

# Tenderizing Spent Fowl Meat with Calcium Chloride. 4. Improved Oxidative Stability and the Effects of Additional Aging<sup>1</sup>

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**ABSTRACT** The goal of these experiments was to determine the effects of CaCl<sub>2</sub> and NaCl injections on spent fowl meat tenderness and oxidative stability. Two hundred spent Leghorn hens were used in this two-part study. In the first experiment, breast fillets from 160 spent Leghorn hens were harvested immediately after death, injected with 0.3 M CaCl<sub>2</sub> or H<sub>2</sub>O, vacuum tumbled, and either cooked immediately after tumbling or aged at 1 C for 23 h prior to cooking. Although the CaCl<sub>2</sub> injection reduced shear values without aging, additional tenderization occurred during the aging period. In the second experiment, breast fillets from 40 spent Leghorn hens were harvested immediately after

death, injected with 0.3 M CaCl<sub>2</sub>, 0.6 M NaCl, 0.15 M CaCl<sub>2</sub> + 0.3 M NaCl, or H<sub>2</sub>O, vacuum tumbled, and then aged at 1 C for 23 h before cooking. The three salt injection treatments reduced shear values to a similar extent, but the sarcomeres were significantly longer for the NaCl treatment than the CaCl<sub>2</sub> or combination treatments. Panelists preferred the CaCl<sub>2</sub> + NaCl fillets over the CaCl<sub>2</sub> fillets. Replacing some of the CaCl<sub>2</sub> with NaCl maintained the tenderizing effect, and panelist comments indicated that the slight aftertaste of the 0.3 M CaCl<sub>2</sub> treatment was reduced. The sodium contribution of the 0.6 M NaCl treatment would also be reduced by the CaCl<sub>2</sub> + NaCl treatment.

(Key words: calcium, sodium, oxidation, spent fowl, tenderness)

1997 Poultry Science 76:548-551

## INTRODUCTION

Because of unacceptable toughness and brittle bones, the use of spent fowl meat has long been a problem for the poultry industry. Tenderness is considered to be the most important organoleptic characteristic of meat (Lawrie, 1991). The toughness associated with spent fowl meat is primarily due to the increased crosslinking in the connective tissue of older animals (Bailey and Light, 1989). The primary use of spent fowl meat is for retorted products such as soup that receive extreme heat treatments. Presently, there is no economically feasible way to increase tenderness by decreasing collagen crosslinking in spent fowl meat. If tenderness could be improved by physical degradation of the collagen protein, it would be possible to expand the market for the spent hen meat and increase its value (Kondaiah and Panda, 1992).

Two methods of tenderization examined in this study are ionic strength and the activation of calpains, which are calcium-dependent proteases (Nurmahmudi and Sams, 1996b,c). The primary tenderizing effect of

calpains on the muscle fiber is due to degradation of proteins at the Z-line of the sarcomere. Although injecting meat with CaCl<sub>2</sub> tenderizes meat (Nurmahmudi and Sams, 1996a,b,c), detrimental effects include reduced palatability (Eilers *et al.*, 1994) and loss of moisture binding capacity (Young and Lyon, 1989). In addition to studies conducted on bovine and ovine carcasses, Nurmahmudi (1994) demonstrated that injection immediately post-mortem to 10% (wt/wt) with 0.3 M CaCl<sub>2</sub> combined with vacuum tumbling is necessary for tenderization of spent fowl meat deboned immediately after picking and that delaying injection until 24 h post-mortem gave no additional tenderization. Increased ionic strength has been reported to increase post-mortem protein solubilization and therefore contribute to meat tenderness (Wu and Smith, 1987).

Another important aspect of meat quality is lipid oxidation. Calcium has been reported to function as an antioxidant at certain concentrations, which would extend the shelf-life of the product. Cho and Rhee (1995) determined that at low concentrations (< 0.1%) CaCl<sub>2</sub> injection resulted in increased oxidation, whereas higher concentrations (> 0.1%) resulted in decreased oxidation.

It was therefore hypothesized that injection with a CaCl<sub>2</sub> solution would tenderize the meat and increase shelf life by decreasing lipid oxidation occurring during storage of the product. Additionally, replacing some of the CaCl<sub>2</sub> with NaCl would maintain the antioxidant

Received for publication June 21, 1996.

Accepted for publication October 8, 1996.

<sup>1</sup>Financial support of this research was provided by the Southeastern Poultry and Egg Association.

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property of the  $\text{CaCl}_2$  while reducing its bitter taste. The objective of this study was to determine the effects of  $\text{CaCl}_2$  and  $\text{NaCl}$  injected singly or in combination into the *Pectoralis major* of spent fowl meat on tenderization, sensory characteristics, and oxidative storage stability.

