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Effects of Electrical Stimulation and Simulated Conventional- and Extended Chilling Method on Cooked Chicken Breast Meat Texture and Yield

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Abstract: This study was conducted to determine effects of carcass electrical stimulation and alternative carcass chilling methods on texture and yield of early-harvested boneless broiler-breast fillets. New York dressed broiler carcasses were electrically stimulated for 90 s immediately after defeathering. Control carcasses were held similarly for 90 s but not stimulated. After evisceration, half the stimulated and half the control carcasses were chilled for 3 h in ice-water (extended immersion chilled). Remaining carcasses were chilled in ice-water for 1 h and then stored for an additional 2 h (conventionally chilled). Breast fillets (*Pectoralis major* muscles) were manually harvested immediately after chilling (3.5 h post-mortem). After weighing and overnight storage, all muscles were cooked and evaluated for shear values and cooked yields. Fillets from stimulated carcasses required significantly less force to shear and exhibited greater cooked yields than those from non-stimulated carcasses. Fillets from conventionally chilled carcasses exhibited greater yield than those from extended chilled carcasses, but chilling method did not affect shear values.

Key words: Electrical stimulation, shear, tenderness, broilers, cooked yield

Introduction

Deboning prematurely after slaughter can cause excessive toughness in chicken breast meat (Koonz *et al*., 1954; Lyon and Wilson, 1986; Dawson *et al*., 1987). Research has shown that electrical stimulation (ES) of the carcass during early processing speeds onset of rigor and allows earlier deboning of the large breast fillets (*Pectoralis major*) without the expense associated with refrigerated storage of carcasses or front-halves (Lyon *et al*., 1989; Sams, 1990; Hirschler and Sams, 1998). Various conditions under which electrical stimulation has been applied and the results related to poultry meat quality have been summarized in review articles (Li *et al*., 1993; Sams, 1999). Variables evaluated include electrical potential, current, frequency, pulse form, number of stimulations per unit time, duration of stimulation, stage of processing where stimulation was applied and parts of the carcass in contact with electrodes.

Most experimental work with electrical stimulation has been conducted using conventional water immersion chilling (i.e., chilling in cold water for about 1 h and subsequently ageing the chilled carcasses for 1 or more h), but alternative chilling regimes such as chilling with cold air and extended water immersion chilling (i.e., chilling in cold water for a much longer duration with no post-chilling ageing) are being implemented commercially. Results obtained with conventionally chilled carcasses may not apply to carcasses chilled by other means due to differing rates of chilling or other factors. Two recent studies reported success in hastening tenderization of fillets from air-chilled carcasses (Skarovsky and Sams, 1999; Kranen, 2003); however, efficacy of ES in hastening post-mortem tenderization of extended-chilled carcasses has received only limited attention (Zocchi and Sams, 1999). Moreover, with one exception (Kranen, 2003), all published research involved stimulation prior to defeathering, but most new commercially available ES equipment stimulates carcasses after defeathering. The present experiment was carried out to evaluate the effects of electrical stimulation of defeathered carcasses and either conventional 1 h immersion chilling followed by 2 h of refrigerated storage or 3 h immersion chilling without further storage on shear values and yield of early-harvested cooked breast fillets.

Materials and Methods

For each of three replicates, forty commercially grown, mixed sex, 52 to 56 days old broilers free of obvious flaws were obtained at the holding shed of a commercial processing facility. Birds were transported 32 km (20 miles) to the research facility in conventional plastic coops each containing 10 broilers. Mean live body weight ±sd was 3063 ± 444 g. Randomly selected birds were suspended from overhead shackles in groups of ten, stunned at 12 volts pulsed DC in a pre-stunner[1] and killed by exsanguination using an automatic knife[2]. After bleeding for 90 s, carcasses were scalded in a 56°C triple-pass three-stage scald system[3] and picked for 15 s in a four bank picker[4]. Each New York dressed carcass was identified and then half the birds on each group

Table 1: Weights and cooked yield of breast fillets (± sd) from stimulated and non-stimulated carcasses chilled by two different methods

