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ARTICLE

Presalting Condition Effects on the Development of Pink Color in Cooked Ground Chicken Breasts

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Abstract The effects of presalting conditions (storage temperature and duration) with/without sodium tripolyphosphate (STPP) on the color and pigment characteristics of cooked ground chicken breast were investigated. Meat mixtures containing 2% NaCl (control) or 2% NaCl and 0.5% STPP (STPP treatment) were stored for 0, 3, 5, 7, and 10 d at 2℃ or 7℃, followed by cooking to 75℃, and cooling and storage at 2℃–3℃ until further analysis. The treatment was the most effective on the pink color defect of all independent variables. The effect of storage temperature was only observed on CIE L* values and percentage myoglobin denaturation (PMD). The control was redder than the STPP treated samples and the CIE a* values increased ($p<0.05$) from 0 to 5 d in the control and STPP treated samples. Compared to the STPP treatment, the control exhibited increased reducing conditions (more negative oxidation reduction potential), lower undenatured myoglobin, and greater PMD. No differences in the cooking yields of the control and STPP-treated samples were observed for various storage durations. Products with STPP showed higher ($p<0.05$) pH values than those without STPP, but no differences ($p>0.05$) in PMD were observed over the storage period in the control and STPP treated samples, except for day 0. Thus, STPP is effective at reducing the pink color in cooked chicken breasts. In addition, presalting for longer than 5 d resulted in increased pink color of the cooked chicken breasts.

Keywords ground chicken breast, NaCl, sodium tripolyphosphate, pink color, pigment properties

Introduction

Pink color defect is a condition where well-cooked white meat retains a pink color or develops pinkness with storage after cooking (King and Whyte, 2006). This is a major problem widely reported and studied in poultry and can affect the purchasing behavior of consumers because the appearance of uncooked pink color in fully cooked, uncured poultry products is not unexpected (Holownia et al., 2003; Suman et al., 2016).

The causes of the pink defect have been proposed to be related to various types of pigments, preslaughter factors, stunning techniques, incidental nitrate/nitrite contamination

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through the water supply, diet, processing equipment, nonmeat ingredients, cooking method, and irradiation of the precooked products (Cornforth et al, 1998; Froning, 1995; Holownia et al., 2003; Maga, 1994). Because the factors associated with pink color development in poultry meat are complex, previous studies have attempted to explain the mechanism and identify novel methods to control this defect. Several studies have reduced or prevented the development of pink color in cooked meat products by incorporating pink inhibiting ingredients such as whey protein concentrate (Sammel and Claus, 2003b; Sammel et al., 2007; Slesinski et al., 2000), non-fat dry milk (Dobson and Cornforth, 1992; Slesinski et al., 2000), sodium citrate (Sammel and Claus, 2003a; Sammel and Claus, 2006; Sammel et al., 2006), citric acid (Kieffer et al., 2000; Sammel and Claus, 2006), and calcium chloride (Claus et al., 2010; Sammel and Claus, 2007). Most of these studies successfully reduced pink color defects, but the products tested with pink inhibiting ingredients contained intentionally added pink-color-generating ligands such as nitrite and/or nicotinamide to develop a cured pink color (Sammel and Claus, 2006; Sammel and Claus, 2007; Kieffer et al., 2000; Sammel et al., 2007). Therefore, some studies have attempted to create a natural pink color defect without pink generating ligands by presalting before cooking over a few days of storage (Claus and Jeong 2018; Jeong, 2017; Jeong and Claus, 2010). Jeong (2017) reported that salt addition to a level of more than 2% to ground chicken breasts may reduce the redness of cooked products and presalting storage longer than 3 d showed a natural pink color of the products with less than 1% salt. Claus and Jeong (2018) found that 2% NaCl added to ground turkey breasts and stored for 7 d resulted in the most reducing condition (lowest oxidation reduction potential) and the most red coloration in cooked products.

NaCl (sodium chloride) and phosphate are the most commonly used ingredients in the meat processing industry and can affect meat color. Sodium chloride addition to meat may solubilize myofibrillar proteins, providing amino acid chains to form more heme complexes and decrease the redox potential, resulting in a pink color defect in cooked products (Ahn and Maurer, 1989a; Cornforth et al., 1986). Sodium chloride increases the stability of hemoglobin and myoglobin due to the presence of chloride ions. The addition of sodium tripolyphosphate (STPP) results in increased heat stability of myoglobin due to increased pH (Ahn and Maurer, 1989c). Thus, changes in the pH by NaCl and phosphate addition may affect the state of myoglobin and redox potential of the meat, which are critical for forming heme complexes and developing the pink color of cooked products. Additionally, prolonged storage of presalted meat before cooking promotes pink defect formation after cooking (Cornforth et al., 1991).

