EFFECTS OF STORAGE AND SALT CONCENTRATION ON THE DEVELOPMENT OF PINK COLOR IN COOKED CHICKEN BREASTS

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Abstract – This study was conducted to investigate the processing conditions for natural development of the pink color associated with presalted and ground chicken breasts during storage. Four treatments of varying salt concentrations (0%, 1%, 2%, and 3%) were prepared and the samples were stored for 0 and 3 days prior to cooking. Cooking yield increased with salt concentration. However, there were no significant differences in the pH value and oxidation reduction potential of cooked products. As the salt level increased, the residual nitrite contents increased but remained at very low values (0.19–0.56 ppm). Although considerable amounts of undenatured myoglobin were observed, CIE *a values (2.44–3.95) were not noticeably increased across treatments on both day 0 and day 3. Further, products with more than 2% NaCl had lower CIE *a** values on day 3 than on day 0. The effects of storage time and the level of salt addition on nitrosyl hemochrome and total pigment content were minimal. These results demonstrate that storage for 3 days does not contribute to the natural development of pink color in salted ground chicken products whereas salt addition of more than 2% to ground meat may reduce redness in cooked products.**

Key Words – NaCl, Pinking, Processing.

I. INTRODUCTION

In fully cooked poultry items, the presence of a pink or undercooked appearance is a major concern. This problem, while not a food safety issue, does present a quality issue as well as an economic concern for the processor [1]. The causes of undesirable pink color including high pH, high reducing conditions, the state and level of meat pigments, incidental nitrate/nitrite contamination, and processing ingredients have been well documented [2][3]. Thus, many researchers have investigated solutions to reduce pink color development by food ingredients [4][5][6]. Interestingly, Jeong et al. [7] attempted to create a natural pink color defect without the addition of pink generating ligands such as nitrite or nicotinamide in cooked ground turkey breast products at different processing conditions. They concluded that prolonged storage of salted ground turkey meat under anaerobic conditions may contribute to the undesirable development of a pink color defect in cooked ground turkey. Therefore, the goal of this research was to investigate the effects of storage time and salt concentration in the natural development of the pink color in presalted and stored ground chicken breasts and identify the pigment properties in cooked ground products.

II. MATERIALS AND METHODS

A. Raw material preparation

Fresh chicken breasts (1 day postmortem) were obtained from a local processor and ground with a 0.3 cm plate using a chopper (TC-22 elegant plus, Tre Spade, Valperga, Italy). The ground chicken trimmings were separated into four individual batches (2.4kg) depending on NaCl concentrations as follows: 0% NaCl, 1% NaCl, 2% NaCl, and 3% NaCl, respectively. In each treatment, salt was incorporated into the ground meat and mixed (5K5SS, St. Joseph, Michigan, USA) for 5 min followed by division into two sets for the length of storage (day 0 and day 3). All salted ground meat was vacuum-packaged and samples for day 3 were further stored under refrigeration (2-3 °C) prior to being mixed or stuffed. At the designated day (day 0, day 3), the ground meat was stuffed into conical centrifuge tubes (50 g each). The tubes were centrifuged at 2000 × g for 10 min (FELTA5, Hanil Science Corp., Incheon, Korea) to remove air pockets. All samples were stored overnight at 2-3 °C then cooked to an internal endpoint

temperature of 75 °C in a 90 °C water bath (CB60L, Dongwon Scientific Machinery Corp., Busan, Korea), cooled (20 min) on ice, and stored (2-3 °C) overnight in the dark until further analysis.

B. Analysis

Instrumental color determination. CIE *L*a*b** values were measured on the freshly cut surfaces of each cooked sample using a chroma meter (CR-410, 1-cm aperture, illuminant C; Konica Minolta Corp., Osaka, Japan), calibrated with a white plate (*L** 94.90, *a** -0.39, *b** 3.88).

Cooking yield, pH, and oxidation-reduction potential (ORP) determination. Cooking yield was calculated as: [cooked sample weight/raw sample weight] × 100. A pH meter (Accumet AB50, Thermo Fisher Scientific Inc., Singapore, Singapore) was used to measure pH on a 10 g cooked chicken sample homogenized in 50 ml of distilled, deionized water. ORP was measured on cooked chicken products following the modification of Cornforth *et al*. [8] and John *et al*. [9]. A sample (10 g) from each product was homogenized with 20 ml 0.1 M sodium carbonate and the ORP values were determined after 3 min of stabilization using a platinum Ag/AgCl combination electrode (No. 13-620-631, Thermo Fisher Scientific Inc., Singapore, Singapore) attached to the pH meter set to the milli volt scale.

