PROCESSING EFFECTS ON THE PINK DEFECT IN COOKED GROUND TURKEY BREASTS

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***Abstract*—This study was conducted to characterize the pink pigments associated with storing presalted (2%) and ground turkey breast trim at different processing conditions. Four treatments included: Treatment 1 (no NaCl, stored 7 days before cooked), Treatment 2 (NaCl, stored 7 days before cooked), Treatment 3 (NaCl added and immediately cooked), and Treatment 4 (stored 7 days before salted and cooked). All treatments were cooked to four endpoint temperatures (71.1, 73.9, 76.7, and 79.4 °C). Processing conditions affected pink discoloration in cooked ground turkey breast. Undenatured myoglobin in salted meat (Treatment 2, 3, 4) still remained (17-19%) after cooking. Salted and stored ground turkey (Treatment 2) produced a cooked product with the most reducing condition (lowest oxidation reduction potential, ORP) and one of the most red (CIE *a** value). Final internal temperature had limited effects on pigment properties. ORP was similar across cooking temperatures while CIE *a** values decreased with temperature. Even at 79.4 °C, 15% undenatured myoglobin remained. Cooking yield decreased with temperature as expected (92.8 to 89.5%). Results indicate that to limit the degree of the pink color development processors should avoid storage of ground turkey, particularly when mixed with salt.**

***Index Terms*—Cooking temperature, Ground turkey breast, Pink color defect, Processing condition.**

I. INTRODUCTION

Cooked uncured turkey occasionally exhibits an undesirable pink color even when cooked to temperatures ensuring food safety. Consumers may interpret the pink discoloration as an indication the product was undercook and is unsafe to eat. Therefore, this defect can result in serious economic losses to the retailers, processors, and producers of poultry products (Holownia, Chinnan & Reynolds, 2004). Researchers have reported that numerous factors influence the pink color defect of poultry meat (Ahn & Maurer, 1990; Cornforth, Vahabzadeh, Carpenter & Bartholomew, 1986; Holownia et al., 2004). Some researchers have evaluated the ability to control pink color development using different non-meat ingredients (Slesinski et al., 2000; Sammel & Claus, 2003, 2007). A challenge with studying the pink color defect is its sporadic occurrence. To overcome this problem, many have created a pink defect by adding nitrite, nicotinamide, or other pink generating ligands. Although this has value, it may not be indicative of the actual sporadic pink pigment. Based on unpublished industry observations, storage of ground turkey appeared to be more prone to causing a pink defect, particularly when presalted. Thus, a goal of this study was to create a pink color defect (*natural* pink) without the addition of pink generating ligands such as nitrite or nicotinamide and identify the pigment characteristics in the cooked ground turkey breast products at different processing conditions.

II. MATERIALS AND METHODS

A. Raw material preparation

Fresh ground turkey breast trimmings (1 day postmortem, 0.64-cm plate) were obtained from Jennie-O Turkey Store. The ground turkey trimmings were separated into four individual batches (3 Kg) depending on processing conditions as followings: Treatment 1 (no NaCl, stored 7 days before cooked), Treatment 2 (NaCl, stored 7 days before cooked), Treatment 3 (NaCl added and immediately cooked), and Treatment 4 (stored 7 days before salted and cooked). At the time of salt (2%) addition, the ground meat was mixed (Model A120T, Hobart Corporation, Troy, OH) for 3 min and stored under refrigerated temperature (2-3 °C) prior to being mixed or stuffed. At designated days (day 6: Treatment 1, 2, 4; day 0: Treatment 3), ground meat was stuffed into conical centrifuge tubes (50 g each). The tubes were centrifuged at 2000 × g for 10 min (Model J-6M, Beckman Instruments Inc., Palo Alto, CA) to remove air pockets. All samples were stored overnight at 2-3 °C and cooked to four different internal endpoint temperatures (71.1, 73.9, 76.7, and 79.4 °C) in a 90 °C water bath (Isotemp 228; Fisher Scientific, Pittsburgh, Pa., U.S.A.), cooled (20 min) in ice, and

stored (2-3 °C) overnight in the dark until further analysis.