Although early studies have reproduced the natural pink color defect without adding pink color generating ligands and revealed the effects of salt and salt addition timing of 0 d or 7 d on pink color defects in cooked chicken and turkey products (Jeong, 2017; Jeong and Claus, 2018), the effect of temperature and presalting duration in the absence and presence of sodium polyphosphate on pigment characteristics of cooked meats has not yet been established. Therefore, this study was performed to examine the effects of presalting conditions (storage temperature and duration) with and without STPP on the color and pigment characteristics of cooked ground chicken breasts.

Materials and Methods

Processing and preparation

Fresh, skinless, and boneless chicken breasts (1 d postmortem) were obtained from a local processor (Kwangsung Food, Yangsan, Korea). The raw material was shipped in an insulated cooler and refrigerated at 2°C–3°C until use. Three replicates of ground chicken breast were received and used immediately after arrival in this study. A total of 50 kg of raw chicken trimmings were used for each replicate and ground with a 0.3 cm plate using a chopper (TC-22 elegant plus, Tre Spade, Valperga, Italy). The ground meat was separated into two portions for addition of STPP. For the first portion, the ground meat was mixed with only 2% NaCl of meat weight basis using a mixer (5K5SS, Whirlpool, St. Joseph, MI, USA) for 10 min (control). In the second portion, the ground meat was mixed with 2% NaCl and 0.5% STPP for 10 min (STPP treatment group), as was tested by previous studies (Jeong and Claus, 2010; Sammel and Claus, 2007) for turkey breasts. Based on USDA-FSIS (2019) recommendation, industrial practice was considered and two temperature were selected (2℃ or 7℃). Therefore, all salted ground meat was divided into two sets depending on the storage temperature (2℃ or 7℃) and individually vacuum-packaged (2 kg each) in polyethylene/nylon bags (oxygen transmission rate=0.7 $cm^3/m^2/24$ at 23℃ and 90% relative humidity; SNF-100, SamYoung Chemical, Seoul, Korea) using a vacuum packaging machine (M6-TM, Leepack, Incheon, Korea), which were stored for 0, 3, 5, 7, and 10 d under refrigeration (2℃ or 7℃) prior to being remixed and stuffed. At the designated day, the packages were opened, the salted ground meat was remixed using a mixer (5K5SS, Whirlpool) for 5 min, and subsequently stuffed into conical centrifuge tubes (50 g each). These tubes were centrifuged at 2,000×g for 10 min (FELTA5, Hanil Science, Gimpo, Korea) to remove any air pockets. All stuffed samples were cooked to an internal endpoint temperature of 75℃ in a 90℃ water bath (CB60L, Dongwon Scientific Machinery, Busan, Korea). The temperature was monitored by placing four thermocouples attached to a 4-channel digital thermometer (Tes-1384, Ketech Scientific Instrument, Kaohsiung, Taiwan) in the center of the extra samples throughout the water bath. After cooking, the samples were immediately cooled on ice for 20 min and stored at 2℃–3℃ overnight in the dark before further analysis. Experiments were performed in triplicate.

Instrumental color determination

A colorimeter (CR-400, 8 mm aperture, illuminant C, 2° standard observer; Konica Minolta, Osaka, Japan) calibrated with a white plate (L* 94.90, a* –0.39, b* 3.88) was used for determination of the CIE L*a*b* values and measured freshly cut surfaces of each cooked sample following immediately cutting.

Cooking yield, pH, and oxidation-reduction potential (ORP) determination

Stuffed ground chicken meat samples were weighed prior to cooking to determine raw sample weights. Cooked weights were also measured to determine cooking yields. Cooking yield was calculated as: [cooked sample weight/raw sample weight]×100. The sample (5 g) was homogenized in 25 mL of distilled water and pH values were measured with a pH electrode attached to a pH meter (Accumet AB50, Thermo Fisher Scientific, Singapore). Oxidation-reduction potential (ORP) was measured for cooked chicken breasts following the method of Cornforth et al. (1986) and John et al. (2005) with slight modifications.

