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Abstract

This study investigated freeze- or oven-dried winter mushroom powder (FDP or ODP, respectively) as an alternative to phosphate in beef patties. The beef patties were prepared with four treatments: no addition of phosphate and winter mushroom (control), addition of 0.3% sodium pyrophosphate (BP), addition of 1% FDP (BFW), and addition of 1% ODP (BOW). The pH of FDP and ODP was 6.73, and 7.00, respectively. FDP and ODP contained phenolic compound at a level of 3.50 and 5.45 g gallic acid equivalent/kg, respectively. The cooking loss of beef patties was the highest in the control and lowest in BP ($p<0.05$). BFW had lower cooking loss than the control ($p<0.05$), and BOW showed similar cooking loss as that of the control ($p>0.05$). Inhibition of lipid oxidation was found in BP and BOW as compared with control ($p<0.05$). BFW was similar to the control in terms of the degree of lipid oxidation ($p>0.05$). BOW showed lower L* and higher a* values than those of the control, BP, and BFW ($p<0.05$). Texture properties such as hardness, springiness, cohesiveness, gumminess, and chewiness were the highest in BP ($p<0.05$). A slight increase in hardness and springiness was observed in BOW compared to those of the control ($p<0.05$). The results showed that FDP and ODP did not exhibit all the properties of phosphate in beef patties. Therefore, FDP and ODP can be used for partial substitution of phosphate in beef patties.

Keywords: beef patty, phosphate, winter mushroom, drying method

1. Introduction

The increase in consumer demand for healthy foods has led to a growing interest in the clean-label food market (Asioli et al., 2017). Clean labels are granted to foods that meet several requirements (Yong et al., 2020), including the absence of synthetic additives. Synthetic nitrite, phosphate, and antioxidants have been used to improve the shelf life and sensorial quality of processed meat products (Sebranek, 2009; Jo et al., 2020c). Although synthetic food additives have advantageous effects on the quality of processed foods, natural-based ingredients have been developed for the substitution of synthetic additives in processed meat products (Jo et al., 2020b; Yong et al., 2020).

Phosphate is an essential additive for meat products. It increases product yield and improves sensorial properties by increasing water retention and gel strength and inhibiting lipid oxidation (Chen et al., 2019; Choe et al., 2018; Thangavelu et al., 2019). Winter mushrooms have plenty of antioxidative substances such as phenolic compounds and ergothioneine, which show activities of metal ion chelation and free radical scavenging (Jo et al., 2020b). In addition, the water retention in the meat products was improved with the addition of winter mushrooms because of high dietary fiber and pH in winter mushrooms (Choe et al., 2018). Recent studies reported that winter mushroom could be a suitable alternative to phosphate in pork sausage, chicken sausage, and enhanced beef (Choe et al., 2018; Choi et al., 2020; Jo et al., 2018; Jo et al., 2020b).

Drying is a general process to increase the shelf life and ease-of-use of natural products. Freeze drying is a well-known method that can be widely used for the preservation of various natural products without the deterioration of their functional properties, such as antioxidant and antimicrobial activities (Thamkaew et al., 2020). However, this method involves considerable time and cost (Soysal and Öztekin, 2001). Oven drying is a relatively inexpensive and simple process that is commonly used in the food industry (Soysal and Öztekin, 2001). In addition, some previous studies reported that drying of various natural substances with hot air at approximately 170℃ increased the antioxidant activity with the Maillard reaction (Chang et al., 2006; Lin et al., 2016). Maillard reaction is a type of non-enzymatic browning which involves the chemical reaction of an amino acid with carbonyl group of a reducing sugar, and the reaction product exhibits an antioxidant activity owing to its hydrogen-donating ability (Namiki, 1988). In addition, it can be a major factor in the formation of a desirable flavor in heated foods by generating various flavoring compounds (Van Boekel, 2006).

