two independent sessions. Two sessions were conducted over two days and the same twenty panels were participated in each session. Sausages from three batches were combined and cut regularly (30 × 15 × 15 mm). The sausages were reheated at 180 °C for 3 min using an electric steam oven (EON-C305CSM, Tong Yang Magic Co., Korea) and served to consumer panels on white glass plates. The scoring of each sample was done on a single sheet using a 9-point hedonic scale (1 = strongly dislike, 9 = strongly like). The color, flavor, taste, texture, and overall acceptability were each scored.

### 2.8. Statistical analysis

The data from this study were analyzed using the PROC GLM procedure in a randomized complete block design (batch as a block). The experimental unit was a sausage. For analyzing the data from the sensory evaluation, the panel was included in the model 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 considered for $p < 0.05$. The SAS software (version 9.3, SAS Institute Inc., Cary, NC, USA) was used for statistical analyses.

## 3. Results and discussion

### 3.1. Effect of WMP on the pH of meat batter and retention of water and fats

The pH of meat batter without phosphate (WMP 0) was the lowest among all treatments and the addition of WMP significantly increased its pH ($p < 0.05$, Table 2). The meat batters with the addition of > 1.0% WMP had similar pH values to that of the batter with phosphates. This result was consistent with previous studies. The research performed by Bao et al. (2008) showed that the addition of winter mushroom extracts to beef and fish meat slightly increased the pH of their products, although the increase was not statistically significant. Ko and Kim (2007) observed an increase in the pH of rice batter with the addition of mushroom (*Pleurotus eryngii*) powder, and reported that it might be caused by the buffering effect of proteins in the powder. Winter mushroom contains relatively high levels of basic amino acids such as histidine and arginine compared with acidic amino acids such as aspartic acid and glutamic acid (Ito, Ueno, & Kikuzaki, 2017).

**Table 2**
Measurement of the pH of the meat batter and separation of jelly and melted fat from sausages added with phosphate or winter mushroom powder.

| Treatments | pH | Exuded jelly and melted fat |
|---|---|---|
| Phosphate | 6.30[a] | 7.37[cd] |
| WMP 0 | 6.08[c] | 21.37[a] |
| WMP 0.5 | 6.13[b] | 15.27[b] |
| WMP 1.0 | 6.31[a] | 8.45[c] |
| WMP 1.5 | 6.31[a] | 6.59[cd] |
| WMP 2.0 | 6.33[a] | 5.39[d] |
| SEM[1] | 0.012 | 0.538 |

a-d Different letters within the same column represent significant differences ($p < 0.05$).
[1] Standard error of the mean (n = 18).

The amount of exuded jelly and melted fat from sausages was the highest in WMP 0 (21.37%) (Table 2). The exudation of jelly and melted fat from sausages significantly decreased with the addition of increasing amounts of WMP ($p < 0.05$). In addition, sausages treated with > 1.0% WMP showed no differences in the separation of jelly and melted fat compared with those treated with phosphate. This result was closely related to the increase in pH of the meat batters containing WMP, because the high pH of the meat batter would have increased its water holding capacity owing to the increased net negative charge of the meat proteins and, subsequently, decreased the exudation of fat and water (Lee, Jo, et al., 2018; Sebranek, 2009). In addition, the dried winter mushrooms contain dietary fibers at a level of 50.3% (Ulziijargal & Mau, 2011). Dietary fibers have oil absorption and hydration (water uptake, retention, and swelling) properties (Chaplin, 2003; Han & Bertram, 2017). Previous studies have reported improvements in water and fat retention in meat products with the addition of dietary fiber sources (Han & Bertram, 2017; Talukder, 2015; Verma, Sharma, & Banerjee, 2010). Based on the results, the addition of > 1.0% WMP to sausages had a similar effect to addition of phosphate, in terms of the pH of the meat batter and the separation of jelly and melted fat.