Myoglobin content, percentage myoglobin denaturation (PMD), pigment determination

Myoglobin (Mb) was extracted from both uncooked and cooked chicken products using a procedure of Warriss (1979) and Trout (1989). The absorbance (A) of the filtrate was subsequently determined at 525, 572, and 700 nm (Krzywicki, 1979) using a UV/VIS spectrophotometer (UV-1800, Shimadzu, Kyoto, Japan). The total myoglobin (Mb) content and PMD were calculated using the following formulas (Trout, 1989): Mb (mg/g)=(A525–A700)×2.303×dilution factor; PMD=[1–(Mb concentration after heating/Mb concentration before heating)]×100. To obtain the percentage reflectance, the absorbance data on the filtrate from 400 to 700 nm were converted to percentage reflectance using the equation described by Stewart et al.

(1965). Nitrosyl hemochrome (rNIT) was estimated using the percent reflectance ratio, %*R*650 nm/%*R*570 nm (AMSA, 1991). Nicotinamide hemochrome (rNIC) was estimated by the percent reflectance ratio of %*R*537 nm/%*R*553 nm (Schwarz et al., 1998).

Statistical analysis

All experiments were performed in triplicate and were analyzed in a completely randomized 2×2×5 factorial design (absence and presence of STPP by storage temperature by storage duration before cooking). The main effects and their interactions were analyzed using a Proc Mixed procedure in the SAS 9.4 software (SAS, 2013). When significance ($p<0.05$) was observed in the models, the means were separated by pairwise comparisons using the PDIFF (p-values for DIFFerences of the Least Square means) option in the software.

Results and Discussion

Instrumental color

The CIE L* values of the cooked ground chicken breasts were affected by the treatment (T, $p<0.0001$), storage temperature (S, $p<0.05$), and storage duration (D, $p<0.05$; Table 1). However, no three-way interactions between the main effects were observed ($p>0.05$) for the CIE L* values. The samples treated with 0.5% STPP exhibited lower ($p<0.05$) CIE L* values compared to the control without STPP (Table 2). These results are similar to those of Lopez et al. (2012), showing that the addition of 1.5% NaCl and 0.35% STPP in the marinade solution decreased lightness (CIE L* values) for marinated broiler breasts compared to those with 0% NaCl and 0.35% STPP. Overall, when the samples were stored at the higher temperature (7℃), the CIE L* values were increased compared to those obtained at the lower temperature (2℃). After 5 d storage, the CIE L* values of the cooked chicken products increased ($p<0.05$) compared to those stored for 0 or 3 d. However, no

Table 1. Significance of main and interaction effects on presalting condition with/without sodium tripolyphosphate on color and pigments properties of cooked ground chicken breasts

Main and interaction effects[1)]	Dependent variables[2)]									
	CIE L*	CIE a*	CIE b*	rNIT	rNIC	Cooking yield	pH	ORP	Myoglobin	PMD
Treatment (T)[3)]	**	**	**	**	NS	**	**	*	**	**
Storage temperature (S)[4)]	*	NS	NS	NS	NS	NS	NS	NS	NS	*
Storage day (D)[5)]	*	**	**	NS	NS	NS	NS	NS	NS	*
T×S	NS	NS	NS	*	NS	NS	NS	NS	*	*
T×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T×S×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

1) Main and interaction effects: * $p<0.05$, ** $p<0.0001$, NS=not significant.
2) Dependent variables: CIE L* (lightness), CIE a* (redness), CIE b* (yellowness), rNIT (reflectance estimator of nitrosyl hemochrome, %*R*650nm/%*R*570nm, higher ratio more), rNIC (reflectance estimator of nicotinamide hemochrome, %*R*537nm/%*R*553nm, higher ratio more), ORP (oxidation-reduction potential), Myoglobin (amount of undenatured myoglobin), and PMD (percentage myoglobin denaturation).
3) Treatment: Ground meat were mixed with 2% NaCl alone (Control) or 2% NaCl and 0.5% sodium tripolyphosphate (STPP treatment).
4, 5) Storage temperature and day: Treatments were periodically stored for 0, 3, 5, 7, or 10 d at different temperatures (2℃ or 7℃) before being cooked.