Beef patty is a popular food consumed globally and a major meat product in the home meal replacement market. Beef is highly nutritious because it contains balanced amino acids, vitamins, and minerals (Lee et al., 2020b). However, beef products are easily oxidized because of the abundant iron content, which is a critical prooxidant in meat (Baron and Andersen, 2002; Choi et al., 2020; Lee et al., 2020a). Lipid oxidation affects the sensory and nutritional value of meat products, and lipid oxidation products, including malondialdehyde (MDA), are negatively recognized by consumers for their genotoxicity and cytotoxicity (Jung et al., 2016; Min et al., 2010).

We hypothesized that winter mushrooms could improve the quality of beef patties owing to their antioxidant activity, dietary fiber, and pH increase effect and exhibit actions similar to those of phosphate in beef patties. In addition, oven-dried winter mushrooms may be more effective in improving the quality of beef patties by maximizing antioxidant activity and enhancing sensorial properties. Therefore, the antioxidant activity and additional effects of freeze- and oven-dried winter mushroom powder in beef patties and its use as an alternative to phosphate were investigated in this study.

2. Materials and Methods

2.1. Properties of the freeze- or oven-dried winter mushroom powder

2.1.1. Preparation of the winter mushroom powder

Winter mushrooms (*Flammulina velutipes*) were purchased from a local market (Daejeon, Korea). The mushrooms were frozen at −70℃ for 24 h, and lyophilized using a freeze dryer (Bondiro, Ilshin Co., Seoul, Republic of Korea) at room temperature and the 5 mTorr of chamber pressure, and then pulverized using a food processor (FPM250, Kenwood Ltd., Havant, UK), yielding the freeze-dried powder (FDP). The oven-dried winter mushroom powder (ODP) was prepared using a drying oven (JSOF-150, JS Research Inc., Gongju, Republic of Korea) at 170℃ for 15 min and pulverized using a food processor (FPM250). The moisture contents of FDP and ODP were 5.72% and 4.67%, respectively. The powders were stored at −20℃ until their use.

2.1.2. Antioxidant potential

The methanolic extracts of winter mushroom powder were prepared by the extraction of 0.5 g mushroom powder in 49.5 mL of 70% (v/v) methanol while shaking for 60 min.

The total phenolic content in the methanolic extracts of FDP and ODP was measured using the Folin–Ciocalteu method (Subramanian et al., 1965) and is expressed as gallic acid equivalents (g/kg).

The 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity of the methanolic extract was estimated using the method described by Jung et al. (2017), and the half-maximal effective concentration (EC_{50}) for scavenging DPPH radicals was calculated.

Reducing power was determined based on the reduction rate of ferric iron to ferrous iron using the method described by Oyaizu (1986). The sample solutions of FDP and ODP (15, 12.5, 10, 7.5, and 5 mg/100 mL in 70% (v/v) methanol and 7, 5.75, 4.5, 3.25, and 2 mg/100 mL in

70% (v/v) methanol, respectively) were used to measure the reducing power. The half-maximal effective concentration (EC_{50}) for 0.5 absorbance at 700 nm was calculated using a spectrophotometer (DU® 530, Beckman Instruments Inc., Fullerton, CA, USA).

2.1.3. pH and color

The 1 g of FDP and ODP were homogenized with 9 mL distilled water using a homogenizer (T25 basic, IKA® -Werke GmbH & Co. KG, Staufen, Germany) and centrifuged at 2,090×g for 10 min using a centrifuge machine (ScanSpeed 1580R, Labogene ApS, Lillerød, Denmark). The supernatant was filtered using filter paper (No. 4 filter paper, Whatman, Maidstone, England) and the pH value was measured using a pH meter (SevenEasy, Mettler-Toledo Intl Inc., Schwerzenbach, Switzerland).

The instrumental color (CIE L*, a*, b*) of FDP and ODP was measured using a spectrophotometer (CM-3500d, Konica Minolta Inc., Tokyo, Japan). The measurements were taken perpendicular to the measuring mini petri dish (CM-A128, Konica Minolta Inc., Tokyo, Japan) containing powder with an illumination area of 30 mm, illuminant D65, and 10 ° standard observer. The results were analyzed using SpectraMagic Software (SpectraMagic™ NX, Konica Minolta Inc., Tokyo, Japan).