## MATERIALS AND METHODS

### Experiment 1

One hundred and sixty Single Comb White Leghorn hens were divided into two replications, 16 birds in each of five treatment groups per replication. The birds were obtained from a local commercial laying operation 1 d prior to slaughter and were taken off feed (but not water) 12 h prior to slaughter. The birds were electrically stunned<sup>3</sup> for 5 s using 35 mA and allowed to bleed for 90 s from a unilateral neck cut severing the carotid artery and the jugular vein. The hens were subsequently subscalded together at 61 C for 45 s and picked in a rotary drum picker<sup>4</sup> for 30 s. The control carcasses were eviscerated, chilled in 2 C static tap water for 45 min, and aged on ice for 23 h. The fillets were then excised from the carcasses and cooked according to Sams (1990) in a convection oven to an internal temperature of 76 C. Both the fillets from experimental carcasses were excised immediately after picking (< 5 min post-mortem) (Hamm, 1981), and injected to 10% (wt/wt) with a pickle pump<sup>5</sup> with 20 C solutions of 0.3 M  $\text{CaCl}_2$  or distilled and deionized  $\text{H}_2\text{O}$ . The fillets were tumbled in a 30-L plastic tumbler<sup>6</sup> (-635 mm Hg, 20 rpm, 20 C for 1 h). One fillet from each carcass was aged on ice for 23 h and then cooked (Sams, 1990) in a convection oven to an internal temperature of 76 C, whereas the other fillet from each carcass was cooked immediately after tumbling. Allo-Kramer shear value was evaluated on all *Pectoralis* fillets and on the *Pectoralis* muscles from the cooked, control carcasses by taking one sample (35 × 20 × 7 mm) from each fillet with the long axis of the sample parallel to the direction of the muscle fibers. Each sample was weighed and then sheared on an Instron Universal Testing Machine<sup>7</sup> using a 10-blade Allo-Kramer shear compression cell, a 500-kg load cell with a 200-kg load range, and a crosshead speed of 500 mm/min. The shear value was recorded as kilograms of force per gram of sample.

To compare overall production systems (the various combinations of aging, injection, and tumbling) rather than individual levels of main effects, the data were analyzed as a completely randomized design. The data were subjected to least squares means analysis and the means were separated using Duncan's multiple range test

(SAS Institute, 1989). Because no significant interaction between replicates and treatments was detected, the data from the replicates were combined.

### Experiment 2

In each of two replications, 20 birds were processed as detailed in Experiment 1, 4 birds in each of five treatment groups per replication. Both breast fillets were harvested immediately after picking and injected to 10% (wt/wt) with a solution of either 0.3 M  $\text{CaCl}_2$ , 0.6 M  $\text{NaCl}$ , 0.15 M  $\text{CaCl}_2$  + 0.3 M  $\text{NaCl}$ , or distilled and deionized  $\text{H}_2\text{O}$ . Fillets were then tumbled for 1 h as described in Experiment 1, and aged for 23 h prior to cooking as described in Experiment 1. The three salt treatments were of similar ionic strength (as indicated by similar conductivities) in order to better elucidate the antioxidant, sensory, and tenderizing effects of the different solutions without the confounding contribution of ionic strength. The control fillets were excised from the carcasses after aging and then cooked as in Experiment 1. Allo-Kramer shear value (Sams, 1990), sarcomere length (Sams *et al.*, 1990), thiobarbituric acid reactive substances (TBARS), and sensory characteristics (preference test) were evaluated on fillets from all carcasses. The TBARS analysis (Rhee, 1978) was conducted on one sample per carcass that was vacuum packaged in a pouch<sup>8</sup> and stored at 2 C for 0 or 5 d. Fifty grams of each sample were blended with 75 mL dd  $\text{H}_2\text{O}$  and 25 mL propyl gallate-EDTA solution (0.5% of each component). A 30-g aliquot of the slurry (10 g meat) was distilled in duplicate. Results were expressed as milligrams of malonaldehyde per kilogram of sample.

The preference test was conducted on samples after 5 d storage at 2 C by presenting samples from the  $\text{H}_2\text{O}$ ,  $\text{CaCl}_2$ , and  $\text{CaCl}_2$  +  $\text{NaCl}$  treatments to panelists who were asked to evaluate all three in random order and rank them according to overall flavor. The untrained panelists consisted of university personnel and students of both sexes and ranged in age from 20 to 55 yr. The panelists were also asked for comments, which were recorded along with the preference data.