Chilling Method	Stimulation Treatment		
	Stimulated	Non-stimulated	
	Harvest weight (g)		mean
Conventional[1]	395.7±77	416.9±72	
Extended[2]	430.5±64	413.7±77	
Cooked weight (g)			
Conventional	325.1±66	336.3±61	
Extended	347.2±52	325.9±62	
Cooked yield (%)			
Conventional	82.0±2.4	80.6±2.4	81.3[a]±2.2
Extended	80.7±2.2	78.7±2.2	79.7[b]±2.4
mean		81.3[a]±2.3	79.7[b]±2.3

Each weight and cooked yield is the mean of 30 observations.
[a,b]Means with different superscripts within and between treatments are significantly different (P< 0.05).
[1]Conventional chill: immersion chilled for 1 h, stored 2 h.
[2]Extended chill: 3 h immersion chilled, no post-chill storage.

subjected to ES. Carcasses to be stimulated were removed from the line in groups of five and hung by the feet on grounded shackles of a prototype stimulator with the breast skin in the area of the sternum contacting a charged stainless steel plate. Birds were stimulated at a controlled, pulsed potential of 220 volts (alternating current). Pulse durations were 0.5 s on and 1 s off for 90 s. Current varied, but under the conditions of this study maximum current ranged between 132 and 140 mA per carcass. Non-stimulated carcasses remained on the slaughter line for an equivalent period. Stimulated carcasses were then re-hung on the evisceration line with the non-stimulated carcasses. All birds were mechanically eviscerated and then rinsed with water to remove blood, feathers or other loose debris. In order to simulate the two chilling methods, first and third groups of carcasses on each processing day were chilled in a 1°C to 3°C pilot-scale ice-water- immersion paddle-chiller for 1 h and then immediately stored uncovered and breast up in a 4°C cold room (conventional), and second and fourth groups of carcasses on each processing day were chilled for 3 h in a similar chiller but not subsequently stored (extended). All breast fillets were removed from carcasses at 3.5 h post-mortem (Hamm, 1982). Fillets were weighed (harvest weight), placed in labeled bags[5] and held overnight at 4°C. The next day, all bags were vacuum sealed and the fillets were cooked to an internal temperature of 80°C in an 85°C temperature-controlled steam bath. Fillets were tempered 20 min to room temperature in ice-cooled baths, removed from the bags, and re-weighed (cooked weight). Cooked fillet yield was calculated as a percentage of harvest weight. Because cooked yields were based on raw harvest fillet weights immediately after deboning, they reflect both the moisture loss during storage ("purge" or "drip") and in during cooking. For instrumental texture evaluation, two adjacent 1.9 cm. thick by 1.9 cm wide strips were removed from the middle area of each fillet parallel with the surface fibers. Texture was measured by shearing each strip twice with a Warner-Bratzler shear device and recording the maximum shear value in kilograms (Pool *et al.*, 1959).
Data were analyzed by ANOVA using stimulation treatment, chilling method and replicates as main effects and testing for interactions using the residual MS. No statistically significant interactions ($P < 0.05$) were detected, so data were pooled over main effects to test for statistical significance ($P < 0.05$) using the residual MS.

Results and Discussion

Under the stimulation conditions used in this study, visual effects of the pulsed electric current (wing tuck, body rigidity) decreased through the duration of treatment and were almost absent after 90 s. These gross observations suggest that the ES treatment led to reduction in muscle ATP reserves similar to what might be expected in an advanced state of rigor.
Harvest and cooked weights and percent cooked yields for the breast fillets are shown in Table 1. All values in this study are reported as means ± sd. Harvest fillet weight and cooked fillet weight were not significantly affected by either the electrical stimulation treatment or chilling method. Fillet cooked yield was significantly affected by both the electrical stimulation treatment and chilling method. When the data were pooled across either stimulation treatment or chilling method, the mean values were significantly different. Fillets from ES carcasses exhibited significantly higher cooked yields than fillets from non-stimulated carcasses. The effect of applying ES to speed the onset of rigor involves biochemical reactions that result in reduced muscle pH, which is usually associated with lower cooked yields due to impaired moisture binding (Froning and Uijttenboogaart, 1988; Dickens *et al.*, 2002; Lyon *et al.*, 2002). There is no obvious explanation for this apparent inconsistency; however, this development is not completely without precedent. In a recent study Kranen (2003) reported no difference in tissue fluid loss due to applying ES after feather removal and concluded that the electrical treatment did not negatively affect water-holding capacity of the meat. No data were reported to support that claim, but in an earlier study (Lyon *et al.*, 1989) three electrical potentials (50, 200, 350 V AC) were evaluated to stimulate broilers during bleeding. Fillets from broilers subjected to the 350 V stimulation treatment exhibited the lowest cooked yield and the highest percent of fluids and solids lost during heating than fillets from broilers subjected to 50 V stimulation. There was no significant difference in cooked yield or percentage loss of fluids and solids for fillets from carcasses subjected to the 50 or 200 V