B. Analysis

Instrumental color and pigment determination. CIE *L*a*b** values and visible reflectance (400 to 700 nm) were measured on freshly cut surfaces of each cooked sample using a chroma meter (CR-310, 1-cm aperture, illuminant C; Minolta Corp., Osaka, Japan) and ultraviolet/visible scanning spectrophotometer (model UV-2401PC; Shimadzu. Corp., Kyoto, Japan), respectively, calibrated with a white plate (*L** 97.06, *a** -0.14, *b** 1.93). Nitrosyl hemochrome was estimated using the percentage reflectance (%*R*) ratio, %*R*650 nm/%*R*570 nm where a higher value indicated more pigment (AMSA, 1991) and nicotinamide hemochrome was estimated by the percentage reflectance ratio of %*R*537 nm/%*R*553 nm where a higher value equaled more pigment (Schwarz, Claus, Wang, Marriott, & Graham, 1998).

Cooking yield, pH and oxidation-reduction potential (ORP) determination. Cooking yield was calculated as: [cooked sample weight/raw sample weight] × 100. A pH electrode (910600; Thermo Orion, Beverly, Mass., U.S.A.) attached to a pH meter (Accumet AR50, Fisher Scientific, Pittsburgh, PA) was used to measure pH on a 10 g cooked turkey sample homogenized in 50 ml of distilled, deionized water. ORP was measured on cooked turkey products following the modification of John, Cornforth, Carpenter, Sorheim, Pettee and Whittier (2005) and Cornforth et al. (1986). A sample (10 g) from each turkey 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. 13-620-81, Fisher Scientific Co., Houston, TX) attached to the pH meter set to the milli volt scale.

Percentage denatured myoglobin (PDM) determination. Myoglobin (Mb, undenatured) was extracted from both uncooked or cooked turkey breast products using a procedure by Warriss (1979) and Trout (1989). 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 analysis. Nitrosyl hemochrome was measured on cooked turkey samples after extraction in 80% acetone (Hornsey, 1956). Nitrosyl hemochrome concentration (ppm) = A540 nm × 290.

Statistical analysis. The experimental design was a split plot with four different processing conditions (treatments) representing the whole plot factor and four endpoint cooking temperature (71.1 °C, 73.9 °C, 76.7 °C, and 79.4 °C) representing the split plot factor. The fixed effects for processing conditions and endpoint temperature, and their interactions were performed using PROC MIXED Model of SAS (2002). Dependent variable means were separated ($p < 0.05$) by pairwise comparisons using the pdiff option (SAS, 2002). The experiment was replicated four times.

III. RESULTS AND DISCUSSION

The only two-way interaction (treatment × endpoint temperature) was observed for cooking yield. Therefore, the results will be discussed based on main effects (treatment or endpoint temperature) except for cooking yield in cooked turkey breasts.

Processing conditions (Treatment) effect

Processing conditions affected many dependent variables associated with naturally developed pink color in cooked ground turkey breast products (Table 1). The pH values of treatments 2, 3, and 4 were higher ($p < 0.05$) than those of treatment 1 but were similar ($p > 0.05$) to each other (Table 1). The higher pH was caused by the effect of the added salt. This result was similar to that reported by Holownia et al. (2004). When ground turkey meat was salted and stored (treatment 2), the cooked product had the most ($p < 0.05$) reducing condition (lowest oxidation-reduction potential) while treatment 1 had the least (Table 1). Treatment 1 had the greatest ($p < 0.05$) percentage myoglobin denaturation (Table 1). Treatments 2, 3, and 4 were similar ($p > 0.05$) to one another in percentage myoglobin denaturation. Presence of salt is known to destabilize myoglobin resulting in greater heat denaturation (Ahn & Maurer, 1989; Trout, 1989). Nevertheless, undenatured myoglobin in the salt-containing treatments still remained (16-19%) after cooking. Samples with added salt and stored (treatment 2) or stored prior to added salt (treatment 4) were more ($p < 0.05$) red (higher CIE *a** value) than treatments 1 and 3 (Table 1). Treatment 3 had the lowest CIE *a** value among the treatments. The results of this research indicate that storage of raw turkey under anaerobic condition prior to cooking, rather than the timing of salt addition, may be responsible for development of the pink color defect in cooked ground turkey. Nevertheless, the CIE *a** values of all treatments were indicative of those found in pink products reported by Claus, Shaw and Marcy (1994). Nitrosyl hemochrome content did not differ ($p > 0.05$) among the treatments containing salt (Table 1). However,