The data for each variable, with the exception of the sensory data, were subjected to least squares means and significance of differences among the means were tested with Duncan's multiple range test (SAS Institute, 1989). The sensory data were analyzed using the tables of Meilgaard *et al.* (1991).

## RESULTS AND DISCUSSION

### Experiment 1

As has been previously reported (Nurmahmudi, 1994), injection with 0.3 M  $\text{CaCl}_2$  and tumbling immediately after deboning resulted in significantly reduced shear value means for both aging treatments (Table 1). Also, the shear value mean for the  $\text{CaCl}_2$ -treated meat aged 0 h before cooking was not significantly different than that of

<sup>3</sup>Cervin Electrical Systems, Minneapolis, MN 55410.

<sup>4</sup>Model sp30ss, Brower Corp., Houghton, LA 52631.

<sup>5</sup>KOCH 01-12-27, Kansas City, MO 64108.

<sup>6</sup>Lyco, Model 40, Janesville, WI 53545.

<sup>7</sup>Instron Corp., Canton, MA 02021.

<sup>8</sup>Koch, Kansas City, MO 64108.

TABLE 1. Allo-Kramer shear value means<sup>1</sup> of cooked fillets for various aged and injected treatments

Injected solution	Aging time <sup>2</sup>	Shear value
	(h)	(kg/g)
0.3 M CaCl <sub>2</sub>	0	15.64 <sup>c</sup>
Distilled and deionized H <sub>2</sub> O	0	28.38 <sup>a</sup>
0.3 M CaCl <sub>2</sub>	23	12.48 <sup>c</sup>
Distilled and deionized H <sub>2</sub> O	23	21.66 <sup>b</sup>
Control		11.89 <sup>c</sup>
Pooled SEM		0.58

<sup>a-c</sup>Means within a column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>n = 32 per mean.

<sup>2</sup>Aging time between treatment (injection and tumbling) and cooking.

the CaCl<sub>2</sub>-treated meat aged 23 h before cooking (Table 1). Although this result suggests that no aging after treatment is necessary, the large numerical difference (over 3 kg/g) may be important to processors. However, the statistical analysis used was chosen to compare the mean for the various processing systems to that of the control as an indicator of the current commercial product. If the mean for the 0 h CaCl<sub>2</sub> was compared to the 23 h CaCl<sub>2</sub> with a *t* test procedure of SAS Institute (1989), they are significantly different ( $P < 0.01$ ). If no significant tenderization occurred with aging, processors would save money by eliminating the labor, energy, and space needed for this refrigerated storage period. The observed toughening effect of early post-mortem deboning and the alleviation of this toughness with CaCl<sub>2</sub> have been previously reported (Stewart *et al.*, 1984; Dawson *et al.*, 1987; Nurmahmudi, 1994). Although some tenderization has been reported, the shear values obtained would not be considered tender by consumers according to thresholds reported by Lyon and Lyon, (1990).

## Experiment 2

There was a significantly lower Allo-Kramer shear value for the three salt treatments compared to the H<sub>2</sub>O treatment, but their mean shear values were not lower than those of the aged controls (Table 2). This finding

suggests that the prerigor deboning, injecting, and tumbling toughens the meat, an effect that can be at least partially compensated for by including certain salts in the injection solution. There was no significant difference ( $P < 0.05$ ) among the three salt treatments. As previously mentioned, the ionic strength of the solutions, and in the case of the CaCl<sub>2</sub> and combination treatments, the activation of calpains, may have contributed to the tenderization. Increasing the ionic strength by CaCl<sub>2</sub> or NaCl injection would increase the solubilization of the proteins and result in more tender meat (Wu and Smith, 1987) and the added ions could activate the calpain proteases to degrade the myofibrillar structure (Koochmaraie *et al.*, 1988, 1989). Also, the substitution of CaCl<sub>2</sub> for NaCl in the CaCl<sub>2</sub> + NaCl treatment would reduce the contribution of Na ions relative to the NaCl treatment.

Sarcomere length results (Table 2) indicated that the injection process may have facilitated muscle contraction by the overall trend of shorter sarcomeres in the injected treatments. From the shear data (Table 2), one would expect similar sarcomere lengths for the three salt treatments because the shear values were not significantly different and the ionic strengths of the solutions were the same. Because the CaCl<sub>2</sub> and CaCl<sub>2</sub> + NaCl treatments had significantly shorter sarcomeres than the NaCl treatment, a mechanism of tenderization other than ionic strength is apparently acting on the CaCl<sub>2</sub> and CaCl<sub>2</sub> + NaCl treatments. Calcium is known to facilitate contraction by serving as a cofactor for the interaction of actin and myosin (Lawrie, 1991).