Table 2. Least square means and standard errors for presalting condition effects on CIE L*, a*, b* values, reflectance estimator of nitrosyl hemochrome, and reflectance estimator of nicotinamide hemochrome in cooked ground chicken breasts formulated without adding pink generating ligands

Main effects	Dependent variables[1)]				
	CIE L*	CIE a*	CIE b*	rNIT	rNIC
Treatment (T)[2)]					
Control	76.35[a]	4.18[a]	8.29[a]	1.0137[b]	1.0093
STPP	74.46[b]	3.86[b]	8.03[b]	1.0167[a]	1.0091
SEM	(0.17)	(0.05)	(0.07)	(0.0006)	(0.0005)
Storage temperature (S)[3)]					
2℃	75.27[b]	4.00	8.12	1.0147	1.0092
7℃	75.54[a]	4.04	8.19	1.0157	1.0092
SEM	(0.17)	(0.05)	(0.07)	(0.0006)	(0.0005)
Storage day (D)[4)]					
Day 0	75.12[b]	3.59[c]	8.72[a]	1.0160	1.0087
Day 3	75.18[b]	3.89[b]	8.26[b]	1.0157	1.0090
Day 5	75.62[a]	4.19[a]	8.04[c]	1.0146	1.0091
Day 7	75.61[a]	4.18[a]	8.01[c]	1.0151	1.0094
Day 10	75.48[a]	4.25[a]	7.76[c]	1.0146	1.0098
SEM	(0.19)	(0.07)	(0.09)	(0.0008)	(0.0006)

[1)] Dependent variables: CIE L* (lightness), CIE a* (redness), CIE b* (yellowness), rNIT (reflectance estimator of nitrosyl hemochrome, *%R*650nm/*%R*570nm, higher ratio more), and rNIC (reflectance estimator of nicotinamide hemochrome, *%R*537nm/*%R*553nm, higher ratio more).

[2)] Treatment: Ground meat were mixed with 2% NaCl alone (Control) or 2% NaCl and 0.5% sodium tripolyphosphate (STPP treatment).

[3,4)] Storage temperature and day: Treatments were periodically stored for 0, 3, 5, 7, or 10 d at different temperatures (2℃ or 7℃) before being cooked.

[a–c] Means within a column with unlike superscripts are different ($p<0.05$). Two way interaction found for rNIT (T×S; $p<0.05$).

differences in the CIE L* values of the cooked chicken breast were observed when stored from 5 to 10 d. These findings may be related to light scattering effect during presalting duration of chicken meat at higher temperature rather than lower temperature (Nam and Ahn, 2002; O'Keeffe and Hood, 1981), which resulted in increased lightness.

Treatment (T, $p<0.0001$) had significant effects on CIE a* in the cooked ground chicken breasts (Table 1). Higher CIE a* values were observed in the control (CIE a* 4.18) compared to the STPP treatment (CIE a* 3.86; Table 2). Holownia et al. (2003) showed that the pink discoloration could be visually detected when the a^* value was >3.8 in chicken breast meat. Therefore, when ground chicken breasts were presalted, the pink color in the cooked ground chicken products developed regardless of the presence of STPP. Herein, the CIE a* values of cooked chicken breasts were similar those reported by Sammel et al. (2006), ranging from 3.4 to 4.5 for cooked ground turkey meat. The storage duration (D, $p<0.001$) affected CIE a* in the cooked ground chicken breasts (Table 1). Presalting storage of >5 d before cooking resulted in higher ($p<0.05$) CIE a* values compared to chicken products stored for 0 or 3 d (Table 2). Similarly, Jeong and Claus (2010) reported that cooked ground turkey breast showed pink discoloration when 2% NaCl was added without pink color generating agents and stored for 6 d prior to cooking. However, no differences ($p>0.05$) in the CIE a* values were observed in cooked ground chicken breasts stored for 5 to 10 d. Recently, Claus and Jeong (2018) showed that ground turkey breasts with adding 2% salt and storing for 7 d were redder (higher CIE a* values) than those without salt stored the same duration or with added salt and immediately cooked after 1 d storage. They speculated that there may be a synergistic effect between the salt and storage for pink color defect development in cooked ground turkey breasts. However, the storage temperature (S) did not affect ($p>0.05$) the CIE a* values of cooked ground chicken breasts and no two-way or three-way interactions were observed between the main effects ($p>0.05$; Tables 1 and 2).

