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Abstract

Antioxidant activity of freeze-dried paprika powder and storage properties of emulsion-type pork sausages containing diverse concentrations of this powder (0, 1, 2, and 3%) were analyzed. Antioxidant activities of red and yellow paprika powders were analyzed by evaluating their 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, ferric reducing antioxidant power (FRAP), total phenol content (TPC), and total flavonoid content (TFC). The yellow paprika powder exhibited remarkably higher DPPH radical scavenging activity, FRAP values, and TPC than the red paprika powder ($p<0.05$), while TFC showed no remarkable difference between them ($p>0.05$). Storage properties of sausages containing the yellow paprika powder were analyzed by evaluating their water holding capacity, cooking yield, and thiobarbituric acid reactive substance (TBARS), and volatile basic nitrogen (VBN) values. The 3% yellow paprika powder group showed remarkably higher water-holding capacity and cooking yield compared to the 0% group ($p<0.05$). TBARS values were remarkably lower in the 2 and 3% yellow paprika powder groups than in the 0% group at all weeks ($p<0.05$). VBN value was remarkably lower in the 3% yellow paprika powder group than in the 0% group at all weeks ($p<0.05$). Overall, addition of 3% yellow paprika powder improved the storage properties of emulsion-type sausages.

Keywords: paprika; freeze-dried; antioxidant activity; emulsion-type sausage; storage property

Introduction

Meat products available in the market, such as ham, sausage, and patty, are processed through various steps, such as shaping, curing, and smoking (Kim et al., 2019). Emulsified sausages are manufactured via emulsification to elute the salt-soluble proteins and mix with fat and shaved ice (Jung and Yoon, 2022). These salt-soluble proteins are characterized by the gelation of fat, moisture, and protein under heat treatment, which improves the sausage properties (Kwak et al., 2010).

Approximately 20% fat is added to emulsified sausages and affects various sensory characteristics, such as flavor and taste of food (Lee, 2011). However, the oxidation of fat negatively impacts the color and nutritional quality of meat and meat products (Mun and Chin, 2021). Synthetic antioxidants, for example butylated hydroxyanisole, butylated hydroxytoluene, and nitrite, are used to suppress this deterioration (Kim and Hwangbo, 2011). Owing to the growing demand for healthy food, including products without chemical additives (Park, 2022), natural antioxidants are attracting increasing interest (Jeong and Yang, 2023).

Antioxidants, as a radical inhibitor, are essential additives for meat products that suppress lipid oxidation, by neutralizing the activity of free radicals (Park and Chin, 2023). However, concerns regarding the safety of consuming such harmful synthetic antioxidant, many studies are being conducted on natural antioxidants extracted from edible plants such as broccoli and wasabi (Min et al., 2017; Choi et al., 2022; Lee et al., 2020). Major natural antioxidants include phenolic compounds, carotenoids, flavonoids, and vitamins A, C, E which are abundant in vegetables and fruits (Sadef et al., 2022). Many studies are exploring the efficacy of natural antioxidants as alternatives to synthetic antioxidants by applying cabbage, radish, and paprika to meat products (Jeong et al., 2022; Kim and Chin, 2021).

Paprika (Capsicum annuum var. angulosum) is commonly known as paprika, sweet pepper, bell pepper, or pimento (Lee et al., 2017). It contains phytochemicals, such as phenolic compounds, carotenoids, and flavonoids and antioxidants, such as water-soluble vitamin C (Jeong et al., 2023). It also contains various carotenoids, such as capsanthin, capsorubin, zeaxanthin, and β-carotene, depending on the color (Ponder et al., 2021). Many methods are used to pulverize paprika, including freeze drying, vacuum drying, and hot air drying. Antioxidants become unstable upon contact with heat, light, and oxygen; therefore, the freeze-drying method is suitable to minimize the thermal damage (Shim and Chin, 2013).

In this study, we intended to analyze the antioxidant capacity of freeze-dried paprika powder based on its color and determine its effects on the quality and antioxidant capacity of emulsified sausages. Additionally, we evaluated the possible application of paprika as a natural antioxidant for food products.

Materials and Methods

Manufacture of freeze-dried paprika powder and supernatant

Paprika was purchased online (paprika_unnie, Haman, Korea), freeze-dried, and powdered. Red and yellow paprika were prepared by removing the core, seeds, and stalks, which are inedible, and cutting the flesh into cubes. Then, approximately 400 g was placed on the freeze-drying machine, the entrance was sealed with parafilm, and frozen in a deep freezer (TSE320GPD; Thermo Fisher Scientific, Waltham, MA, USA) at –81 ℃ for 24 h. Then, it was freeze-dried in a freeze dryer (FD 12008; ilShinBioBase, Gyeonggi-do, Korea) at –121 ℃ and 5 mTorr vacuum pressure for 88 h. Freeze-dried paprika was ground for 1 min using a mixer (DP-5800BL; DU-PLEX, Gyeonggi-do, Korea). The crushed paprika was filtered once using a standard mesh sieve No. 18 (DH.Si8031; DAIHAN Scientific, Gangwon-do, Korea) and standardized to a 32 mesh size using a standard mesh sieve No. 35 (DAIHAN Scientific). Then, red and yellow paprika powders were vacuum-sealed and kept at –81 ℃ for later use. The supernatant used in the antioxidant activity experiment of paprika was prepared modifying the method of Park et al. (2015). To extract the water-soluble substances, paprika powder was mixed with distilled water at a ratio of 1:50, stirred for 24 h using a stirrer to homogenize the mixture, and centrifuged for 10 min at 4 ℃ and 983× g using a centrifuge (Supra R22; Hanil Science, Gyeonggi-do, Korea). Subsequently, the filtered supernatant using Whatman No. 1 filter paper (GE Healthcare, Chicago, IL, USA) was used for the experiment.