2.2. Qualitative properties of beef patties

2.2.1. Manufacture of beef patty

Three fresh bottom rounds from three heifer carcasses were prepared, and the bottom round from each carcass was allocated to each batch. The bottom round of beef (390 g) was mixed with pork back fat (60 g), bread powder (30 g), chopped onion (30 g), chopped garlic (12 g), isolated soybean powder (12 g), salt (6 g), and water (60 g) in a mixer for 5 min. The formula for each of the four treatments are as follows: 1) control: patty manufactured without sodium pyrophosphate, 2) Positive control (BP): patty manufactured with sodium pyrophosphate (0.3%); 3) BFW: patty manufactured with FDP (1%); and 4) BOW: patty manufactured with ODP (1%). The meat batter was prepared thrice for each treatment, and the patty (100 g meat batter) was molded with a stainless container (80 mm × 45 mm). Five patties were made from each meat batter and cooked in an electric oven (COR-055KE, SK magic Co., Ltd., Seoul, Republic of Korea) at 170℃ for 15 min. Total nine beef patties (three patties /each batch) were used for the analysis of physicochemical properties.

2.2.2. pH of meat batter and cooking loss of beef patty

Meat batter (1 g) was homogenized with distilled water (9 mL) using a homogenizer (T25 basic). The homogenates were centrifuged at 2,090×g for 10 min (1580R) and filtered using filter paper (No. 4 filter paper). The pH value of the filtrate was measured using a pH meter (SevenEasy).

Cooking loss of beef patties was calculated by comparing the weight difference between the cooked beef patties and raw beef patties.

2.2.3. Lipid and protein oxidation

Lipid oxidation in beef patties was detected by measuring the MDA content. MDA was extracted from beef patties and then analyzed using a high-performance liquid chromatography (HPLC) system (1200 series, Agilent Technologies Inc., USA) with an Atlantis T3 C18 RP column (Waters corp., Milford, MA, USA) (4.6 × 250 mm, 5 μm-particles). The analysis procedures were performed in accordance with the method described by Jung et al. (2016). 1,1,3,3-tetraethoxypropane was used as the standard compound, and the MDA content in beef patties was expressed as mg MDA/kg beef patties.

Protein oxidation in beef patties was measured by analyzing the total carbonyl content using the derivatization method of 2,4-dinitrophenylhydrazine (DNPH), as described by Jo et al. (2020b). 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.

2.2.4. Instrumental color measurements

A colorimeter (CM-3500d) was used to measure the color (CIE L*, a*, b*) of each beef patty. The measurements were taken perpendicular to the inner surface of the patty at two different locations per sample with an illumination area of 30 mm, illuminant D65, and 10 ° standard observer. The results were then analyzed using SpectraMagic Software (SpectraMagic™ NX).

2.2.5. Texture profile analysis (TPA)

The texture of beef patties was measured with a two-bite system using a texture analyzer (Model A-XT2, Stable Micro Systems Ltd., Godalming, UK) with a compression probe that had a diameter of 70 mm. The patties were cut to regular size (2 × 2 × 1.5 cm^3) and subjected to two cycles of 70% compression at a test speed of 2 mm/s. The texture characteristics of beef patties were expressed as hardness, springiness, cohesiveness, gumminess, and chewiness.

2.3. Statistical analysis

This study was independently repeated thrice (three batches). The data from the quality measurements of beef patties were statistically analyzed using the mixed model under a randomized complete block design (with a batch corresponding to a block). The least-square mean values and standard error of the least-square means (SEM) were reported, and Tukey's multiple range test was performed to draw specific comparisons. SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA) was used for the statistical analyses.

