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Tenderization of chicken and turkey breasts with electrically produced hydrodynamic shockwaves

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Abstract

Eighty early deboned (45 min, post mortem) postrigor chicken breasts were exposed (24 h post mortem) to two levels (number of pulse firing networks, PFN; 45% energy) of electrically produced hydrodynamic shockwaves (HSW). In addition, 21 turkey breasts (72 h post mortem) were HSW treated (two PFN, 72% energy). Samples were water cooked in bags (78°C internal). Two PFN's were required to decrease ($P<0.05$) chicken Warner-Bratzler shear (WBS) force by 22% from the control (4.67 kg). WBS force of the HSW treated turkey breast decreased ($P<0.05$) by 12% from the control (3.20 kg). Cooking loss was higher ($P<0.05$) in the turkey breast portions but not in the chicken breasts. The electrically produced shockwave process has the potential to provide chicken processors with the ability to early debone and produce tender breasts and to provide turkey processors with tenderness-enhanced fillets. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Chicken; Turkey; Tenderness; Electrical; Shockwave; Pulsed-power

1. Introduction

A concern for the broiler industry is the need to store the front half of the carcass intact for 4–6 hours after chilling before deboning the breast to ensure a tender product (Lyon, Hamm, & Thompson, 1985). This storage of product requires added financial input for the poultry processor. The issue with turkey is not the aging time prior to deboning but rather that turkey has a somewhat limited retail market exposure due to the inherent lack of tenderness associated with fresh turkey breast meat. To optimize tenderness of turkey breast generally requires that the meat be slow cooked utilizing moist heat cookery. In addition, the majority of turkey goes into further processed products and whole bird markets (Romans, Costello, Carlson, Greaser, & Jones, 1994). The tenderization of turkey breast meat would facilitate a retail market for turkey breast fillets similar to the broiler breast fillet market.

Hydrodynamic shockwaves (HSW) produced by explosives have been reported effective in tenderizing poultry (Meek et al., 2000) and a variety of red meats (Solomon, 1998). This technology was invented by Long (1993, 1994) originally for use in red meats. HSW are produced by detonating a small amount of explosive in a water-filled container. The HSW travel through the water and anything that is an acoustical match with water (Kolsky, 1963). Meat is about 75% water, which makes meat an acoustical match to water. As the HSW travel through the meat, ultrastructure damage is inflicted within the meat (Zuckerman & Solomon, 1998). These changes in the ultrastructure of red meat result in an increase in tenderness (Zuckerman & Solomon).

Meek et al. (2000) found a 19.1–28.1% increase in tenderness in early-deboned broiler breast when treated with explosive produced HSW. Schilling (2000) found a 42% improvement in Warner-Bratzler shear (WBS) values when treated with explosive produced HSW in a cylinder configuration.

Further development of the explosive generated shockwave process for poultry has not been pursued because of the limitations of the batch-type process and the packaging requirements when using explosives.

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Hydrodyne Incorporated has recently adapted existing electrical-based pulsed plasma technology (US Patent Pending) to the application of hydrodynamic shockwaves to food. Hydrodyne Inc. has development a small self-contained unit that can rapidly produce HSW at a variety of energy flux densities and rapid sequential energy discharges.

The objective of the current study was to determine if the electrically produced shockwaves are effective in decreasing the WBS values of stored, early deboned chicken breasts and normal deboned turkey breasts.

2. Materials and methods

2.1. Experiment one, broiler breast

Eighty butterflied broiler breasts were obtained from a local processor (To Ricos Inc., Aibonito, Puerto Rico) and early deboned at 45-min post mortem. The average weight of the individual boneless, skinless broiler breasts (non-butterflied) was 122.8 g (standard deviation, 18.0). These breasts were transported on ice to the Hydrodyne, Inc. pilot plant (Canovanas, Puerto Rico) and stored 24 h (4°C) before treatment. Butterflied breasts were split medially and one breast was treated and the other breast used as a control. Ten breasts were used as a replication for a total of four replications per level of shockwave. The HSW processor (Pulsed Plasma Arc Generator, Hydrodyne Inc., San Juan, Puerto Rico; Hydrodyne is a registered trademark) machine settings were 45% energy — with either one pulse firing network (PFN) or two PFN activated. Percent energy refers to the percentage of the machine's design capability.