Table 2: Effects of electrical stimulation after feather removal and chilling method on Warner-Bratzler shear values (mean±sd) of broiler breast fillets

Treatment	n	Shear values (kg)
Stimulated	60	3.4^{b}±1.1
Non-stimulated	59	7.7^{a}±4.1
Conventional[1]	59	5.1±3.1
Extended[2]	60	6.1±4.2

a,b Means with different superscripts within treatments are significantly different (P< 0.05).
[1]Conventional chill: immersion chilled for 1 h, stored 2 h.
[2]Extended chill: 3 h immersion chilled, no post-chill storage.

treatments. The report concluded that the higher voltage level resulted in a loss of functional properties and muscle integrity compared to the lower voltages, a result the authors ascribed to the rapid decline in pH of the carcasses stimulated at 350 V compared to those stimulated at lower voltages. These reports suggest that effects of ES on moisture binding may vary somewhat depending on conditions of the stimulation.

Fillets from conventionally chilled carcasses exhibited a significantly greater cooking yield than fillets from extended chill carcasses, 81.3 to 79.7%, respectively. No time was allotted for the carcasses to drip after 3 h of immersion chilling prior to breast muscle removal. Likewise, no attempt was made to remove moisture from the surface of the fillets during deboning. It is possible that the breast fillets from extended chill carcasses had more water held loosely on the muscle surface compared to the fillets from conventionally chilled carcasses. The loosely held water from the carcasses immersion chilled for 3 h would have been lost during heating, resulting in a lower cooked yield.

The stimulation treatment significantly affected fillet texture, but the chilling method effects were not significant (Table 2). Mean shear value for breast fillets from stimulated carcasses was 3.4 kg, but fillet shear values from non-stimulated carcasses was 7.7 kg.

Statistical differences in shear values illustrate the effect of speeding post-mortem biochemical reactions by subjecting defeathered carcasses to ES and deboning the breast muscle after a 3 h chill, regardless of chilling method. The standard deviation for fillet shear values from stimulated carcasses was 1.1 kg compared to 4.1 kg for fillets from non-stimulated carcasses (Table 2). This trend of less variation (smaller standard deviations) due to ES has also been previously reported (Dickens and Lyon, 1995; Dickens *et al.*, 2002) and may indicate less carcass-to-carcass variation at time of onset of rigor for stimulated carcasses and ultimately less variation in the shear value of the cooked fillets. Minimizing carcass-to-carcass variation is important commercially, because a lower mean shear value with a lower standard deviation is necessary to market large numbers of breast fillets with the likelihood of few or no customer complaints of tough meat.

The practical importance of the numerical differences in shear values can be illustrated by placing the values on a scale that encompasses the sensory perception of broiler breast meat texture (tough to tender) in relation to shear values (Lyon and Lyon, 1991). The shear value for cooked breast fillets from non-stimulated carcasses (7.7 kg) would be perceived by consumers as slightly tough to slightly tender, (9.6 to 6.6 kg on the scale), while the shear values of cooked fillets from the stimulated carcasses (3.4 kg) would be considered very tender, (< 3.6 kg on the scale). Clearly, ES offers real potential for hastening poultry processing times, reducing costs without impairing product quality.

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[2]Model SK-5 automatic knife. Simmons Engineering, Dallas, GA USA 32714

[3]Model SGS-3Ca three stage scalder, Stork-Gamco, Inc., Gainesville, GA USA 30503

[4]Model D-8 picker, Stork-Gamco, Inc., Gainesville, GA USA 30503

[5]Model 50128 Seal-A-Meal, Dazey Corp., Industrial airport, KS USA 66031

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