The CIE b* values of cooked ground chicken breast were affected by the treatment (T, $p<0.0001$) and storage duration (D, $p<0.0001$; Table 1). The control without STPP showed higher ($p<0.05$) CIE b* values (yellowness) compared to the samples with added STPP (Table 2). Sammel and Claus (2007) reported that STPP decreased the yellowness of cooked ground turkey formulated with pink-color inducing ligands, such as 10 ppm sodium nitrite or 1% nicotinamide. As the storage duration was prolonged from 0 to 10 d, the CIE b* values of the cooked chicken breast decreased ($p<0.05$). The CIE b* values were the highest ($p<0.05$) in samples stored for 0 d and decreased for samples stored for up to 5 d, but no differences in CIE b* values ($p>0.05$) were observed among the samples stored for 5, 7, or 10 d. Jeong (2017) reported that a short-term presalting period of 3 d did not significantly affect CIE b* values, except that chicken products with 1% NaCl showed lower CIE b* values after 3 d storage compared to those cooked immediately, which is partially consistent with our results in the current study. However, the storage temperature (S) did not affect ($p>0.05$) CIE b* values and no two-way or three-way interactions were observed ($p>0.05$) for the CIE b* values (Tables 1 and 2).

Reflectance estimator of nitrosyl hemochrome (rNIT) and nicotinamide hemochrome (rNIC)

Nitrosyl hemochrome is the stable pink pigment of cured meat formed by the reaction between myoglobin and nitrates/nitrites after the cooking (Cassens, 1997; Suman and Joseph, 2013), leading to the pink color of cooked meat products. Even though nitrite is not intentionally added to meat, the inherent nitrite present in the meat itself has been observed in poultry meat (Ahn and Maurer, 1987; Claus and Jeong, 2018). In this study, the rNIT ratio, a reflectance estimator of nitrosyl hemochrome, was affected by treatment (T, $p<0.0001$) of the cooked ground chicken breasts (Table 1). The samples with STPP (STPP treatment) showed higher ($p<0.05$) rNIT ratios than the control without STPP (Table 2). These results were likely due to the increased pH by STPP addition, which promoted hemochrome formation (Sammel and Claus, 2007; Trout, 1989). However, the storage temperature (S) and storage duration (D) showed no effect ($p>0.05$) on the rNIT ratio in the cooked ground chicken products. Significant interaction effects between the treatment (T) and storage temperature (S) were found for rNIT ($p<0.05$) in cooked ground chicken breasts (Tables 1 and 4). The storage temperature had no effect ($p>0.05$) on the rNIT ratio of the control without STPP. However, STPP treatment at 7℃ had higher ($p<0.05$) rNIT ratios compared to those stored at 2℃. STPP treatment had higher rNIT ratio ($p<0.05$) than the control at both storage temperatures.

The rNIC ratio, a reflectance estimator of nicotinamide hemochrome, was not influenced by the treatment (T), storage temperature (S), or storage duration (D) of the cooked ground chicken products ($p>0.05$; Table 1). No two-way or three-way interactions significantly affected the rNIC ratio. Nicotinamide is a pyridine derivative with a relatively high concentration in poultry meat and has been reported as a potential pigments involved in the pink defect of cooked, uncured turkey (Ahn and Maurer, 1990; Schwarz et al., 1998). Claus and Jeong (2018) indicated that the storage of ground turkey and salt addition promote conditions associated with the formation of reduced nicotinamide-denatured globin hemochrome, leading to pink color in the cooked products. However, this discrepancy from our results is probable affected by nicotinamide content for different types of poultry meat (Schwarz et al., 1997).

Cooking yield, pH values, and oxidation-reduction potential (ORP)

The treatment (T, p<0.0001) affected cooking yield and pH values in the cooked ground chicken breast, but storage temperate (S) and storage duration (D) did not affect (p>0.05) cooking yields or pH values (Tables 1 and 3). No significant interactions were found among the main effects (p>0.05; Table 1). The samples with STPP (STPP treatment) had higher (p<0.05) cooking yield than the control (Table 3). As expected, the pH values of cooked ground chicken breast was increased by 0.5% STPP addition and was higher (p<0.05) than the control without STPP. These results are similar to those reported by Holownia et al. (2004), showing that the combination of sodium chloride and tripolyphosphate significantly increased the pH of cooked chicken meat. It is well-known that alkaline phosphate such as tripolyphosphate can increase the pH of meat and improve the water holding capacity, resulting in reduced cooking loss of meat products (Lamkey, 1998; Long et al., 2011; Sebranek, 2015). In terms of meat pigments, increased pH values can increase the heat stability of myoglobin, allowing it to retain a native state after cooking (Ahn and Maurer, 1989c), in agreement with the results of the myoglobin content and PMD reported in this study (Table 3).

