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Enhancement of Beef Chuck and Loin Muscles with Ammonium Hydroxide and Salt

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ABSTRACT: The objective of this study was to evaluate the tenderness of beef chuck and round muscles when enhanced with ammonium hydroxide and salt at different pump levels. A randomized, complete block design of 4 treatments and 3 muscles with 3 replications was used, with a total of 15 subprimals per treatment. Treatments included a 0% (CON), 15% (T15), 22.5% (T22), and 30% (T30) target pump. The triceps brachii (TB), biceps femoris (BF), and rectus femoris (RF) muscles were studied. Muscles were injected with a solution of ammonium hydroxide and sodium chloride (patent-pending technology from Freezing Machines Inc., Dakota Dunes, SD). Individual steaks were cut to a thickness of 2.54 cm, vacuum-packaged in trays, and frozen. Warner-Bratzler shear force, pH, and sensory evaluations were determined. Shear force decreased as the target pump percentage increased for all muscles ($P < 0.050$): TB = 39.9, 35.1, 32.1, and 27.0 N; BF = 39.4, 26.2, 23.3, and 19.3 N; RF = 42.7, 32.9, 30.7, and 28.9 N for CON, T15, T22, and T30, respectively. In all cases, there were no shear force differences between T15 and T22 ($P > 0.050$). As percentage pump increased, pH increased. The ultimate pH was moderately strongly to strongly related to shear force (r = 0.55, 0.70, and 0.80 for RF, TB, and BF, respectively). Trained taste panel ratings revealed an increase in tenderness, decrease in connective tissue, and an increase in juiciness as pump level increased for all muscles. In all cases but one (juiciness of the RF), the CON had the least desirable ratings and shear force values ($P < 0.050$). There were no major differences between T15 and T22, and T30 steaks tended to have an uncharacteristic soft and mushy texture. For this reason a 20% target pump level was determined to be the optimum pump level. These data suggest that adjusting pH in beef with ammonium hydroxide and salt can increase tenderness in muscles from the beef chuck and round. Any level of treatment was beneficial, with the greatest shear force benefit occurring in muscle pumped to 30%.

Key words: ammonium hydroxide, beef, enhancement, tenderness

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INTRODUCTION

A major problem facing the beef industry is inconsistency in meat tenderness at the consumer level (Voges et al., 2007). Boleman et al. (1997) stated that consumers were willing to pay a premium for beef that was guaranteed tender. Because of the large tenderness inconsistencies between carcasses, muscles, and locations within a muscle, enhancement procedures have been developed to create more consistent products and upgrade others.

Enhancement systems have traditionally been comprised of water, salt, and phosphate. Injection with a salt/phosphate solution has shown to increase water-binding capacity and tenderness (Vote et al., 2000; Lawrence et al., 2004; Baublits et al., 2006). The chloride ions of salt are thought to bind to the myofilaments and increase the electrostatic repulsive force between them (Offer and Trinick, 1983). This allows for more water to fill into the space and be held by capillary forces. In the presence of phosphates, the concentration of chlorine needed for maximum swelling is reduced.

A new development to enhancement systems has been developed by Freezing Machines Inc. (Dakota Dunes, SD). The patented process employs an enhancement solution composed of water, salt, ammonium hydroxide, and carbon monoxide. The ingredients in this solution increase the water-holding capacity of meat, while eliminating the off-flavors that are often associated with salt/phosphate enhancements. Other research (Everts et al., 2006a,b; Hand et al., 2006; Nath et al., 2006) have studied the effectiveness enhancement with salt and ammonium hydroxide. Nath et al. (2006)

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showed that pH of meat increased, purge loss increased, calculated moisture after cooking increased, and shear force decreased as pump percentage increased.

The objectives of this study were to evaluate the tenderness of low-valued muscles from the beef chuck and round when enhanced with this solution at varying pump levels, and to determine the optimum pump level for the muscles.

MATERIALS AND METHODS

No approval was obtained from the Institutional Animal Care and Use Committee because samples were obtained from a federally inspected slaughtering facility.