3. Results and discussion

3.1. Properties of the winter mushroom powder

3.1.1. Antioxidant potential

Winter mushrooms are fungi that exhibit a high antioxidant activity (Shah et al., 2018; Zhang et al., 2013). Phenolic compounds are anti-oxidizing substances that remove reactive oxygen species existing in plants and play a role in reducing oxidative stress. The total phenolic content of the oven-dried winter mushroom powder (ODP) was 5.45 g GAE/kg that was significantly higher than that of the freeze-dried winter mushroom powder (FDP) at 3.50 g GAE/ kg (Table 1, $p<0.05$). The EC_{50} values of FDP and ODP for DPPH radical scavenging were 16.89 g/kg and 11.52 g/kg, respectively, which were significantly different between treatments ($p<0.05$). In addition, ODP had a significantly lower EC_{50} value of reducing power than that of FDP ($p<0.05$), indicating that ODP has a higher antioxidant potential than FDP. This is analogous to the phenomenon that previous studies report of an increase in phenolic compound content and antioxidant activity of natural products subjected to heat treatment (Li and Shah, 2013; Saad et al., 2014). Another study suggests that heat treatment of plants could improve the antioxidant activity by releasing phenolic compounds from the collapsed cell wall and the rapid inactivation of polyphenol oxidase (PPOs) such as tyrosinase, catecholase, and laccase (Nguyen et al., 2018). In addition, Maillard reaction products have antioxidant activity, which might be due to the action of reductones and melanoidins formed in the reaction process (Namiki, 1988). The reductone can effectively donate hydrogen, and melanoidin can block the reaction of metal ions or residues generating radicals (Namiki, 1988).

3.1.2. pH and color

The pH of the ingredients is an important property of meat products because the increase in pH with the addition of ingredients can improve water retention in meat products (Choe et al., 2018; Jo et al., 2020a). When the pH of fresh winter mushroom was 6.81 (data not shown), the pH of ODP and FDP was 7.00 and 6.73, respectively, and the pH of ODP was significantly higher than that of FDP (Table 1, $p<0.05$). Evidently, the oven-drying process resulted in the increased pH of winter mushrooms. However, these results may not be common. Brands and Van Beokel (2002) reported that formic acid and acetic acid are the main products of the Maillard reaction. Lertittikul et al. (2007) also reported a decrease in the pH value of porcine plasma protein–glucose Maillard reaction products with increasing heating time. Previous studies found that the pH of foods containing proteins increased after heat treatment, which might be attributed to the release of basic amino acids from heat-denatured proteins (Vasanthi et al., 2007; Oz et al., 2017). Thus, a similar effect may occur in winter mushrooms subjected to heat treatment.

The application of oven-drying altered the color of winter mushrooms to brown by the Maillard reaction. ODP had a lower L* value and higher a* and b* values than that of FDP (Table 1, $p<0.05$), and this change could be an effect of the brown pigment melanoidin as the final Maillard reaction product (Namiki, 1988).

3.2. Properties of beef patty

3.2.1. pH of meat batter and cooking loss

The high pH of meat products is one of the major factors determining the quality and increasing the economic value of meat products. Meat batter containing no phosphate and winter mushroom powder (control) showed the lowest pH among the treatments (Table 2, p<0.05). Although the addition of winter mushroom powders (BFW and BOW) to meat batter at a concentration of 10 g/kg increased the pH compared to the control (p<0.05), the effect of the winter mushroom powder on the pH of the meat batter was not notable. In addition, no difference in pH between BFW and BOW was found despite the higher pH of ODP than that of FDP. The pH of BFW and BOW was significantly lower than that of BP, which was manufactured with the addition of 0.3% sodium pyrophosphate (p<0.05). Choe et al. (2018) reported no difference in pH between pork batter containing 1% winter mushroom powder and 0.3% sodium pyrophosphate. However, chicken meat batter containing 1% winter mushroom powder had a lower pH than that of chicken meat batter containing 0.3% sodium pyrophosphate (Jo et al., 2018). The different effects of winter mushroom powder addition on the pH of meat batter may be caused by the differences in buffering capacity of meats such as beef, pork, and chicken.