The ORP is important for pink color formation and is affected by processing ingredients such as salt and phosphate (Holownia et al., 2003). Lower ORP values (more reducing conditions) is favorable for the development of pink discoloration

Table 3. Least square means and standard errors for presalting condition effects on cooking yield, pH values, oxidation-reduction potential, myoglobin content, and percentage myoglobin denaturation in cooked ground chicken breasts formulated without adding pink generating ligands

Main effects	Dependent variables[1)]				
	Cooking yield (%)	pH	ORP (mV)	Myoglobin (mg/g)	PMD (%)
Treatment (T)[2)]					
Control	97.94[b]	6.19[b]	–109.75[a]	0.18[b]	85.46[a]
STPP	98.96[a]	6.39[a]	–97.50[b]	0.21[a]	82.95[b]
SEM	(0.18)	(0.01)	(3.64)	(0.005)	(0.85)
Storage temperature (S)[3)]					
2℃	98.52	6.30	–102.12	0.19	84.79[a]
7℃	98.38	6.29	–105.13	0.20	83.62[b]
SEM	(0.19)	(0.01)	(3.64)	(0.005)	(0.85)
Storage day (D)[4)]					
Day 0	98.59	6.33	–113.50	0.19	81.46[b]
Day 3	98.27	6.28	–108.37	0.20	84.86[a]
Day 5	98.62	6.26	–103.79	0.19	85.33[a]
Day 7	98.31	6.28	–90.53	0.19	84.31[a]
Day 10	98.47	6.30	–101.93	0.19	85.06[a]
SEM	(0.25)	(0.01)	(5.60)	(0.006)	(0.95)

[1)] Dependent variables: ORP (oxidation-reduction potential), Myoglobin (amount of undenatured myoglobin), and PMD (percentage myoglobin denaturation).

[2)] Treatment: Ground meat were mixed with 2% NaCl alone (Control) or 2% NaCl and 0.5% sodium tripolyphosphate (STPP treatment).

[3,4)] Storage temperature and day: Treatments were periodically stored for 0, 3, 5, 7, or 10 d at different temperatures (2℃ or 7℃) before being cooked.

[a,b] Means within a column with unlike superscripts are different (p<0.05). Two way interaction found for myoglobin contents (T×S; p<0.05) and PMD (T×S; p<0.05).

in cooked meat because it encourages the complexation of denatured protein with heme pigments (Dobson and Cornforth, 1992). In the current study, ORP was affected by the treatment (T, $p<0.05$; Table 1). The addition of 2% NaCl alone to ground chicken breasts (control) promoted reducing conditions (more negative ORP values) to a larger extent compared to the STPP treatment (Table 3). Ahn and Maurer (1989b) suggested that the decreased ORP by salt addition may influence the formation of heme complexes in turkey breast products. Cornforth et al. (1986) also showed that reducing conditions (more negative ORP values) can promote pink color formation in cooked turkey rolls. These previous reports support the CIE a* values reported in this study. However, the storage temperature (S, $p>0.05$) and storage duration (D, $p>0.05$; Table 1) did not affect ORP. These results are similar to those reported by Jeong (2017), showing that no significant differences in the ORP of cooked chicken breasts occur when samples are presalted and stored for 0 to 3 d prior to cooking.

Myoglobin content and percentage myoglobin denaturation (PMD)

The treatment (T, $p<0.0001$) affected the myoglobin content and PMD of cooked ground chicken breasts (Table 1). The STPP treatment resulted in higher ($p<0.05$) myoglobin content compared to the control (Table 3). Trout (1989) reported that the addition of phosphate increased the stability of myoglobin in meat system. Ahn and Maurer (1989c) reported that sodium chloride significantly decreased myoglobin heat stability, whereas STPP increased the stability of myoglobin. It is also possible that water retention ability by STPP addition could reduce water release containing water soluble components such as myoglobin in meat (Ghorpade et al., 1992). However, storage temperature (S) and duration (D) did not affect ($p>0.05$) the myoglobin content of the cooked ground chicken products. Interaction effects between the treatment (T) and storage temperature (S) were significant ($p<0.05$) for myoglobin content in the cooked ground chicken breasts (Tables 1 and 4). The control samples were not different ($p>0.05$) in myoglobin content at both storage temperatures. However, the chicken products with STPP at 7°C showed greater myoglobin content ($p<0.05$) than those stored at 2°C or the control at 7°C. It could be speculated that an increase of storage temperature may reduce the oxygen tension (Seideman et al., 1984) and the redox form of myoglobin can be changed into be more deoxymyoglobin, which may result in greater thermal stability at higher pH (Hunt et al., 1999).