Dry yield

Drying yield was calculated by measuring the weight of fresh paprika and the weight after drying when producing freeze-dried paprika powder. The determined value was entered into the corresponding calculation formula and expressed as a percentage.

$$\text{Dry yield (\%)} = \frac{\text{weight after drying (g)}}{\text{weight of fresh paprika (g)}} \times 100$$

pH

In the case of powder, distilled water was added to red and yellow paprika powder at a ratio of 1:9 and homogenized with a vortex mixer for 1 min. For sausages, distilled water was added to pork sausages to containing yellow paprika powder was at a ratio of 1:4 and homogenized at 6,451× g for 1 min by an ultra-turrax (HMZ-20DN; Poonglimtech, Gyeonggi-do). The pH was then measured by a calibrated glass electrode pH meter (Model S220; Mettler-Toledo, Schwerzenbach, Switzerlnad) buffers (Suntex Instruments) with pH 4.01, 7.00, and 10.00.

Color

Lightness (CIE L* value), redness (CIE a* value), and yellowness (CIE b* value) of the red paprika powder, yellow paprika powder, and heated pork sausage were measured by a colorimeter (CR-10; Minolta, Tokyo, Japan). A white standard plate CIE L* value of +97.83, a* value of –0.43, and b* value of +1.98 was used as the reference.

2,2-Diphenyl-1-picrylhydrazy (DPPH) radical scavenging activity

1 mL of distilled water was included to 1 mL of each supernatant of red and yellow paprika powders, mixed with 0.2 mM DPPH solution in 1:1 ratio, and vortexed. Then, the reaction was performed at room temperature in the dark for 30 min, and the absorbance (Abs) was determined

at 517 nm using a multi-mode microplate reader (SpectraMax iD3; Molecular Devices, San Jose, CA, USA). DPPH radical scavenging activity of the paprika supernatant was determined. The value was entered into the corresponding calculation formula and expressed as a percentage, using distilled water as a blank sample instead of the paprika supernatant.

$$\text{DPPH (\%)} = \frac{B-S}{S} \times 100$$

B: blank Abs

S: sample Abs

Ferric reducing antioxidant power (FRAP)

FRAP reagents were prepared by mixing 10 mM 2,4,6-tripyridyl-s-triazine (TPTZ) and 20 mM FeCl3 in a ratio of 10:1:1 with 0.3 M sodium acetate buffer and 40 mM HCl, followed by reaction at 37 °C for 15 min. Thereafter, 300 μL of each supernatant of red paprika powder, yellow paprika powder, and 900 μL of FRAP reagent were mixed to vortex, and light was blocked and reacted at 37 ℃ for 15 min. The absorbance of the reaction mixture was determined at 593 nm using a multi-mode microplate reader (SpectraMax iD3; Molecular Devices, San Jose, CA, USA), and the value was calculated by substituting the absorbance into a standard curve using Trolox as a standard material.

Total phenol contents (TPC)

Next, 80 μL of 2 N Folin-Ciocalteu was included to 40 μL of each supernatant of red paprika powder and yellow paprika powder, and after 3 min, 800 μL of Na_2CO_3 was included and vortexed. Absorbance was measured at 765 nm using a multimode microplate reader (SpectraMax iD3; Molecular Devices, San Jose, CA, USA) after reaction at 37 ℃ in the dark for 30 min. The standard curve was converted to mg GAE/g (GAE) using gallic acid.

Total flavonoid contents (TFC)

100 μL of 1 N NaOH and 1 mL of diethylene glycol were included to 100 μL of the supernatant of red and yellow paprika powder and reacted in the dark at 37 ℃ for 1 h. Then, measurements were made at 420 nm using a multimode microplate reader (SpectraMax iD3, Molecular Devices, San Jose, CA, USA). Finally, the standard curve was converted to mg NE/g (NE: naringin acid equivalent) using naringin.

Manufacturing emulsified sausages

The sausage recipe is presented in Table 1. The hind legs of a sow weighing between 89-94 kg (Daon, Yesan, Korea) 24 h after slaughter were used as raw meat, and the back fat, raw meat was ground using a grinder (PA-82; Mainca, Barcelona, Spain) equipped with a 3 mm plate. Based on the antioxidant analysis results according to the color of paprika, yellow paprika powder was selected owing to its superior antioxidant activity. Using a bowl cutter (K-30, Talsa), the final emulsion was prepared by mixing and chopping the raw meat, back fat, and shaved ice at a ratio of 3:1:1 three times for 1 min. The prepared emulsion was filled into a natural pig cage by a stuffer (EM-12, Mainca). Afterwards, it was heated in a chamber (10.10ESI/S, Alto Shaam Co.) set at 80℃ for 30 min and then cooled at 25℃ for 30 min. The prepared sausage was sealed using a vacuum pack and stored in a at 4℃ for 3 weeks before being used in the experiment.