The increase in pH of meat batter for comminuted meat products improves their water and fat retention because the increased electrical repulsion forces among proteins increases the space available for water in myofibrillar filaments and gel structure and fat droplets in the gel structure (Chen et al., 2019). The highest and lowest cooking loss of beef patties occurred in the control group and the BP, respectively (Table 2, p<0.05). BFW showed a significantly lower cooking loss than the control group (p<0.05). However, the cooking loss in BOW was similar to that in the control (p>0.05). Previous studies found that the addition of winter mushroom powder to pork and chicken sausages with the same level of concentration as that used in the present study resulted in a decrease in cooking loss, which was attributed to the increase in pH and the water holding and fat binding capacity of dietary fiber in winter mushroom powder (Choe et al., 2018; Jo et al., 2018). In the present study, there were no notable pH changes in meat batter with the addition of winter mushroom powder. The decrease in the cooking loss of BFW might be due to dietary fiber. However, the dietary fiber in ODP might lose its water holding capacity and fat binding capacity by heat treatment. A previous study reported a reduced water-holding capacity of dietary fiber with structural damage induced by heat treatment (Miranda et al., 2010; Vega-Gálvez et al., 2015).

3.2.2. Lipid and protein oxidation

The content of MDA, a secondary product of lipid oxidation, in beef patties was the highest in the control and the lowest in the BP (Table 3, $p<0.05$). This result was attributed to the antioxidant activity of phosphate in the BP. Phosphate suppresses lipid oxidation through metal-ion chelating activity in the meat system (Choe et al., 2018). Beef contains considerable myoglobin, and the iron ions released from myoglobin can generate hydroxyl radicals via the Fenton reaction (Lloyd et al., 1997). Therefore, the antioxidant activity of phosphate by chelating metal ions may be maximized in beef compared to that in chicken and pork. Previous studies found that freeze-dried winter mushroom at l.0% level of concentration in pork and chicken sausages served as an alternative to phosphate and decreased lipid oxidation (Jo et al., 2018; Jo et al., 2020b). However, there was no inhibition of lipid oxidation in BFW compared to that in the control used in the present study ($p>0.05$).

This result might be attributed to the different lipid oxidation potential with the major oxidants and substrates among beef, pork, and chicken (Rhee et al., 1996). Phenolic compounds in winter mushroom powder can effectively suppress lipid oxidation in pork and poultry. However, its effect as a prooxidant might be less in beef because the main factor of lipid oxidation in beef is metal ions (Min et al., 2010). Nonetheless, the MDA content of BOW was lower than that of the control and BFW ($p<0.05$), although it was higher than that of BP ($p<0.05$). These results were attributed to the increased antioxidant activity of winter mushrooms after oven-drying. The ODP showed an increase in antioxidant activity with an increase in phenolic content and the generation of Maillard reaction products (Table 1). Alfawaz et al. (1994) and Smith and Alfawaz (1995) reported the inhibitory effects of Maillard reaction products on lipid oxidation in cooked ground beef.

There were no significant differences in the carbonyl content among the treatments (Table 3, p>0.05). Phosphate and winter mushroom powders had no inhibitory effect on protein oxidation in beef patties. This result is in line with that of a previous study. Jo et al. (2018) reported that phosphate and winter mushroom powder had no effect on the protein oxidation in chicken sausages. However, the effect of winter mushrooms on protein oxidation in meat products should be further studied with other protein oxidation parameters, such as free sulfhydryl content and tryptophan fluorescence intensity. The carbonyl content might not be a suitable indicator of protein oxidation in beef patties. In this study, the carbonyl content of beef patties that included winter mushroom powders, tended to be higher than that of control and BP. This might be due to the action of quinones generated by the oxidation of phenolic compounds (Pourcel et al., 2007). Quinones can accelerate the oxidative deamination of responsive amino acids and consequently produce applicable carbonyl compounds (Estévez and Heinonen, 2010). Cando et al. (2014) reported an increase in the carbonyl content and inhibition of lipid oxidation in beef patties with the addition of the phenolic-rich extract of Willowherb (*Epilobium hirsutum L.*).