In the case of PMD, STPP treatment resulted in lower ($p<0.05$) PMD values compared to the control and samples stored at 2°C showed higher ($p<0.05$) PMD than those stored at 7°C (Table 3). Holownia et al. (2004) found that the presence of STPP

Table 4. Interaction effects of presalting condition on estimator of nitrosyl hemochrome (rNIT), myoglobin contents, and percentage myoglobin denaturation (PMD) in cooked ground chicken breasts formulated without adding pink generating ligands

Treatment[1)]	rNIT			Myoglobin (mg/g)			PMD (%)		
	Storage temperature[2)]			Storage temperature			Storage temperature		
	2°C	7°C	(SEM)	2°C	7°C	(SEM)	2°C	7°C	(SEM)
Control	1.0138^{b}	1.0136^{b}	(0.0006)	0.18	0.18^{b}	(0.005)	85.22	85.71^{a}	(0.85)
STPP	1.0157^{ay}	1.0178^{ax}	(0.0006)	0.19^{y}	0.22^{ax}	(0.005)	84.36^{x}	81.53^{by}	(0.85)
SEM	(0.0006)	(0.0006)		(0.005)	(0.005)		(0.85)	(0.85)	

[1)] Treatment: Ground meat were mixed with 2% NaCl alone (Control) or 2% NaCl and 0.5% sodium tripolyphosphate (STPP treatment).
[2)] Storage temperature: Treatments were periodically stored at different temperatures (2°C or 7°C) before being cooked.
[a,b] Means within a column with unlike superscripts are different ($p<0.05$). Standard error of interaction effects was 0.0008 for rNIT, 0.006 for myoglobin contents, and 0.92 for PMD.
[x,y] Means within a row with unlike superscripts are different ($p<0.05$). Standard error of interaction effects was 0.0008 for rNIT, 0.006 for myoglobin contents, and 0.92 for PMD.

with sodium chloride decreased the PMD in cooked chicken breast meat, which is similar to our result. In addition, presalting periods of >3 d prior to cooking resulted in higher ($p<0.05$) PMD values compared to the initial storage (0 d; Table 3). The increased PMD is probably due to the synergistic effect between the salt and storage (Rhee and Ziprin, 2001). It is likely that salt addition destabilized myoglobin in the meat (Ahn and Maurer 1989c; Min et al., 2010) and the anion or cation promoted alteration in the denaturation behavior of myoglobin (Trout, 1989), resulting in increased PMD. The treatment (T) and storage temperature (S) interaction was found ($p<0.05$) for PMD in cooked ground chicken breasts (Tables 1 and 4). The addition of STPP to samples did not result in differences ($p>0.05$) in PMD compared to the control at 2℃ (Table 4). When the samples were stored at 7℃, PMD was decreased ($p<0.05$) by addition of STPP to the ground chicken breast. PMD was not changed ($p>0.05$) with varying storage temperature in the control, but decreased ($p<0.05$) when stored at 7℃ compared to the 2℃ storage in the STPP treatment.

Conclusion

Presalting of ground chicken meat in the absence of STPP rather than the presence of STPP facilitated the development of a natural pink color in the final products without the addition of nitrogenous compounds such as nitrate and nitrite. However, the storage temperature prior to cooking did not affect the redness and pigments associated with the pink color in cooked ground chicken breasts. Storage periods of >5 d may contribute to spontaneous pink color development in cooked ground chicken products. The results indicate that poultry meat processors can control the natural pink color defects by limiting the storage periods to <5 d when chicken meat is presalted without the addition of any pink-inhibiting ligands. Further researches are necessary to investigate the effectiveness of pink inhibiting ligands to reduce the development of pink color defects in cooked meat products.

Conflict of Interest

The authors declare no potential conflict of interest.

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Author Contributions

Conceptualization: Jeong JY. Data curation: Bae SM, Cho MG. Formal analysis: Bae SM, Cho MG. Methodology: Bae SM, Cho MG. Software: Bae SM. Validation: Jeong JY. Investigation: Jeong JY. Writing - original draft: Bae SM, Cho MG. Writing - review & editing: Bae SM, Cho MG, Jeong JY.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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