Thiobarbituric acid reactive substances data on Day 0 indicated an antioxidative effect for the two CaCl<sub>2</sub> treatments (0.3 M CaCl<sub>2</sub> and 0.15 M CaCl<sub>2</sub> + 0.3 M NaCl) and a prooxidative effect for the NaCl (0.6 M) treatment. By Day 5, the prooxidative effect of the NaCl was no longer apparent (Table 2), possibly because the TBARS values were high for the control by Day 5. Thiobarbituric acid reactive substances of the CaCl<sub>2</sub> and CaCl<sub>2</sub>+NaCl treatments were significantly lower than those of all other treatments on both Days 0 and 5 and the CaCl<sub>2</sub> treatment was significantly lower than the combination treatment on Day 5 (Table 2). These results are consistent with the

TABLE 2. Allo-Kramer shear value, sarcomere length, and TBARS<sup>1</sup> means<sup>2</sup> for meat from various injection treatments

Injected solution	Shear value	Sarcomere length	TBARS	
			Day 0	Day 5
	(kg/g)	( $\mu$ m)	(mg/kg)	
0.3 M CaCl <sub>2</sub>	13.60 <sup>b</sup>	1.51 <sup>c</sup>	0.53 <sup>c</sup>	5.89 <sup>e</sup>
0.6 M NaCl	14.45 <sup>b</sup>	1.60 <sup>ab</sup>	0.96 <sup>a</sup>	16.03 <sup>b</sup>
0.15 M CaCl <sub>2</sub> + 0.3 M NaCl	16.17 <sup>b</sup>	1.51 <sup>c</sup>	0.55 <sup>c</sup>	10.84 <sup>d</sup>
Distilled and deionized H <sub>2</sub> O	20.04 <sup>a</sup>	1.53 <sup>bc</sup>	0.86 <sup>b</sup>	14.24 <sup>c</sup>
Control	10.95 <sup>c</sup>	1.64 <sup>a</sup>	0.82 <sup>b</sup>	16.77 <sup>a</sup>
Pooled SEM	0.45	0.01	0.04	0.92

<sup>a-c</sup>Means within a column with no common superscript differ significantly ( $P < 0.05$ ).

<sup>1</sup>TBARS = thiobarbituric acid reactive substances.

<sup>2</sup>n = 8 per mean.

TABLE 3. Flavor preference of meat from various injection treatments

Treatment	Number of panelists preferring flavor		
	Trial 1	Trial 2	Total
	(n)		
Distilled and deionized H <sub>2</sub> O	4 <sup>c</sup>	6 <sup>b</sup>	10 <sup>c</sup>
0.3 M CaCl <sub>2</sub>	12 <sup>b</sup>	8 <sup>b</sup>	20 <sup>b</sup>
Combination	21 <sup>a</sup>	14 <sup>a</sup>	35 <sup>a</sup>

<sup>a-c</sup>Means within a column with no common superscript differ significantly ( $P < 0.05$ ).

report of Cho and Rhee (1995). The mechanism by which CaCl<sub>2</sub> may act as an antioxidant has not yet been elucidated, but it has been suggested that calcium may displace iron from its binding site on phospholipids, thus obstructing the process of oxidation (Graf and Panter, 1991). It has also been proposed by St. Angelo *et al.* (1991) that injection with CaCl<sub>2</sub> may cause an increase in oxidation by its effect on such enzymes as lipases and lipid oxidizing enzymes. Evidently there is a need for further studies to elucidate this mechanism.

Sensory data indicate that the combination treatment was preferred over the CaCl<sub>2</sub> alone or the H<sub>2</sub>O (Table 3). More panelists preferred the flavor of the CaCl<sub>2</sub>-treated meat over that of the water-injected control meat in Trial 1 but not in Trial 2. The results of the combined trials is represented in Table 3 because the trends in the two trials were similar (significant preference for the combination treatment) and when combined they indicated a significant preference for the combination treatment over the other two treatments. In addition to their preference, panelists were asked for comments on the flavor of the meat. When comments were provided, they indicated that the preference for the combination treatment was most frequently due to decreased bitterness compared to the CaCl<sub>2</sub> treatment and decreased warmed-over-flavor compared to the H<sub>2</sub>O treatment.

Although CaCl<sub>2</sub>+NaCl injection successfully tenderized the spent hen meat and resulted in more palatable meat than CaCl<sub>2</sub> alone or H<sub>2</sub>O injection, the Allo-Kramer shear value was not low enough to be considered tender by consumers (Lyon and Lyon, 1990). According to Lyon and Lyon (1990), shear values must be at or below 8.8 and 6.0 kg/g to be considered "slightly tender" or "moderately tender" by consumers, respectively.

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