Experimental Design

This study was designed to determine the optimum pump level for 3 different muscles injected with a solution containing water, salt, ammonium hydroxide, and carbon monoxide. The 3 muscles (n = 60 for each muscle) were the triceps brachii (**TB**), biceps femoris (**BF**), and rectus femoris (**RF**). There were 4 pump levels: 0% (**CON**), 15% (**T15**), 22.5% (**T22**), and 30% (**T30**). Subprimals were randomly assigned to each pump level and to 1 of 3 replications. Pump levels were compared for Warner-Bratzler shear force (**WBS**) and trained sensory evaluations.

Raw Meat Materials

Subprimals containing the TB, BF, and RF (60 clod hearts, NAMP #114E; 60 sirloin caps, NAMP #184D; and 60 peeled knuckles, NAMP #167A; NAMP, 2007) were obtained from Tyson Foods in Dakota City, Nebraska. Subprimals (2 to 3 d postmortem) were randomly assigned to 1 of 4 pump levels and to 1 of 3 replications. For each muscle there were 20 subprimals per replication (5 per pump level). Preparation of the samples took place at the Beef Products Inc. facility in Dakota City, Nebraska.

Injection of Samples

For each replication, 5 subprimals assigned to the 0% pump level were unpackaged and temperature and pH were recorded. The pH values were recorded with an Orion Model #920A+ (Orion Research Inc., Beverly, MA) with a bulb tip combination electrode (Cole-Parmer Model #5998–21FF6, Vernon Hills, IL). For the next 3 treatments, 5 subprimals assigned to each treatment were unpackaged and an initial weight, temperature, and pH were taken. Subprimals were injected with a solution containing 1% sodium chloride and sufficient ammonium hydroxide to bring the pH of the brine to 11.4. The solution also contained carbon monoxide formulated so that a 30% pump would result in less than 0.4% CO in the finished product. This is patented technology from Freezing Machines Inc. Subprimals were injected to the target pump level (T15, T22, and T30) by a Fomaco injector (Model #FGM-88SW, Køge, Denmark). The injector was adjusted to the next pump level after 5 subprimals were injected to ensure complete replications. Once injected, subprimals were weighed to determine the actual pump level and final pH was recorded. The second and third replications followed in the same manner.

Cutting Procedures

After a final weight and pH were recorded, 4 steaks from each subprimal were cut parallel to the cut surface to a thickness of 2.54 cm. The TB was cut ventral to dorsal; the BF was cut dorsal to ventral; and the RF was cut proximal to distal. The order of each steak was maintained from this point on through the whole study. Steaks were then trimmed of excess fat and muscles, leaving the muscle of interest (TB, BF, and RF) intact.

Packaging Procedures

Steaks were vacuum-packaged on a Ross Jr. A-10 model packaging machine (Midland, VA) in 0.635-cm trays (#10 tray, Jamestown Plastics, Brockton, NY) containing an absorbent pad (PL-75, Sealed Air Corp., Duncan, SC). The trays were sealed with the Cryovac lid 1050 film (Duncan, SC).

Packaged trays were then placed in a Styrofoam cooler with a small amount of dry ice, sealed, and frozen. Coolers were then placed in a freezer at Beef Products Inc. (Dakota City, NE) before shipping to the University of Nebraska.

Boxes containing the frozen steaks were shipped to the Loeffel Meat Laboratory at the University of Nebraska on the following day and placed in a freezer (–20°C) until further analysis.

Assignment of Steaks

The first steak from each subprimal was used for WBS determination. The second steak from each subprimal was used for trained taste panel evaluations. The third steak was used for pH determination. The fourth steak was placed in storage as an extra.

Cooking Procedure

Steaks to be used for WBS and trained taste panel evaluations were allowed to thaw for 24 h at 4°C. Frozen weights of all steaks were taken once removed from the freezer. Thawed steaks were blotted with paper towels to remove any excess moisture and weighed. The frozen and thawed weights were used to determine thaw loss: Thaw loss percentage = [(frozen weight – thaw weight)/frozen weight] × 100.