Total myoglobin and percentage myoglobin denaturation (PMD) determination. Myoglobin (Mb, undenatured) was extracted from both uncooked and cooked chicken breast products using a procedure described by Warriss [10] and Trout [11]. Total myoglobin (Mb) and PMD was calculated using the following absorbance (A) formulas (Trout, 1989): Mb (mg/g) = (A525 nm – A700 nm) × 2.303 × dilution factor, PMD = [1-(Mb concentration after cooking/Mb concentration before cooking)] × 100.

Nitrosyl hemochrome and total pigment analysis. Nitrosyl hemochrome and total pigments were measured on cooked chicken samples after extraction in 80% acetone and acidified acetone [12]. Nitrosyl hemochrome concentration (ppm) = A540 nm × 290. Total pigment concentration (ppm) = A640 nm × 680.

Statistical analysis. All experiments were replicated three times. Data were statistically analyzed by a two-way ANOVA, for the storage period before cooking and NaCl concentration as the main effects using the statistical analysis system [13]. Duncan's multiple range test was used to determine differences ($P<0.05$) between the mean values.

III. RESULTS AND DISCUSSION

Storage period and salt concentration affected some dependent variables associated with naturally developed pink color in cooked chicken breasts (Table 1, 2, 3). As expected, products containing salt had greater ($P<0.05$) cooking yield compared to those without salt regardless of storage period (Table 1). On day 0, the samples with 2% and 3% NaCl had higher ($P<0.05$) cooking yield than those with 0% and 1% NaCl. This result was similar to that reported by Jeong *et al*. [7]. The cooking yield of products with 0% and 1% NaCl was higher on day 3 than on day 0, but the 2% and 3% NaCl products had similar ($P>0.05$) cooking yield on days 0 and 3. The pH values and ORP were not affected ($P>0.05$) by storage period or salt concentration (Table 1).

Table 1. Effects of storage period and salt concentration on cooking yield, pH, and oxidation reduction potential (ORP) in cooked ground chicken breasts

Traits	Storage day	NaCl concentration			
		0%	1%	2%	3%
Cooking yield (%)	Day 0	89.45^{Cy}	96.05^{By}	97.82^{A}	97.45^{A}
	Day 3	90.40^{Bx}	98.03^{Ax}	98.61^{A}	97.97^{A}
pH	Day 0	6.16	6.13	6.13	6.13
	Day 3	6.11	6.10	6.10	6.12
ORP (mV)	Day 0	-115.53	-114.62	-112.88	-114.55
	Day 3	-113.12	-112.70	-109.33	-108.25

$^{A-C}$ Means within a row with different superscript letters are different ($P<0.05$).
^{x,y} Means within a column with different superscript letters are different ($P<0.05$).

On day 0, 2% NaCl samples were more red (higher CIE *a** values; $P<0.05$) than 0% and 3% NaCl products and were not different ($P>0.05$) from 1% NaCl products (Table 2). On day 3, however, limited differences were observed in the CIE *a** values. Except for products with 1% NaCl,

the CIE *a** values decreased with increasing salt level and products with 3% NaCl had less red color (lower CIE *a** values; $P<0.05$) compared to those with 0% and 1% NaCl. Storage period did not affect ($P>0.05$) the CIE *a** values of products containing 0% and 1% NaCl, but samples treated with 2% and 3% NaCl showed a decrease ($P<0.05$) in CIE *a** values from day 0 to day 3 (Table 2).

Table 2. Effects of storage period and salt concentration on CIE a* values, total myoglobin (Mb), and percentage myoglobin denaturation (PMD) in cooked ground chicken breasts

Traits	Storage day	NaCl concentration			
		0%	1%	2%	3%
CIE *a**	Day 0	3.59^{B}	3.74^{AB}	3.95^{Ax}	3.67^{Bx}
	Day 3	3.60^{AB}	3.90^{A}	3.02^{BCy}	2.44^{Cy}
Mb (mg/g)	Day 0	0.24^{Ax}	0.22^{ABx}	0.21^{Bx}	0.23^{AB}
	Day 3	0.20^{Ay}	0.19^{ABy}	0.18^{By}	0.21^{A}
PMD (%)	Day 0	80.22^{B}	82.74^{AB}	84.93^{A}	81.91^{B}
	Day 3	80.49^{B}	81.94^{AB}	83.50^{A}	79.40^{B}

$^{A-C}$ Means within a row with different superscript letters are different ($P<0.05$).
^{x,y} Means within a column with different superscript letters are different ($P<0.05$).