Proximate composition

Moisture content of the emulsified pork sausage with yellow paprika powder was analyzed according to the AOAC (2016) method. Briefly, moisture content was measured using the oven-drying method (105 ℃; AOAC 950.46), crude protein content using the Kjeldahl method (AOAC 992.15), crude fat content using the Soxhlet method (AOAC 960.39), and inquiry content using the direct conversion method (550 ℃, AOAC 920.153) and expressed as a percentage.

Water-holding capacity (WHC)

Emulsion-type pork sausage sample (5 g) with yellow paprika powder was wrapped in a filter paper (Whatman No. 1; GE Healthcare, Chicago, IL, USA), placed in a conical tube, and centrifuged for min at 246×g using a centrifuge (Supra R22; Hanil Science, Gyeonggi-do, Korea). Weight change in the sample after centrifugation was determined, entered into the corresponding calculation formula, and expressed as a percentage.

$$\text{water holding (\%)} = \frac{X-Y}{X} \times 100$$

$$X = \frac{\text{Weight before centrifugation (g)} \times \text{Moisture content (\%)}}{100}$$

$$Y = \text{Weight before centrifugation (g)} - \text{Weight after centrifugation (g)}$$

Cooking yield

Cooking yield was calculated by measuring the weight before and after heating of the emulsified pork sausage to which yellow paprika powder was added, the heating conditions were the same as in the emulsified sausage manufacturing process. The determined value was entered into the corresponding calculation formula and expressed as a percentage.

$$\text{Cooking yield (\%)} = \frac{\text{initial weight} - \text{cookedweight (g)}}{\text{initial weight (g)}} \times 100$$

Thiobarbituric acid reactive substance (TBARS)

The TBARS value of emulsion-type pork sausage with yellow paprika powder was measured using the extraction method. Briefly, 5 g of sample was mixed with 12.5 mL of distilled water, 12.5 mL of 10% perchloric acid, and 200 μL of 0.3% butylated hydroxytoluene for 1 min using a homogenizer (AM-5; Nihonseiki Kaisha Ltd., Tokyo, Japan) at 5,614× g speed. Then, the supernatant was extracted through filter paper, and the supernatant was mixed with 0.02 M 2-thiobarbituric acid at a 1:1 ratio. The mixture was reacted in a 100 ℃ water bath for 10 min. Absorbance was measured at 532 nm using a multimode microplate reader (SpectraMax iD3, Molecular Devices, San Jose, CA, USA). Standard curves were prepared using 1,1,3,3-tetraethoxypropane and expressed as milligram malondialdehyde (MDA)/kg.

Volatile basic nitrogen (VBN)

Next, 30 mL of distilled water was included in 10 g of the emulsified pork sausage sample containing yellow paprika powder was added and homogenized at a speed of 5,614× g using a homogenizer for 1 minute. The homogenate was transferred to a graduated cylinder and mixed with distilled water up to the 100 mL mark. After filtering the mixture using filter paper, 1 mL of the filtrate was included in the outer chamber of the Conway vessel, and 1 mL of 0.01 N H_3BO_3 and 100 μL of Conway reagent were included in the inner chamber. The lid was slightly opened, and 1 mL of 50% K_2CO_3 was included in the outer chamber to prevent evaporation. The main body and portable lid were tightly fixed and incubated at 37 ℃ for 2 h. Then, the nitrogen captured by volatilization in H_3BO_3 was titrated with 0.02 N H_2SO_4 and substituted into the following equation to measure VBN.

$$\text{VBN (mg\%)} = (V1 - V2)/a \times 0.14 \times b \times c \times 100$$

V1: titration amount of the sample (mL)

V2: titration of blank (mL)

a: sample weight (g)

b: Titer value of 0.02 N sulfuric acid

c: Dilution factor

Statistical analysis

Experiments on red and yellow paprika powder were conducted on dry yield, pH, color, TPC, TFC, DPPH, and FRAP, and each paprika powder (0, 1, 2, 3%) was repeated at least three times. In the case of experiments on sausages (0, 1, 2, 3%) added with yellow paprika powder, proximate composition, water holding capacity, cooking yield, color, pH, TBARS, and VBN were measured at least three times while stored for 0, 1, 2, and 3 weeks. The analysis was conducted through the above repeated experiments. The results were expressed as mean values and standard deviations using the statistical processing program SAS (version 9.4 for window, SAS Institute Inc.). Analysis of variance on the experimental results was performed using One way Analysis of variance, and remarkable differences ($P<0.05$) were verified by Ducan's multiple range test.