3.2.3. Color and texture

The intense color of natural ingredients incorporated in meat products results in color changes in meat products (Jeong et al., 2020; Lee et al., 2019). There were no significant differences in L* and a* values, except for b* value among control, BP, and BFW (Table 4, p>0.05). Previous study reported that the lack of an effect of winter mushroom based on its white color on the color of meat products could be a suitable property as a natural ingredient for meat products (Choe et al., 2018; Choi et al., 2020; Jo et al., 2018; Jo et al., 2020b). BP had a higher b* value than control and BFW (p<0.05). This result might be attributed to the increase in Maillard reaction by the increase of pH with the phosphate addition. Maillard reaction rate is faster in high pH environments, and some studies reported that phosphate accelerates Mallard reaction (Bell, 1997). The ODP showed lower L* and higher a* values with the Maillard reaction compared to FDP (Table 1). From the results, BOW showed the lower L* and the higher a* values compared to those of control, BP, and BFW ($p<0.05$). However, the difference in color among the treatments was small.

The texture properties of beef patties were presented as hardness, springiness, cohesiveness, gumminess, and chewiness (Table 5). BP showed the highest values for all the texture properties ($p<0.05$). The addition of phosphates in meat products increases the solubility of myofibrillar proteins by the dissociation of actomyosin and an increase in ion strength (Chen et al., 2019). The increase in solubilized myofibrillar proteins results in the strong and elastic gel structure of comminuted meat products (Choe et al., 2018). In addition, the phosphorylation of myofibrillar proteins leads to an increase in the interaction between insolubilized and solubilized myofibrillar proteins, thereby increasing the gel strength (Chen et al., 2019). There were no differences in cohesiveness, gumminess, and chewiness among the control, BFW, and BOW groups ($p>0.05$). The hardness of BOW and springiness of BFW and BOW were higher than those of the control ($p<0.05$). The effect of winter mushroom powder addition on the texture of meat products differed between beef patties and sausages. Choe et al. (2018) and Jo et al. (2018) reported a decrease in hardness and springiness of pork and chicken sausages with the addition of winter mushroom powder and reported that these results were caused by the hindrance of gelling by dietary fiber in winter mushroom. The difference in texture changes in meat products with winter mushroom addition might be different in the organization of structure among meat products. The structure of sausages, especially emulsion sausages, is densely organized by the interaction of solubilized proteins, insoluble proteins, and small particles of myofibrillar filaments (Chen et al., 2019). However, the structure of beef patties is relatively less dense compared to that of sausage because it is organized by the interaction of partly solubilized protein and meat particles. Therefore, the interactions among structural components in beef patties might not be affected by dietary fiber from winter mushrooms. In the present study, the pH of the meat batter increased for BFW and BOW (Table 2). The increase in pH of meat batter results in a decrease of the electrical attraction force among myofibrillar proteins, resulting in increased solubility of myofibrillar proteins (Thangavelu et al. 2019). Therefore, the myofibrillar proteins in BFW and BOW might be more solubilized and form a more intense structure than the control.

4. Conclusion

The antioxidant activity and effects of freeze- and oven-dried winter mushroom powder in beef patties were observed to investigate its potential as a phosphate substitute.

Phosphate reduced the cooking loss and lipid oxidation and increased the texture properties including hardness, springiness, cohesiveness, gumminess and chewiness of beef patties. The addition of FDP in beef patties reduced the cooking loss, whereas it had no antioxidant effect. However, the addition of ODP inhibited lipid oxidation without affecting the cooking loss of beef patties. Both FDP and ODP showed no notable effects on the texture of beef patties. These results showed that winter mushroom powder showed different activities based on the drying processes as an alternative to phosphate in beef patties. Furthermore, winter mushroom powder did not reproduce all the actions of phosphate in beef patties. Therefore, FDP and ODP can be used for the partial substitution of phosphate activity in beef patties, and the combined effects with other natural ingredients should be further studied in beef patties.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Ethics approval

This study did not require IRB/IACUC approval because it did not involve human or animal participants.

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Tables

Table 1. Properties of the winter mushroom powder

Properties	FDP[3]	ODP[4]	SEM[5]
Total phenolic content (g GAE[1]/kg)	3.50^{b}	5.45^{a}	0.157
EC_{50}[2] value of scavenging			
DPPH (g/kg)	16.89^{a}	11.52^{b}	0.105
Reducing power (g/kg)	6.03^{a}	3.63^{b}	0.109
pH	6.73^{b}	7.00^{a}	0.011
L*	87.02^{a}	52.65^{b}	0.165
a*	0.16^{b}	8.78^{a}	0.076
b*	20.98^{b}	23.48^{a}	0.150

[1]Gallic acid equivalent.