### 3.2. Effect of WMP on lipid oxidation of meat products

The MDA content of sausages with added phosphate was not significantly different from that of those without WMP (Fig. 1). In principle, suppressing lipid oxidation is one of the main functions of phosphates in meat products, although phosphates are not typically classified as antioxidants (Sebranek, 2009). The best-recognized antioxidant mechanisms of phosphates are metal chelation and the removal of catalysts that initiate lipid oxidation (Sebranek, 2009). However, the antioxidant effect of phosphate could not be confirmed in the current

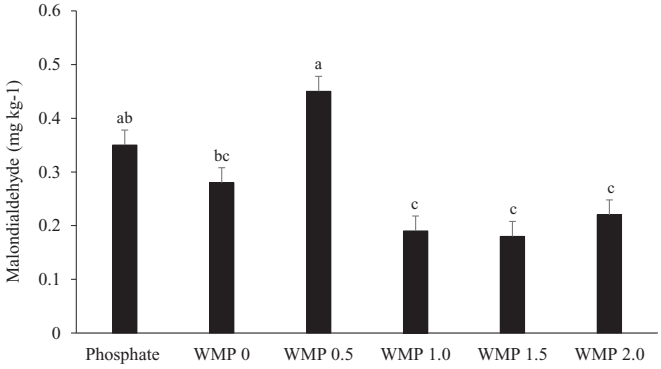


**Fig. 1.** The malondialdehyde content (mg/kg) of sausage added with phosphate or winter mushroom powder. Standard error of the mean = 0.028 ($n = 18$).
[a-c]The different letters represent significant differences ($p < 0.05$).

study. In addition, WMP 0 showed a significantly ($p < 0.05$) lower content of MDA than WMP 0.5. This result may be attributed to a substantial loss of jelly and melted fats. Various factors influence the formation of MDA, one of which is the fat content (Steppeler, Haugen, Rødbotten, & Kirkhus, 2016). A positive association between the fat content and MDA content was demonstrated (beef sirloin with a low fat content had a lower level of MDA than a minced beef product with a high fat content) (Steppeler et al., 2016). Thus, WMP 0 may have a reduced MDA content because of the loss of jelly and melted fat in which MDA was solubilized.

Sausages with the addition of > 1.0% WMP showed lower ($p < 0.05$) MDA contents than those with the addition of phosphates. There have been previous reports on the antioxidant activity of winter mushrooms. Winter mushrooms contain phenolic compounds (e.g., quercetin, chlorogenic acid, gallic acid, and protocatechuic acid) and flavonoids, which are well-known antioxidants (Mugisha, Asekova, Kulkarni, Park, & Lee, 2016; Zhang, Shin, Hong, & Lee, 2016; Lee, Lee, et al., 2018). The WMP used in the present study contained phenolic compounds at a level of 3.20 mg/g gallic acid equivalent (data not shown). The antioxidant activity of winter mushrooms has been evaluated using various methods, showing a strong reducing power, high scavenging activities, and an inhibitory effect on rancidity (Dong et al., 2017; Kang, 2012; Oh & Lee, 2010). Moreover, Bao et al. (2008) have reported the practical antioxidant effects of winter mushrooms, showing high reducing power and radical scavenging activity when winter mushroom extracts were added to beef and fish products. Furthermore, this study showed that winter mushrooms have an antioxidative activity when added to meat products, not only as extracts but also as powders.

### 3.3. Effect of WMP on the color of meat products

WMP 0 showed the lowest L*-value and the highest a* value among all treatments (Table 3). This may result from the low pH of the meat batter and the reduced retention of water and fats. The same amount of sodium nitrite was added to all experimental samples; nitrite is converted to nitric oxide, which is involved in the nitrosyl hemochrome (Sebranek, 2009). The decomposition of nitrites can be accelerated under acidic conditions (Braida & Ong, 2000; Honikel, 2008). Meat batter with WMP 0 showed the lowest pH value among treatments. Moreover, the greatest loss of water and fats was observed with WMP 0, implying that it may have concentrated myoglobin and nitrosyl hemochrome. The sausages containing > 1.0% WMP showed no significant differences in their L*-values compared with sausages containing phosphate, but had significantly higher a*-values ($p < 0.05$). The b*-values of WMP 1.0 and WMP 1.5 were similar to those of phosphate. There were no significant differences in color difference ($\Delta E$) values among all treatments, although the a*-values did differ significantly. These results imply that the addition of WMP does not negatively affect the color of meat products.