2.2. Experiment two, turkey breast

Fresh, boneless turkey hen breasts (*pectoralis superficialis*, $n=21$) were shipped on ice overnight from a commercial turkey processor (North Carolina) to the Hydrodyne, Inc. pilot plant in Puerto Rico. The average weight for the boneless, skinless turkey breasts (non-butterflied) was 250.0 g (standard deviation, 46.1). Upon delivery from the turkey processor (24 h post mortem), the breasts were kept refrigerated at 4°C for 2 days prior to HSW treatment. The frontal portion of the breasts were removed and trimmed parallel to the fibers. This frontal portion of the breasts were then cut in half with one half serving as a control and the corresponding half being treated. The inner surface where the breast portions were separated was identified with branding ink to identify the surface from each breast to be subsequently sampled for WBS determinations. Three portions were treated at a time for a total of seven replications. The HSW machine settings were 72% energy — with both PFN (1 and 2) activated.

2.2.1. Product handling, cookery, and shearing

All samples were placed in cotton netting (#32SMR-0301C, Jiff-Pack Industrial Netting, Carlsbad, CA, 92008) to facilitate placement in the active zone of the shockwave machine. The treatment breasts were placed into the machine and positioned in the treatment area that was filled with 8°C water. The control breasts were handled and placed in 8°C water to mimic the treatment conditions.

Samples were water cooked immediately after shockwave processing, in a jacketed steam kettle (Model # KET-12-T, Cleveland Steam Cooking Specialists, Cleveland Range, Ltd., Toronto, Canada) maintained at 80°C. Samples were vacuum packaged (Model Easypack, Koch Supplies, Inc., Kansas City, MO, 64108) in 15.2×20.3 cm bags (VAK 3 L #01BS1116-155205, Docket #148052-1, Koch Supplies, Inc., Kansas City, MO). Breast portions were cooked to an internal temperature of 78°C. Internal temperature was monitored with T-type thermocouples (Model # 91100-20, Cole-Parmer Instrument Company, Vernon Hills, IL).

Cooked samples were allowed to equilibrate to room temperature before WBS determination. Breast portions were cut into 1×1 cm, variable length strips parallel to the muscle fibers for shear force determination. Six to eight strips were taken from each breast portion and sheared (perpendicular) once per strip. Samples were sheared with a tabletop Warner-Bratzler shear machine (G-R Electrical Manufacturing Co., Manhattan, KS). A mean was calculated for each breast portion.

The cooking loss was determined on all turkey samples and half of the chicken samples cooked for tenderness determination. Cooking loss values were calculated based on initial raw weights.

2.3. Statistical analysis

Each test was analyzed as a completely randomized block design. Two independent chicken tests were conducted with one using one PFN and the other with two PFN. This was done because the chicken for each test was not processed on the same day. Paired portions from the same individual turkey breast were compared using a General Linear Model (SAS, 1996) with treatment and replication as blocking factors. Means were evaluated by examination of least square means (SAS, 1996).

3. Results and discussion

3.1. Experiment one, broiler breast

3.1.1. WBS on cooked broiler breasts

The control breasts had an average WBS value of 5.34 kg (Table 1) which is similar to the WBS values reported by Meek et al. (2000) for early deboned broiler breasts.

Table 1
Warner-Bratzler shear values and cooking loss for early-deboned (45 min post mortem) and stored (24 h) chicken breasts treated with electrically produced hydrodynamic shockwaves[a]

	Warner-Bratzler shear (kg)			Cooking loss (%)		
Pulse firing units (PFN)	Control	Hydrodynamic shockwaves	S.E.	Control	Hydrodynamic shockwaves	S.E.
One PFN (S.D)	5.34a (2.3)	4.68a (2.5)	0.39	24.3a (3.5)	26.3a (3.2)	0.50
Two PFN (S.D.)	4.67a (2.2)	3.64b (1.6)	0.18	24.7a (1.8)	25.2a (2.0)	0.77

[a] Produced with machine setting of 45% energy. Means within a row and dependent variable with unlike letters are different ($P < 0.05$). For each PFN level, there were 40 breast pairs. Breasts were alternated between the control and hydrodynamic shockwave treatments.