Steaks were trimmed of excess fat and connective tissue. The trimmed samples were weighed. Steaks were cooked on Farberware Open-Hearth broilers

Table 1. Effects of pump percentage (0, 15, 22.5, or 30%) on meat quality characteristics

Target pump (%)	Pump %	WBS[1]	pH	Thaw loss %	Cook loss %	Cook time
Triceps brachii						
0	0.00[a]	39.9[a]	5.58[a]	2.11[a]	33.36[a]	30.92
15	15.29[b]	35.1[b]	6.14[b]	3.44[b]	36.87[b]	31.67
22.5	21.19[c]	32.1[b]	6.24[b]	4.19[c]	37.06[b]	32.38
30	31.45[d]	27.0[c]	6.66[c]	5.26[d]	37.17[b]	30.34
SE	0.75	1.3	0.06	0.24	0.64	0.74
Biceps femoris						
0	0.00[a]	39.4[a]	5.52[a]	2.04[a]	33.19	24.61[a]
15	17.48[b]	26.2[b]	6.16[b]	3.75[b]	34.09	21.84[b]
22.5	20.23[c]	23.3[b]	6.24[b]	3.30[b]	33.96	20.35[bc]
30	26.26[d]	19.3[c]	6.47[c]	3.96[b]	33.00	18.56[c]
SE	1.02	1.4	0.03	0.44	0.81	0.92
Rectus femoris						
0	0.00[a]	42.7[a]	5.60[a]	2.26[a]	31.75[a]	26.52
15	15.44[b]	32.9[b]	6.24[b]	3.26[b]	35.11[b]	27.87
22.5	21.74[c]	30.7[bc]	6.41[b]	3.68[bc]	35.12[b]	28.66
30	28.71[d]	28.9[c]	6.72[c]	4.28[c]	33.50[ab]	28.44
SE	0.86	1.3	0.07	0.24	0.73	0.98

[a–d]Means in the same column without common superscripts differ ($P < 0.050$).
[1]Warner-Bratzler shear force is expressed as N.

(Model 455N, Walter Kidde and Co., Bronx, NY) to a final internal temperature of 70°C (AMSA, 1995). Internal temperatures were monitored by an Omega 450ATT thermometer with a type T thermocouple (Omega Engineering Inc., Stamford, CT). Cooked steaks were blotted with a paper towel to remove any excess moisture and weighed. This weight was used with the trimmed, precooked weight to determine cooking loss of steaks, as follows: Cooking loss percentage = [(trimmed weight – cooked weight)/trimmed weight] × 100.

Warner-Bratzler Shear Force Analysis

Steaks were handled and cooked as described above. Once the steaks were cooked, they were allowed to cool for 4 h at 4°C. After cooling, 6 to 10 (1.27-cm-diameter) cores were removed with a drill press, parallel to the arrangement of the muscle fibers. Cores were then sheared on an Instron Universal Testing Machine (Model 55R1123, Instron, Canton, MA) with a Warner-Bratzler shear attachment. Setup of the machine was for a crosshead speed of 250 mm/min, and a load cell of 500 kg. An average of the peak shear force (kg) was calculated for each steak from at least 6 cores.

pH Determination

Steaks used for pH determination were powdered in liquid nitrogen using a Waring blender. A 10-g sample of powdered muscle was placed into a beaker and 90 mL of distilled, deionized water was added. The mixture was homogenized for 30 s at 10,800 rpm using a Polytron blender (Brinkman Instruments, New York, NY). A stir bar was placed in the homogenized solution and the pH was recorded with an Orion SA 720 pH meter (Orion Research Inc., Boston, MA) with a bulb tip combination electrode (Orion model 9256BN).

Trained Taste Panel Evaluations

Panelists (n = 8) were recruited from the University of Nebraska staff and graduate students in the animal science department. Training was accomplished using the guidelines and procedures of Meilgaard et al. (1991).