Results

The physicochemical and antioxidant properties of paprika powder

The drying yield, pH, Chromaticity, DPPH radical scavenging activity, FRAP, TPC, and TFC of paprika powders according to color are presented in Table 2. The dry yield showed no remarkable difference of approximately 8.40% for yellow paprika powder and red paprika powder ($p>0.05$). Similarly, Ryu et al. (2021) discovered that there was no notable disparity in the water content between red (91.87%) and yellow (91.74%) paprika in their study analyzing the nutritional content based on color. In this study, the moisture content of red and yellow paprika was similar, therefore, it was judged that there was no difference in dry yield.

pH values were remarkably higher in yellow paprika powder than in red paprika powder ($p<0.05$), possibly due to the higher content of organic acids, including ascorbic and citric acids, in red paprika than in yellow paprika, resulting in a lower pH value in red paprika (Matsufuji et al., 2007). The pH of yellow paprika powder is approximately 5.19 and that of red paprika is approximately 5.05 (Jung and Hong, 2017; Lee et al., 2017), which is similar to our results, with the pH of yellow paprika powder being higher than that of red paprika powder.

Yellow paprika powder had remarkably higher lightness and yellowness than the red paprika powder ($p<0.05$), whereas the redness of red paprika powder was remarkably higher than that of yellow paprika powder ($p<0.05$). This may be because, among the carotenoids, lutein, which is yellow in color, is abundant in yellow paprika, whereas capsorubin and capsanthin, which are red in color, are abundant in red paprika (Kim et al., 2011). Similarly, Hong et al. (2013) discovered that the lightness and yellowness were higher in yellow paprika, whereas the redness was higher in red paprika.

DPPH and FRAP values were remarkably higher in yellow paprika powder than in red paprika powder ($p<0.05$). Baek and Shin (2020) discovered that yellow paprika had a better DPPH radical scavenging ability than red paprika in vine sweet varieties. Yellow paprika has higher levels of ascorbic acid compared to red paprika (Ryu et al., 2021), and Shim and Chin (2013) suggested in their study on the antioxidant activity of minced pork supplemented with paprika powder that the increased ascorbic acid content enhances reducing power, thereby leading to higher FRAP values observed in yellow paprika.

TPC was remarkably higher in yellow paprika powder than in red paprika powder ($p<0.05$), while there was no remarkable difference in TFC between the two ($p>0.05$). Phenolic compounds have a hydroxyl structure that weakens the bond of hydrogen ions, and the active hydrogen ions that dissociate from the bond remove free radicals and exhibit antioxidant activity (Yan et al., 2020). Macoris et al. (2012) discovered that ascorbic acid reacts with the Folin-Ciocalteu reagent used in the TPC experiment and affects the value of TPC. Therefore, it is judged that the TPC value was higher for yellow paprika, which has a higher ascorbic acid content than red paprika. Baek and Shin (2020) discovered that yellow paprika powder had higher TPC than red paprika powder in the flesh of vine sweet, a mini paprika, and that there was no remarkable difference in the flavonoid content of the two, which was similar to the present results.

Phenolic compounds mainly contribute to antioxidant activity and that TPC and DPPH have a positive correlation because the higher the TPC content, the higher the DPPH and reducing power (Zhao et al., 2008). In this study, yellow paprika powder with a higher TPC content showed better antioxidant properties, such as DPPH scavenging activity and FRAP. Therefore, yellow paprika powder, which showed remarkably higher values of DPPH scavenging activity, FRAP, and TPC, was added to the emulsified pork sausages to evaluate their storage properties according to the amount of paprika added.

Quality characteristics of pork sausages with added paprika powder

Proximate composition

Proximate compositions of pork sausages emulsified with yellow paprika powder are presented in Table 3. The moisture content of the group treated with 3% yellow paprika powder was remarkably higher compared to the control group and other treated groups ($p<0.05$). Incorporating dietary fiber into meat products can enhance their ability to retain moisture due to the fiber's moisture-absorbing properties (Chol et al., 2008). Zaki et al. (2013) discovered that the dietary fiber content of paprika powder was approximately 36%. Dietary fiber in paprika powder possibly combines with moisture to increase its moisture content. The protein content remarkably declined with the increasing addition of yellow paprika powder ($p<0.05$). This is attributed to the increased moisture content caused by the dietary fiber in the paprika powder, which likely resulted in a relative decrease in protein content. Hong et al. (2020a) discovered that as the amount of dietary fiber added to chicken breast Tteokgalbi increases, the moisture content increases and protein content decreases, which is similar to the results of this study. The fat content tended to decrease as the amount of paprika powder added increased, with the 3%

addition group showing the lowest values remarkably (p<0.05). Moreover, ash content as the amount of paprika powder increased. As the amount of dietary fiber added to meat products increases, the fat content decreases and the ash content increases (Choi et al., 2008). Kim et al. (2016) discovered that increasing the amount of red pepper seed powder, which is rich in dietary fiber, raises the fat content of products. Similarly, Go et al. (2021) discovered that, as the content of red cabbage added to emulsified pork sausage increases, ash content increases with a higher level of dietary fiber content, which is consistent with our findings.