[2]Half-maximal effective concentration.

[3]FDP: freeze-dried winter mushroom powder.

[4]ODP: oven-dried (170℃) winter mushroom powder.

[5]Standard error of the least square mean (n=6).

^{a,b} Different letters in the same row indicate significant differences between means ($p<0.05$).

Table 2. pH of meat batter and cooking loss of beef patty added with winter mushroom powder

Treatments[1]	pH	Cooking loss (%)
Control	5.73[c]	15.20[a]
BP	6.08[a]	10.23[c]
BFW	5.78[b]	12.93[b]
BOW	5.76[b]	14.34[a]
SEM[2]	0.006	0.320

[1]Control: beef patty manufactured without sodium pyrophosphate; BP: beef patty manufactured with sodium pyrophosphate; BFW: beef patty manufactured with 1% freeze-dried winter mushroom powder; BOW: beef patty manufactured with 1% oven-dried winter mushroom powder.

[2]Standard error of the least square mean (n=12).

[a-c]Different small letters in the same column indicate significant differences between means ($p<0.05$).

Table 3. Malondialdehyde and carbonyl contents in the beef patty added with winter mushroom powder

Treatments[1]	Malondialdehyde content (mg/kg)	Carbonyl content (nmol/mg)
Control	2.16[a]	1.97
BP	1.60[c]	1.92
BFW	2.14[a]	2.20
BOW	1.79[b]	2.07
SEM[2]	0.035	0.091

[1]Control: beef patty manufactured without sodium pyrophosphate; BP: beef patty manufactured with sodium pyrophosphate; BFW: beef patty manufactured with 1% freeze-dried winter mushroom powder; BOW: beef patty manufactured with 1% oven-dried winter mushroom powder.

[2]Standard error of the least square mean (n=12).

[a-c]Different small letters in the same column indicate significant differences between means ($p<0.05$).

Table 4. Meat color of the beef patty added with winter mushroom powder

Treatments[1]	L*	a*	b*
Control	39.57^{a}	6.58^{b}	15.37^{c}
BP	39.56^{a}	6.84^{b}	17.48^{a}
BFW	39.07^{a}	6.87^{b}	16.91^{b}
BOW	37.10^{b}	7.50^{a}	17.03^{ab}
SEM[2]	0.352	0.126	0.316

[1]Control: beef patty manufactured without sodium pyrophosphate; BP: beef patty manufactured with sodium pyrophosphate; BFW: beef patty manufactured with 1% freeze-dried winter mushroom powder; BOW: beef patty manufactured with 1% oven-dried winter mushroom powder.

[2]Standard error of the least square mean (n=12).

$^{a-c}$Different letters in the same column indicate significant differences between means ($p<0.05$).

Table 5. Texture properties of the beef patty added with winter mushroom powder

Treatments[1]	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)
Control	36.41^{c}	0.50^{c}	0.39^{b}	14.07^{b}	7.01^{b}
BP	76.83^{a}	0.68^{a}	0.45^{a}	34.50^{a}	23.40^{a}
BFW	40.59^{bc}	0.55^{b}	0.36^{b}	14.51^{b}	8.02^{b}
BOW	43.66^{b}	0.55^{b}	0.36^{b}	15.56^{b}	8.58^{b}
SEM[2]	1.450	0.012	0.009	0.815	0.492

[1]Control: beef patty manufactured without sodium pyrophosphate; BP: beef patty manufactured with sodium pyrophosphate; BFW: beef patty manufactured with 1% freeze-dried winter mushroom powder; BOW: beef patty manufactured with 1% oven-dried winter mushroom powder.

[2]Standard error of the least square mean (n=12).

$^{a-c}$Different small letters in the same column indicate significant differences between means ($p<0.05$).