During taste panels, steaks were handled and cooked as described in the cooking procedures. Once cooked to 70°C, steaks were placed in double-broilers to stay warm for up to 15 min. Steaks were cut into 1 × 2 × 1-cm pieces and served to the panelists. During each taste panel session, trained panelists evaluated 8 samples (2 from each treatment) labeled with a random 3-digit code and served in random order. Samples were evaluated for tenderness, connective tissue, juiciness, and off-flavor intensity on an 8-point hedonic scale. Panelists were trained to identify the specific off-flavors (metallic, sour, rancid, bloody, and bitter) contributing to the off flavor score for the steak. Specific off-flavors were reported as a percentage of the panelists indicating that particular off-flavor.

Statistical Analysis

The experiment was arranged in a randomized, complete block design. For each muscle, there were 4 treatments and 3 replications. Both treatment and replication were considered fixed effects. The design was blocked by replication.

Data were analyzed using the GLIMMIX procedure (SAS Inst. Inc., Cary, NC). When significance ($P \leq 0.050$) was indicated by ANOVA, means separations were performed using the LSMEANS and DIFF functions of

Table 2. Means for trained taste panel ratings[1] for beef steaks as affected by target pump percentage (0, 15, 22.5, or 30%)

Target pump (%)	Tenderness	Connective tissue	Juiciness	Off-flavor	Off-flavor[2] Metallic	Sour	Rancid	Bloody	Bitter
Triceps brachii									
0	5.5^{a}	5.4^{a}	5.3^{a}	7.2^{a}	0.04^{a}	0.20^{a}	0.18	0.06^{a}	0.03^{ab}
15	6.1^{b}	6.0^{b}	5.8^{b}	7.5^{b}	0.00^{b}	0.13^{b}	0.12	0.05^{a}	0.05^{a}
22.5	6.6^{c}	6.4^{c}	6.2^{c}	7.5^{b}	0.04^{a}	0.10^{b}	0.12	0.06^{a}	0.03^{ab}
30	7.1^{d}	6.7^{d}	6.7^{d}	7.5^{b}	0.02^{ab}	0.08^{b}	0.15	0.13^{b}	0.01^{b}
SE	0.16	0.15	0.19	0.12	0.02	0.04	0.05	0.03	0.02
Biceps femoris									
0	5.7^{a}	5.7^{a}	5.6^{a}	6.8^{a}	0.07	0.20^{a}	0.25^{a}	0.07	0.07
15	7.1^{b}	6.8^{bc}	6.3^{bc}	7.4^{b}	0.03	0.07^{b}	0.19^{ab}	0.07	0.06
22.5	7.0^{b}	6.7^{b}	6.2^{b}	7.5^{b}	0.04	0.09^{b}	0.15^{bc}	0.09	0.05
30	7.5^{c}	7.1^{c}	6.7^{c}	7.5^{b}	0.04	0.04^{b}	0.11^{c}	0.11	0.03
SE	0.17	0.18	0.18	0.14	0.03	0.04	0.04	0.04	0.03
Rectus femoris									
0	5.3^{a}	5.1^{a}	5.5^{a}	6.8^{a}	0.11^{ab}	0.23^{a}	0.23^{a}	0.05	0.08
15	6.0^{b}	5.8^{b}	5.6^{a}	7.1^{b}	0.07^{b}	0.13^{b}	0.23^{a}	0.1	0.07
22.5	6.2^{b}	5.9^{b}	5.8^{ab}	7.1^{b}	0.15^{a}	0.07^{b}	0.13^{b}	0.11	0.08
30	6.4^{b}	6.0^{b}	6.2^{b}	7.2^{b}	0.10^{ab}	0.10^{b}	0.12^{b}	0.13	0.08
SE	0.22	0.23	0.22	0.11	0.04	0.04	0.04	0.05	0.03

[a–d]Means in the same column without common superscripts differ ($P < 0.050$).