Treatment with one PFN was not sufficient to decrease ($P > 0.05$) WBS values compared to the control breasts. However, treatment with two PFN decreased ($P < 0.05$) the WBS values by 22.1% compared to the controls (Table 1). In addition, HSW treatment with two PFN tended to decrease the standard deviation in WBS values. Based on the equipment design, the two PFN provided greater energy flux density than one PFN. Similarly, Meek et al. (2000) demonstrated that increasing the amount of explosive increased the degree of tenderization of early deboned broiler breast. A high variation was expected in early deboned broiler breast (Lyon et al., 1985) and could provide a reason for the lack of significance due to treatment with one PFN. The reduction in WBS in samples treated with two PFN was similar to the 19.1–28.3% decrease reported by Meek et al. (2000) in a 1060 L hemishell HSW unit. Previous research (Schilling, 2000) showed a 42% increase in tenderness due to treatment with an explosive generated hydrodynamic shockwave created in a cylinder-shaped Hydrodyne unit. The lower decrease in WBS values reported in this current study could be due to differences in the force of the shockwave or waveform of the shockwave produced by the electrically generated system in contrast to that produced by explosives. The WBS values of the controls in our study were similar to those obtained from conventionally oven cooked (80°C internal) breasts on 1.0 cm wide × 0.7 cm thick strips sheared (WBS, 4.5 kg; standard deviation, 2.4 kg) by Sams, Janky and Woodward (1990).

3.1.2. Cooking loss

Cooking loss was not affected ($P > 0.05$) by HSW with one or two PFN in the broiler breasts (Table 1). Meek et al. (2000) reported a slightly higher cooking loss in early deboned broiler breasts treated with explosive produced hydrodynamic shockwave compared to early deboned breasts. However, they did not find a difference in cooking loss between aged breasts and early deboned, shockwave treated breasts. Dickens and Lyon (1995) reported similar breast cooking losses (20.2%) for broiler carcasses early deboned after 1 h of chilling, stored overnight, and water cooked (78°C internal).

3.2. Experiment two, turkey breast

3.2.1. Warner-Bratzler shear

WBS values were different ($P < 0.05$) for the treated and the control breast portions (Table 2). The treated breast portions were 12.5% more tender than the untreated companion portion. These turkey breasts were aged bone-in prior to deboning as conducted commercially, which may have increased the uniformity of tenderness from breast to breast, within breast, and between birds as compared to early deboned chicken. A similar apparent change was seen in chicken using the one PFN which was not different than the control chicken breasts. This degree of difference was significant in the turkey and was most likely associated with the uniformity in tenderness among and within the turkey breasts. Fleming, Froning, Beck and Sosnicki (1991) reported higher WBS values (4.4 kg) in comparison to our controls. Possible reasons for the higher values most likely were attributed to differences in their methods of cookery (breast wrapped in aluminum foil and oven baked 81°C) and shear strip configuration (1.27 cm cores).

3.2.2. Cooking loss

In contrast to the broiler breast results, the treated turkey breast portions were 1.3% higher ($P < 0.05$) in cooking loss than the untreated control breast portions (Table 2). It is unknown as to why there was a difference

Table 2
Warner-Bratzler shear and cooking loss of turkey breast portions treated with electrically produced hydrodynamic shockwaves[a]

Treatment mean	Warner-Bratzler shear (kg)	Cooking loss (%)
Control	3.20a (0.7)	20.4a (2.4)
Hydrodynamic shockwave treated	2.80b (0.5)	21.7b (1.5)
Standard error	0.10	0.29

[a] Produced with machine setting of 72% energy and both pulse firing networks. Means within a column with unlike letters are different ($P < 0.05$). Parenthetical values represent standard deviations.

in cooking loss response between turkey and chicken as a result of HSW. The turkey breast was not early deboned and therefore would not have had the opportunity to exhibit various degrees of muscle shortening known to occur in early deboned chicken breasts. Extensively shortened muscle would be expected to loose more moisture during heat processing because of contracted sarcomeres with less space to accommodate intracellular water. In comparison, Meek et al. (2000) did not report a difference in cooking loss in aged broiler breasts compared to early deboned, stored breasts that were treated with hydrodynamic shockwaves. Babji, Froning, and Ngoka (1982) reported a 24.8% cooking loss for breast meat from toms cooked (80°C internal) in a rotary oven.

4. Conclusions

Cooking loss was not affected in broiler breasts but was higher in turkey breasts after HSW treatment. Electrically produced shockwaves can tenderize stored, early deboned chicken breasts and aged turkey breasts. Increasing the energy input from one pulse firing network to two improved the degree of tenderization. Further improvements may be necessary to produce early deboned broiler breasts with tenderness similar to non-early deboned broiler breasts.

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