nitrosyl hemochrome content was the greatest ($p < 0.05$) in the absence of salt. Although Treatment 2 and 4 have been shown to have higher CIE *a** values, nitrosyl hemochrome from those samples did not clearly follow the same trends as CIE *a** value. In addition, the rNIT ratio, an estimator of nitrosyl hemochrome from reflectance data, was less in treatment 3 than treatment 1, 2, and 4 as in the case of CIE *a** value in our study. The reflectance estimator of nicotinamide hemochrome, rNIC ratio was the highest for treatment 2, followed by treatment 4 and treatment 3, and was the lowest for treatment 1 (Table 1). Since this result followed a general trend similar to the oxidation-reduction potential and partially the redness (CIE *a** value) in this research suggests that the increase in redness may be related to an increase in nicotinamide hemochrome in the cooked turkey products. Cornforth et al. (1986) reported that the formation of nicotinamide hemochrome is promoted by reducing conditions.

Endpoint temperature effect

Endpoint internal temperature had limited effects on cooked ground turkey breasts. Regardless of treatments, cooking temperature did not result ($p > 0.05$) in differences in pH and oxidation-reduction potential (Table 2). Percentage myoglobin denaturation was affected by endpoint temperature as indicated by the lowest mean ($p < 0.05$) for turkey breast samples cooked at 71.1 °C (Table 2). However, no differences ($p > 0.05$) in percentage myoglobin denaturation were observed among the other temperatures tested. Interestingly, even when cooked to 79.4 °C, approximate 15% undenatured myoglobin still remained. Undenatured pigments (myoglobin, hemoglobin, cytochrome c) can contribute to the color of cooked meat. As expected, higher endpoint cooking temperature resulted in a general trend toward lower CIE *a** values (Table 2). No differences ($p > 0.05$) in nitrosyl hemochrome were observed between tested temperatures in cooked ground turkey products (Table 2). However, the rNIT ratio generally decreased as the cooking temperature increased from 71.1 °C to 79.4 °C for cooked turkey samples (Table 2). The rNIC means for the intermediate temperatures were greater than either the lowest or highest temperature (Table 2).

Two-way interactions for cooking yield

Interaction effects of processing conditions and endpoint temperature on cooking yield (%) in cooked ground turkey breasts are presented in Table 3. Salted ground turkey products (treatment 2, 3, or 4) exhibited greater cooking yield ($p < 0.05$) than unsalted samples (treatment 1), which is probably due to the effect of added salt. In general, cooking yield decreased as cooking temperature increased as expected (92.8-89.5%). Similarly, Sammel and Claus (2003) reported that cooking yield in cooked ground turkey breast was significantly decreased for all ligand treatments (no ligand, nitrite, and nicotinamide) when end-point cooking temperature was increased from 80 to 85 °C.

IV. CONCLUSION

Processing conditions affected pink discoloration in cooked ground turkey breasts. When ground turkey breast was salted and stored for 7 days, the cooked products had the greatest reducing condition (the lowest oxidation-reduction potential) and redness (highest CIE *a** value). Significant amounts of undenatured myoglobin remained even when cooked to 79.4 °C. Extending the cooking times would be expected to further denature this pigment. The results of this study indicate that prolonged storage time of salted ground turkey meat under anaerobic condition may contribute to the undesirable development of a pink color defect in cooked ground turkey. Therefore, to limit the degree of the pink color development, processors should avoid storage of ground turkey, particularly when mixed with salt.