[1]Based on an 8-point scale: 8 = extremely tender, no connective tissue, extremely juicy, no off-flavor; 1 = extremely tough, abundant amount of connective tissue, extremely dry, extreme off-flavor.

[2]Value indicates the proportion of panelists that detected the off-flavor.

SAS. The CORR procedure was used to evaluate the relationship between pH and WBS.

RESULTS AND DISCUSSION

Thaw Loss and Cook Loss

Regardless of muscle, enhancement significantly increased thaw loss ($P < 0.050$). In regards to cook loss, enhancement had no effect on the BF. However, in both the TB and the RF, enhancement significantly increased cooked loss except for the RF muscles receiving the T30 treatment (Table 1).

Warner-Bratzler Shear Force

Warner-Bratzler shear force values for all muscles (TB, BF, and RF) and all pump levels are summarized in Table 1. For all muscles, shear force decreased as the target pump level increased ($P < 0.050$), which is consistent with Nath et al. (2006). Enhancement led to improvements in WBS values that ranged from 0.49 to 2.0 kg. Steaks pumped to 30% always had the lowest WBS values ($P < 0.050$). There were no significant WBS differences between the T15 and T22 for all muscles ($P > 0.050$). This may be due to the fact that the pump percentage differences between T15 and T22 were always smaller than the pump percentage differences between T22 and T30.

pH Analysis

Values for pH on all muscles and pump levels are summarized in Table 1. Values for pH were 5.58, 5.52, and 5.60 for the TB, BF, and RF, respectively. These values are similar to those found by Von Seggern et al. (2005): 5.78, 5.69, and 5.72. As percentage pump increased, pH always increased, which is also consistent with Nath et al. (2006). pH values increased significantly with enhancement from around 5.60 to 6.14 or higher. This is due to the injection of the enhancement solution that is generally at a pH of 11.4. Steaks pumped to T30 had the highest pH and there were no significant pH differences between the T15 and T22 pump levels ($P < 0.050$). The small pump percentage differences between the T15 and T22 probably resulted in the slight differences in pH. The pump percentage differences between T22 and T30 were much larger, which resulted in significant increases in pH.

The ultimate pH was strongly related to shear force ($r = 0.70$, 0.80, and 0.55 for TB, BF, and RF, respectively). This is because proteins lose their buffering capacity as the distance from the isoelectric point increases (Offer and Trinick, 1983). With a greater change in pH, there is a greater shift in protein repulsion, which could result in lower WBS values.

Sensory Characteristics

Trained taste panel ratings (Table 2) revealed an increase in tenderness, decrease in connective tissue, and an increase in juiciness as pump level increased for all muscles.

Control steaks were generally rated as being slightly tender and slightly juicy by the panel. However, enhanced steaks were rated as being moderately and very tender, as well as moderately juicy.

Although enhancement improved all traits in all muscles, the BF showed the greatest improvement. For the BF, there was little or no difference between T15 and T22. This is probably because the pump percentage difference between those treatments was only 2.75%. In the other muscles the difference between T15 and T22 was around 6.0%.

Muscles pumped to 30% had the highest scores for tenderness, connective tissue, juiciness, and flavor. However, panelists noted that steaks pumped to 30% tended to have an uncharacteristic soft and mushy texture. This is consistent with the results of Nath et al. (2006), who stated that 30% pump resulted in a slightly nonmeat texture and slight off flavors for the biceps femoris. For this reason, as well as the fact that there were no major differences between the 15 and 22.5% pump levels, a 20% target pump level was determined to be the optimum pump level (for all muscles).

By increasing muscle pH with ammonium hydroxide, shear force values of the TB, BF, and RF were decreased and sensory scores for tenderness improved with higher levels of added solution. Any level of treatment was beneficial. In all cases, there were no shear force differences between steaks pumped to 15 and 22.5%. Ultimate pH was strongly related to shear force values. Because steaks pumped to 30% tended to have an uncharacteristically soft and nonmeat texture, a pump level of 20% was suggested to reach an improvement in meat quality characteristics.

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