Water Holding Capacity and Cooking Yield

WHC and cooking yield of the emulsified pork sausages with added yellow paprika powder are shown in Figure 1. WHC improved with increasing amounts of paprika powder, and was remarkably higher in the 2% and 3% treatment groups compared to the control group ($p < 0.05$). Cooking yield did not differ remarkably between the control and 1% and 2% treatment groups ($p > 0.05$), but the 3% treatment group exhibited remarkably higher values than both the control and other treatment groups ($p < 0.05$). Jeong et al. (2021) discovered that soluble dietary fiber in fruits and vegetables can form gels, such that as the dietary fiber content increases, water molecules seep into the network structure of myofibrillar proteins, thereby improving the WHC. Additionally, Choi et al. (2015) discovered that adding dietary fiber to meat products enhances the stabilizing effect of salt-soluble proteins, which have an affinity for moisture and fat, thereby increasing the binding force among protein, moisture, and fat and improving cooking yield. In this study, we also determined that the dietary fiber contained in yellow paprika powder increased the binding force between protein, moisture, and fat, thereby increasing the WHC and cooking yield of the sausages. Hong et al. (2020b) discovered that water holding capacity (WHC) and cooking yield of jerky increase with higher levels of mustard powder enriched with dietary fiber. As the result of this study, addition of 3% yellow paprika powder to emulsified pork sausages improved their water retention capacity and cooking yield and reduced the losses in emulsified meat products, thereby increasing the economic benefits.

Color

Chromaticity of the pork sausages emulsified with yellow paprika powder is shown in Table 4. Redness and yellowness showed significantly higher values as the amount of paprika powder added increased ($p<0.05$), while lightness was significantly higher in the control group ($p<0.05$). Kim and Chin (2018) discovered that in low-fat sausages with added paprika powder, lightness was highest in the control group, and when the highest amount of paprika powder was added, redness and yellowness were elevated compared to the control group, similar to the results observed in this study. This was attributed to the inherent color of the yellow paprika powder (CIE L*: 56.6, CIE a*: –7.4, CIE b*: 30.2), which led to the observed results. Meat color primarily influences consumer preferences when selecting meat products, with most consumers preferring reddish-colored meat (Kim et al., 2022). Nitrites are added to meat products to improve their color, and the demand for natural colorants to replace the side effects of nitrite forming carcinogens in meat products is increasing (Aykın-Dinçer et al., 2021). Therefore, addition of 3% yellow paprika powder, which has the highest redness, may have positive effect on consumer preference as a natural colorant and promote meat consumption.

pH

pH values of emulsified pork sausages with varying amounts of yellow paprika powder and storage periods are shown in Figure 2. The pH values decreased remarkably as the amount of paprika added increased at all weeks ($p<0.05$). This is due to the organic acids present in paprika. Consistently, Lee et al. (2022) revealed that the pH remarkably decreased as the amount of paprika powder increased because of the presence of organic acids, such as malic and tartaric acids. As the storage period elapsed, pH decreased in all treatment and control groups. Changes in pH during the storage of meat products are influenced by microbial activities, accumulation of acid-producing microbes like lactic acid bacteria lowers pH, while microbial action leading to the accumulation of nitrogenous compounds such as ammonia causes meat spoilage and increases pH (Xiong et al., 2022). If pH is low, WHC and texture of meat decreases, and if the pH is high, the storage capacity and color decrease, thus negative affecting the consumer preference (Chan et al., 2011). As the storage period of meat increases, lactic acid bacteria grow and pH decrease owing to the fermentation by lactic acid bacteria (Kim et al., 2023). Dong et al. (2020) discovered a decrease in pH due to acid production in Harbin red sausages as the storage period elapsed because of microbial decomposition, consistent with our findings. Over the storage period, pH decreased gradually with increasing amounts of yellow paprika powder. Jeong and Yang (2023) discovered that, as the amount of paprika extract added to pork patties increases, lipid oxidation is inhibited by antioxidants, such as capsanthin and capsorubin, present in paprika. Therefore, antioxidant components of paprika may contribute to inhibit lipid oxidation and remove active oxygen, thereby slowing the decrease in pH.

TBARS (Thiobarbituric Acid Reactive Substance)