**Table 3**
Instrumental color (CIE L*, a*, and b*) measurements of sausages added with phosphate or winter mushroom powder.

| Treatments | L* value | a* value | b* value | $\Delta E$ |
|---|---|---|---|---|
| Phosphate | $70.46^{a}$ | $6.97^{b}$ | $11.23^{c}$ | 2.62 |
| WMP 0 | $67.46^{c}$ | $8.03^{a}$ | $11.41^{bc}$ | – |
| WMP 0.5 | $68.68^{bc}$ | $7.02^{b}$ | $12.07^{a}$ | 1.88 |
| WMP 1.0 | $69.07^{ab}$ | $7.96^{a}$ | $11.50^{bc}$ | 1.71 |
| WMP 1.5 | $69.46^{ab}$ | $7.99^{a}$ | $11.50^{bc}$ | 2.00 |
| WMP 2.0 | $69.21^{ab}$ | $7.79^{a}$ | $11.83^{ab}$ | 1.84 |
| SEM[1] | 0.356 | 0.106 | 0.122 | 0.378 |

a-c Different letters within the same column represent significant differences ($p < 0.05$).
[1] Standard error of the mean (n = 18).

Meat color, for both fresh meat and processed meat, is the primary factor that influences the perception of product freshness and consumer purchasing decisions (Becker, 2000). In particular, consumers expect a certain color for processed meat products; this unique and distinct color (generally perceived as pink) is usually developed by the addition of nitrites and/or nitrates (Aberle et al., 2001; Becker, 2000; Sebranek, 2009). If the colors of meat products do not match the expectations of consumers, they tend to hesitate in purchasing them. Thus, it is generally required that food additives do not change their color. However, most natural ingredients have strong colors, and alter the foodstuff completely in terms of appearance and sensory properties (Carocho et al., 2015). The color of WMP is white. Therefore, it is considered that WMP as a natural ingredient for addition to meat products would be free of the discoloration problems often caused by the addition of natural ingredients.

### 3.4. Effect of WMP on instrumental texture properties

Sausages with added phosphates had greater hardness, springiness, and chewiness than the WMP 0 sausages ($p < 0.05$, Table 4). This may be a consequence of the function of phosphates in meat systems, which is to facilitate the extraction of salt-soluble proteins by increasing ion strength, resulting in a more stable texture after heat treatment (Sebranek, 2009). In contrast to phosphate addition, sausages with added WMP showed significantly lower degrees of hardness, springiness, gumminess, and chewiness than both WMP 0 and phosphate-treated sausages ($p < 0.05$). This result may be attributed to the absence of phosphate. Sausages with only WMP added had relatively lower concentrations of solubilized proteins, which resulted in the formation of a weaker gel strength compared with those with added phosphates. Furthermore, WMP contains high amounts of dietary fiber. In this research, the values of hardness, gumminess, and chewiness tended to decrease as increase the level of WMP increased, although there were no significant differences. Previous studies found decreased hardness and chewiness in meat products with the addition of dietary fiber (Han & Bertram, 2017; Verma et al., 2010). Han and Bertram (2017) reported that dietary fiber in meat products disrupted the formation of protein-water or protein-protein gel networks and subsequently decreased the gel strength of meat products. Therefore, we conclude that the low solubilization of proteins and dietary fibers in sausages containing WMP led to the softer texture of these sausages.

### 3.5. Effect of WMP on sensory properties

The color score of WMP 1.0 was significantly higher than that of Phosphate, whereas there were no differences in the color scores for the other WMP levels compared to that of phosphate (Table 5). The flavor and taste scores of sausages with added WMP were not significantly different from those with added phosphates. In addition, there were no significant differences in texture scores among phosphate, WMP 1.0, and WMP 1.5. However, the texture scores for WMP 0.5 and WMP 2.0 were significantly lower than those of phosphate. The overall acceptability was not significantly different for the sausages with phosphate and those with WMP, except for WMP 2.0, which received the lowest score of 3.36 ($p < 0.05$). Of the sausages treated with WMP, those with WMP 1.0 received higher scores ($p < 0.05$) for flavor, taste, texture, and overall acceptability than those with WMP 2.0. Yang, Lin, and Mau (2001) found that winter mushrooms have high contents of free amino acids, which are associated with umami (MSG-like), sweet, and bitter tastes. In the present study, although the maximum level of WMP addition was 2.0% based on the total weight of the product, higher amounts of these bitterness-related free amino acids seem to negatively influence the sensory properties. Thus, 1.0% may be an appropriate level of WMP addition to avoid negative effects on consumer perceptions.