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Table 1. Effects of processing condition (treatment) on pH values, oxidation reduction potential, percentage myoglobin denaturation and pigment properties in cooked products made from ground turkey breast trim

	Dependent Variables[1]						
Treatments[2]	pH	ORP (mV)	PMD (%)	CIE *a**	Nitrosyl hemochrome (ppm)	rNIT	rNIC
Treatment 1	6.10^{b}	-58.08^{c}	86.8^{a}	7.17^{b}	1.51^{a}	1.400^{a}	1.025^{d}
Treatment 2	6.14^{a}	-65.85^{a}	81.4^{b}	7.49^{a}	0.54^{b}	1.381^{ab}	1.050^{a}
Treatment 3	6.15^{a}	-60.83^{b}	81.8^{b}	6.83^{c}	0.60^{b}	1.354^{c}	1.037^{c}
Treatment 4	6.14^{a}	-63.13^{b}	83.2^{b}	7.46^{a}	0.42^{b}	1.379^{b}	1.046^{b}
(S.E.)	(0.02)	(3.59)	(0.95)	(0.28)	(0.21)	(0.012)	(0.003)

[1] Dependent variables: ORP (oxidation reduction potential), PMD (Percentage myoglobin denaturation), CIE *a** (higher value more red), 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).
[2] Treatments: Treatment 1 - no NaCl, stored for 7 days before cooked; Treatment 2 - added NaCl, stored for 7 days before cooked; Treatment 3 - added NaCl, cooked; Treatment 4 - stored for 7 days before added NaCl and cooked.
[a-c] Means within a column with unlike superscript letters are different ($p < 0.05$).

Table 2. Effects of endpoint temperature on pH values, oxidation reduction potential, percentage myoglobin denaturation and pigment properties in cooked products made from ground turkey breast trim

	Dependent Variables[1]						
Temperature[2] (°C)	pH	ORP (mV)	PMD (%)	CIE *a**	Nitrosyl hemochrome (ppm)	rNIT	rNIC
71.1	6.13	-62.36	78.7^{b}	7.47^{a}	0.77	1.414^{a}	1.034^{c}
73.9	6.13	-61.60	84.1^{a}	7.30^{ab}	0.75	1.383^{b}	1.043^{a}
76.7	6.13	-61.77	85.3^{a}	7.18^{bc}	0.81	1.365^{bc}	1.043^{a}
79.4	6.13	-62.15	85.0^{a}	7.00^{c}	0.73	1.352^{c}	1.039^{b}
(S.E.)	(0.17)	(3.59)	(0.95)	(0.28)	(0.21)	(0.012)	(0.003)

[1] Dependent variables: ORP (oxidation reduction potential), PMD (Percentage myoglobin denaturation), CIE *a** (higher value more red), 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).
[2] Temperature: Internal temperature was achieved by cooking in a 90 °C water bath..
[a-c] Means within a column with unlike superscript letters are different ($p < 0.05$).

Table 3. Effects of processing condition and endpoint temperature on cooking yield (%) in cooked products made from ground turkey breast trim

	Endpoint temperature[1] (°C)				
Treatments[2]	71.1	73.9	76.7	79.4	Overall Mean
Treatment 1	82.7^{bw}	80.8^{bx}	78.8^{by}	76.1^{bz}	79.6
Treatment 2	95.9^{aw}	95.6^{awx}	95.1^{ax}	94.0^{ay}	95.2
Treatment 3	96.5^{aw}	95.5^{ax}	94.7^{axy}	94.0^{ay}	95.2
Treatment 4	96.2^{aw}	95.7^{awx}	95.1^{ax}	93.8^{ay}	95.2
Overall mean	92.8	91.9	90.9	89.5	

[1] Temperature: Internal temperature was achieved by cooking in a 90 °C water bath. Interaction ($p < 0.001$) found between treatment and endpoint temperature (Standard error, 0.68).
[2] Treatment: Treatment 1 - no NaCl, stored for 7 days before cooked; Treatment 2 - added NaCl, stored for 7 days before cooked; Treatment 3 - added NaCl, cooked; Treatment 4 - stored for 7 days before added NaCl and cooked.
[a,b] Means within a column with unlike superscript letters are different ($p < 0.05$). Standard error of comparing overall mean was 0.64.
[w-z] Means within a row with unlike superscript letters are different ($p < 0.05$). Standard error of comparing overall mean was 0.64.