TBARS results of emulsified pork sausages, varying with the amount of yellow paprika powder added and storage period, are shown in Figure 3. The TBARS value measures the intensity of the red color formed by the reaction of malonaldehyde, resulting from lipid oxidation, with thiobarbituric acid, indicating the degree of lipid spoilage, which increases with advanced lipid oxidation (Park et al., 2016). Throughout all weeks, there was a trend of decreasing lipid oxidation as the amount of yellow paprika powder increased, with significantly lower values observed in the 2% and 3% treatment groups compared to the control and 1% treatment groups ($p<0.05$). Measurement of fat rancidity during the storage period revealed that the TBARS values of the control and paprika powder treatment groups increased as the storage period increased. In the control and 1% treatment groups, TBARS values increased remarkably at all weeks as the storage period elapsed ($p>0.05$). In contrast, 2 and 3% treatment groups did not show any remarkable difference between the 1st and 2nd weeks ($p>0.05$), showing a relatively gradual increase. This may be due to the phytochemicals, such as phenolic compounds, carotenoids, and flavonoids, and antioxidant components, such as vitamin C, present in paprika that inhibit lipid oxidation and reduce lipid rancidity. Unsaturated fatty acids in pork have many double bonds and are easily oxidized by oxygen in air (Moon et al., 2019). Free radicals derived from unsaturated fatty acids promote lipid oxidation by generating secondary oxides, such as aldehydes and ketones. Lipid oxidation reduces the flavor and freshness of meat products and adversely affects their quality via discoloration and destruction of nutrients (Hyun et al., 2019). Lu et al. (2019) discovered that the addition of paprika oleoresin to frozen chicken breasts suppressed the production of secondary products, such as hydrogen peroxide and malonaldehyde, thereby reducing the rate of lipid oxidation. Jeong et al. (2023) discovered effective inhibition of lipid oxidation in treatment groups with 5 and 10 mg paprika extract in pork patties, similar to that in the treatment group with added nitrite (0.70 mg), which is consistent with the findings of this study. The results of this study showed that, reduction in TBARS was due to the high antioxidant capacity of yellow paprika powder owing to its DPPH free radical scavenging ability, FRAP, and TPC. Therefore, addition of 3% paprika powder improves the quality of meat products by suppressing lipid oxidation.

VBN (Volatile Basic Nitrogen)

VBN results of emulsified pork sausages, varying with the amount of yellow paprika powder added and storage period, are shown in Figure 4. VBN values decreased in all treatment groups as the amount of yellow paprika powder increased, and the values were remarkably lower in all paprika powder treatment groups than in the control group ($p<0.05$). Moreover, VBN values increased in the control and all treatment groups as the storage period elapsed. Notably, 3% treatment group showed no remarkable differences across the 1st, 2nd, and 3rd weeks ($p>0.05$), showing a relatively gradual increase compared with the control and other treatment groups. Meat is chemically oxidized by various types of free radicals during storage, and protein deterioration adversely affects its texture and flavor, leading to the production of toxic substances (Kang et al., 2012). Ryu et al. (2021) discovered that the vitamin C content is remarkably higher in yellow paprika than in red and orange paprika. Lee et al. (2012) discovered a positive correlation between the vitamin C content and DPPH radical scavenging activity of paprika. Therefore, vitamin C in paprika could reduces protein spoilage by suppressing free radical productio. Jeong and Yang (2023) added the paprika extract to pork patties and discovered that the higher the amount added, the more effectively protein deterioration was suppressed compared to that in the control as the storage period elapsed, which is consistent with the results of this study. Therefore, yellow paprika powder maintains the quality of meat products and improves their storage properties, acting as a suitable alternative to synthetic antioxidants, such as BHA, BHT and nitrites.

Discussion

In this study, antioxidant capacity of paprika powder was compared by color, and the storage characteristics of emulsified pork sausages containing yellow paprika powder were analyzed. DPPH, FRAP, and TCP experiments revealed that yellow paprika powder exhibited a remarkably higher antioxidant capacity than red paprika powder ($p<0.05$), with no remarkable difference in TFC ($p>0.05$). In emulsified pork sausages containing yellow paprika powder, WHC was remarkably higher in the 3% treatment group than in the control and 1% treatment groups ($p<0.05$). Cooking yield was remarkably higher in the 3% treatment group than in the control and 1 and 2% treatment groups ($p<0.05$). TBARS values were remarkably lower in the 2 and 3% yellow paprika powder groups than in the control group at all weeks ($p<0.05$). As the storage period elapsed, lipid oxidation remarkably increased in the control and 1% treatment groups at all weeks however, the 2 and 3% treatment groups exhibited no remarkable differences between the 1st and 2nd weeks ($p>0.05$). Throughout all weeks, the VBN values in all treatment groups were remarkably lower compared to those in the control group. ($p<0.05$). However, as the storage period progressed, there was an increase observed in both the control and all treatment groups. The 3% treatment group exhibited a relatively steady increase, with no remarkable difference noted between the 1st, 2nd, and 3rd weeks ($p>0.05$). Therefore, addition of 3% yellow paprika powder remarkably increased the antioxidant activity, and improved the storage properties of emulsified pork sausages.

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Tables and Figures

Table 1. Formulation of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder

Ingredients (%)		Freeze-dried yellow paprika powder (%)			
		0 (Control)	1	2	3
Main	Meat	60	60	60	60
	Fat	20	20	20	20
	Ice	20	20	20	20
Additives	Sugar	1	1	1	1
	Salt	1.2	1.2	1.2	1.2
	Yellow paprika powder	-	1	2	3

Table 2. Dry yield, pH, 2,2-diphenyl-1-picrylhydrazy (DPPH), ferric reducing antioxidant power assay (FRAP) and total polyphenol contents (TPC), total flavonoid contents (TFC) of red paprika and yellow paprika

Traits[1)]		Freeze-dried paprika powder	
		Red	Yellow
Dry yield (%)		8.40±0.04[a]	8.40±0.06[a]
pH		4.78±0.00[b]	4.80±0.00[a]
Color	CIE L	62.20±0.17[b]	80.80±0.10[a]
	CIE a	30.40±0.35[a]	10.77±0.15[b]
	CIE b	33.07±0.15[b]	52.87±0.40[a]
DPPH (%)		84.98±0.17[b]	85.50±0.00[a]
FRAP (593 nm)		2.73±0.03[b]	2.89±0.08[a]
TPC (mg GAE/g)		208.16±0.16[b]	258.87±0.03[a]
TFC (mg NE/g)		64.70±6.24[a]	68.46±3.11[a]

All values are mean±SD.
Means in the same row with different letters (a,b) are remarkably different ($P<0.05$).
[1)]GAE: gallic acid equivalents, NE: naringin acid equivalents.