Total myoglobin contents were reduced with increasing salt level on both storage days, except for products with 3% NaCl (Table 2). When samples were treated with 0%, 1%, and 2% NaCl and stored for 3 days prior to processing, total myoglobin contents were lower ($P<0.05$) compared to 0 day samples. However, no differences ($P>0.05$) in total myoglobin contents were found between day 0 and day 3. Although samples were cooked to 75 °C, approximately 15-20% of undenatured myoglobin remained in the products on both day 0 and day 3 (Table 2). Jeong *et al*. [7] reported that approximately 15% of myoglobin was not denatured when presalted and stored ground turkey breast were cooked to 79.4 °C. In the present study, percentage myoglobin denaturation (PMD) in cooked chicken breasts increased ($P<0.05$) as the salt level increased to 2% NaCl but decreased with 3% NaCl. Storage period did not influence ($P>0.05$) the PMD of cooked chicken breasts (Table 2).

Nitrite contents significantly increased as NaCl level increased ($P<0.05$) from 0 to 2% on day 0. Products with 2% and 3% NaCl had the highest ($P<0.05$) nitrite contents and were similar ($P>0.05$) to each other (Table 3). On day 3, the nitrite contents of 0% and 1% NaCl samples were not significantly different but nitrite contents increased with salt concentration, with the highest values ($P<0.05$) in products containing 3% NaCl. Depending on storage period, the nitrite contents of products with 0% and 1% NaCl were lower ($P<0.05$) on day 3 than on day 0. Nevertheless, the nitrite contents observed in this research were less than 1 ppm, which is the amount known to cause a pink color in poultry products [14].

Table 3. Effects of storage period and salt concentration on nitrite, nitrosyl hemochrome, and total pigment in cooked ground chicken breasts

Traits	Storage day	NaCl concentration			
		0%	1%	2%	3%
Nitrite (ppm)	Day 0	0.25^{Cx}	0.32^{Bx}	0.48^{A}	0.54^{A}
	Day 3	0.19^{Cy}	0.24^{Cy}	0.48^{B}	0.56^{A}
Nitrosyl hemochrome (ppm)	Day 0	2.54^{A}	1.35^{B}	1.55^{AB}	0.68^{B}
	Day 3	1.76^{A}	1.45^{A}	0.89^{B}	1.26^{AB}
Total pigment (ppm)	Day 0	14.79	15.02	15.19^{x}	14.45
	Day 3	15.30^{A}	15.19^{AB}	14.39^{By}	14.62^{AB}

$^{A-C}$ Means within a row with different superscript letters are different ($P<0.05$).
^{x,y} Means within a column with different superscript letters are different ($P<0.05$).

Nitrosyl hemochrome contents were higher in products without salt (0% NaCl) compared to those with salt (1%, 2%, 3% NaCl) on both days (Table 3). Similar results were reported by Jeong *et al*. [7] for cooked ground turkey breasts. No differences ($P>0.05$) between day 0 and day 3 in nitrosyl hemochrome contents were found among the NaCl treatments. Storage period and salt concentration had very limited effects on the total pigment contents of cooked ground chicken breasts (Table 3). Total pigment contents were similar ($P>0.05$) across all treatments on day 0. On day 3, there were no differences ($P>0.05$) in total pigment contents among the treatments except for 2% NaCl products, which had lower total pigment contents compared to 0% NaCl products.

IV. CONCLUSION

Storage and salt concentration had limited effects on the development of pink color in cooked ground chicken breasts. When chicken meat with more than 2% salt was stored for 3 days, redness was reduced after cooking. Therefore, to develop a natural pink color in ground chicken meat products, a storage period of longer than 3 days should be employed and processing conditions including lower salt concentration may be needed. On the other hand, to prevent undesirable pink color defects, processors should avoid storage of ground chicken meat when mixed without salt or with less than 1% NaCl.

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