**Table 4**
Instrumental texture properties of sausages added with phosphate or winter mushroom powder.

| Treatment | Hardness (N) | Springiness | Cohesiveness | Gumminess | Chewiness |
|---|---|---|---|---|---|
| Phosphate | 58.61$^{a}$ | 0.67$^{a}$ | 0.22$^{ab}$ | 13.11$^{a}$ | 8.88$^{a}$ |
| WMP 0 | 48.90$^{b}$ | 0.53$^{b}$ | 0.23$^{a}$ | 11.17$^{a}$ | 5.96$^{b}$ |
| WMP 0.5 | 40.58$^{c}$ | 0.44$^{c}$ | 0.21$^{abc}$ | 8.52$^{b}$ | 3.77$^{c}$ |
| WMP 1.0 | 37.10$^{c}$ | 0.48$^{bc}$ | 0.21$^{abc}$ | 7.88$^{b}$ | 3.76$^{c}$ |
| WMP 1.5 | 35.84$^{c}$ | 0.43$^{c}$ | 0.20$^{c}$ | 7.19$^{b}$ | 3.09$^{c}$ |
| WMP 2.0 | 35.51$^{c}$ | 0.42$^{c}$ | 0.20$^{bc}$ | 7.22$^{b}$ | 3.01$^{c}$ |
| SEM[1] | 1.251 | 0.018 | 0.005 | 0.480 | 0.386 |

a-c Different letters within the same column represent significant differences ($p < 0.05$).
[1] Standard error of the mean (n = 18).

**Table 5**
Sensory properties of sausages added with phosphate or winter mushroom powder.

| Treatment | Color | Flavor | Taste | Texture | Overall acceptability |
|---|---|---|---|---|---|
| Phosphate | 5.09$^{b}$ | 4.82$^{ab}$ | 4.91$^{ab}$ | 5.73$^{a}$ | 5.27$^{a}$ |
| WMP 0 | 6.45$^{a}$ | 4.27$^{ab}$ | 4.64$^{ab}$ | 4.36$^{abc}$ | 4.55$^{ab}$ |
| WMP 0.5 | 5.64$^{ab}$ | 4.27$^{ab}$ | 4.00$^{ab}$ | 3.73$^{bc}$ | 4.00$^{ab}$ |
| WMP 1.0 | 6.18$^{a}$ | 5.64$^{a}$ | 5.55$^{a}$ | 4.64$^{ab}$ | 5.46$^{a}$ |
| WMP 1.5 | 5.91$^{ab}$ | 4.73$^{ab}$ | 5.10$^{ab}$ | 4.45$^{ab}$ | 4.91$^{ab}$ |
| WMP 2.0 | 5.64$^{ab}$ | 3.55$^{b}$ | 3.55$^{b}$ | 2.82$^{c}$ | 3.36$^{b}$ |
| SEM[1] | 0.259 | 0.399 | 0.415 | 0.383 | 0.427 |

a-c Different letters within the same column represent significant differences ($p < 0.05$).
[1] Standard error of the mean (n = 12).

## 4. Conclusion

Winter mushroom powder was studied as an alternative to phosphates in emulsion-type sausages. The addition of > 1.0% WMP to sausages inhibited the exudation of fat from sausages and increased the pH of meat batter. In addition, lipid oxidation of sausages was inhibited with the addition of > 1.0% WMP. The sausages containing WMP had softer texture compared to those containing phosphate. However, no adverse effects on color or sensory properties were observed for sausages as a result of adding the WMP, except for the case of the addition of 2.0% WMP. Therefore, this research indicates that WMP could effectively replace phosphates in meat products, and that 1.0% WMP addition may be the most effective level.

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