Table 3. Proximate composition of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder

Traits (%)	Freeze-dried yellow paprika powder (%)			
	0 (Control)	1	2	3
Moisture	57.42±0.09^{b}	57.55±0.17^{b}	57.91±0.33^{b}	58.98±0.82^{a}
Protein	14.80±0.02^{a}	14.68±0.05^{b}	14.43±0.04^{c}	14.23±0.05^{d}
Fat	24.30±0.72^{a}	24.21±0.54^{a}	24.03±0.75^{a}	22.58±0.95^{b}
Ash	1.60±0.11^{b}	1.60±0.10^{b}	1.65±0.03^{ab}	1.79±0.06^{a}

All values are mean±SD.
Means in the same row with different letters (a-c) are remarkably different (P<0.05).

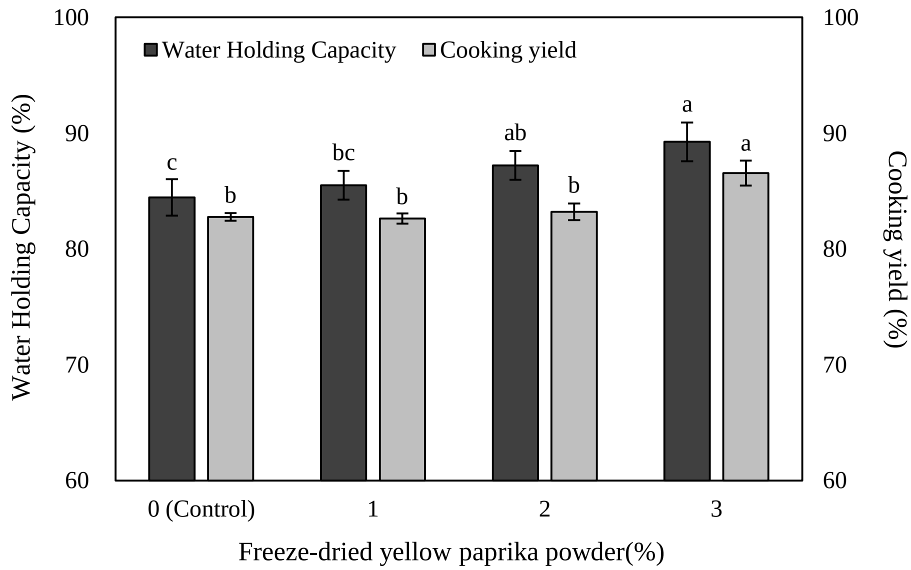

Fig. 1. Water holding capacity and Cooking yield of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder. All mean values are shown on the bar, and the SD values are shown in the error bar. Means in the same color bars with different letters (a-c) are remarkably different (P<0.05).

Table 4. Color of pork emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder

Color	Freeze-dried yellow paprika powder (%)			
	0 (Control)	1	2	3
CIE L*	76.33±0.10^{a}	75.60±0.00^{b}	74.70±0.00^{c}	72.35±0.06^{d}
CIE a*	4.93±0.05^{d}	5.73±0.05^{c}	6.00±0.00^{b}	6.35±0.06^{a}
CIE b*	18.55±0.19^{d}	23.40±0.14^{c}	26.83±0.05^{b}	28.93±0.10^{a}

All values are mean±SD.
Means in the same row with different letters (a-d) are remarkably different ($P<0.05$).

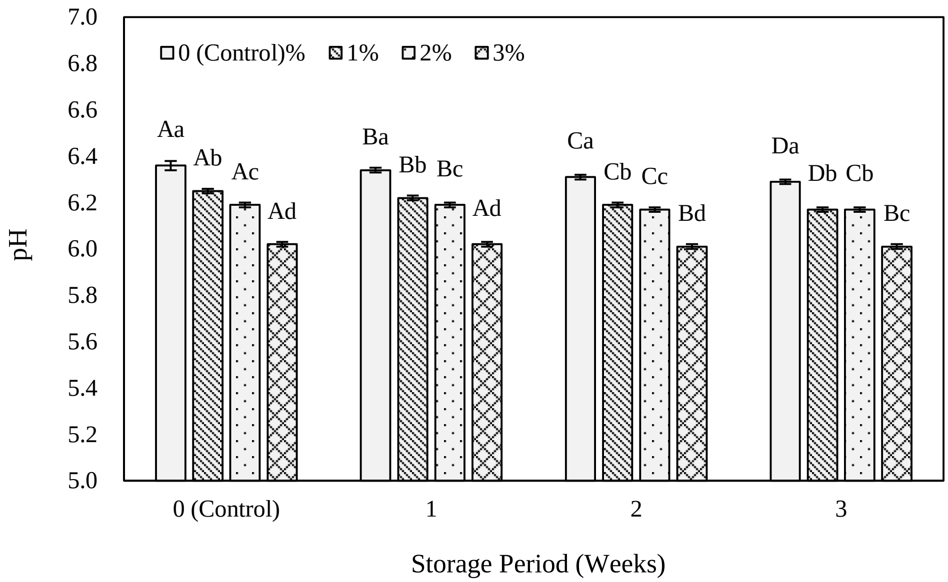

Fig. 2. pH of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder during storage periods. All mean values are shown on the bar, and the SD values are shown in the error bar. Means in the same storage period with different letters (A-D) are remarkably different (P<0.05). Means in the same treatment with different letters (a-d) are remarkably different (P<0.05).

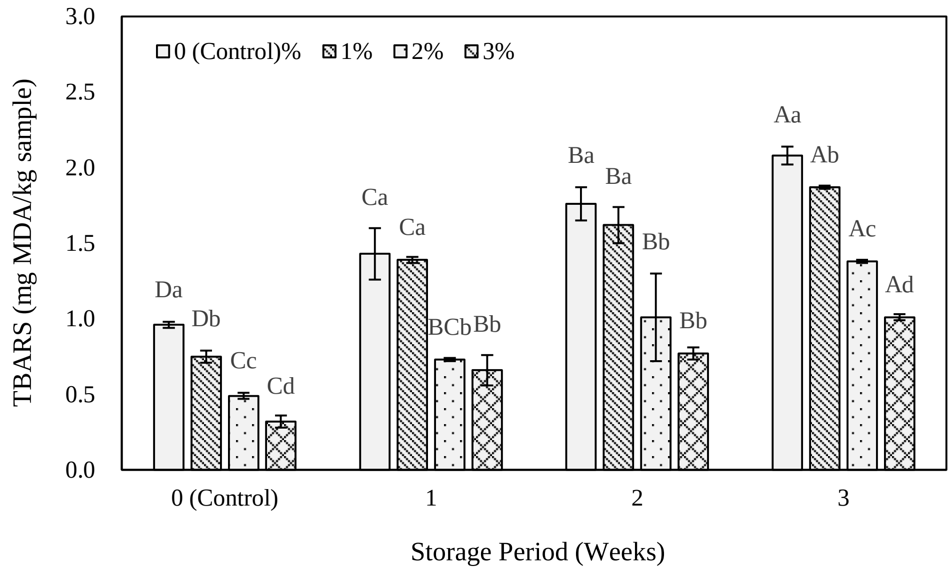

Fig. 3. Thiobarbituric acid reactive substances (TBARS) of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder during storage periods. All mean values are shown on the bar, and the SD values are shown in the error bar. Means in the same storage period with different letters (A-D) are remarkably different ($P<0.05$). Means in the same treatment with different letters (a-d) are remarkably different ($P<0.05$).

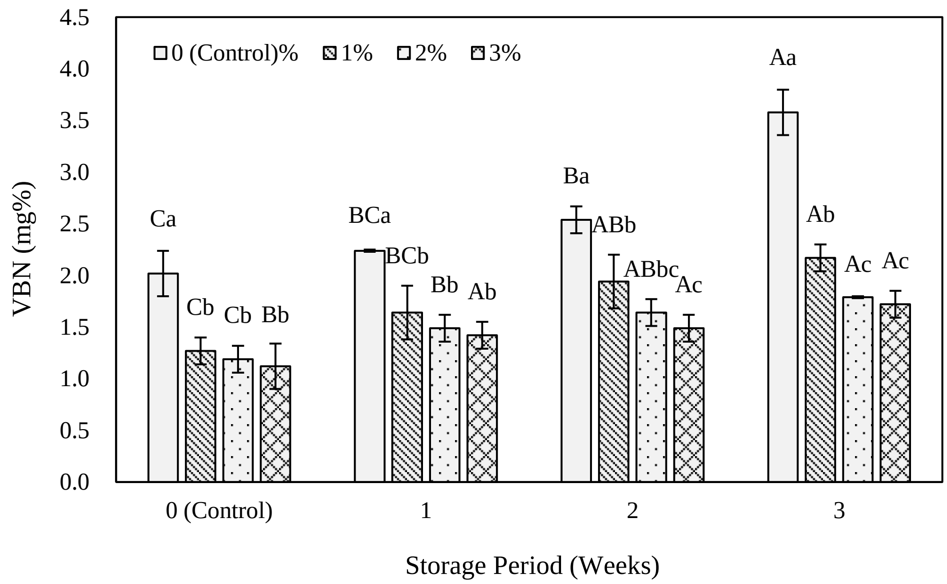

Fig. 4. Volatile basic nitrogen (VBN) of emulsion-type sausage formulated with various levels of freeze-dried yellow paprika powder during storage periods. All mean values are shown on the bar, and the SD values are shown in the error bar. Means in the same storage period with different letters (A-D) are remarkably different ($P<0.05$). Means in the same treatment with different letters (a-d) are remarkably different ($P<0.05$).