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Effects of Aging on Beef Chuck and Loin Muscles Enhanced with Ammonium Hydroxide and Salt

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Effects of aging on beef chuck and loin muscles enhanced with ammonium hydroxide and salt[1,2]

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ABSTRACT: The objective of this study was to determine whether aging would alter the beneficial effects (tenderness, juiciness, and flavor) of enhancing beef chuck and round steaks with a 20% solution of water, ammonium hydroxide, salt, and carbon monoxide. A randomized, complete block design was used, with 2 treatments [0% (control) and 20% (pump)], 3 aging periods (1, 2, and 3 wk), 3 muscles (M. triceps brachii from the clod heart, M. biceps femoris from the sirloin cap, and M. rectus femoris from the knuckle), and 3 replications. There were a total of 12 subprimals per treatment per aging period (n = 72 each). Individual steaks were cut to a thickness of 2.54 cm and packaged in a high-oxygen modified-atmosphere package (80% oxygen, 20% carbon dioxide). At the end of the aging period, steaks were vacuum packaged and frozen. Steaks were used to determine Warner-Bratzler shear force (WBS) and consumer sensory ratings. For all muscles, WBS values were lower for pump steaks than control at every aging period ($P < 0.050$). In addition, as aging period increased, WBS values for all steaks increased. Consumer taste panels revealed more desirability for tenderness, juiciness, flavor, and overall acceptability for pump steaks than control steaks. In addition, steaks aged for 1 d were more desirable than steaks aged for 7 and 14 d ($P < 0.050$). These data indicate that aging does not decrease the benefits (tenderness, juiciness, and flavor) of enhancement.

Key words: aging, beef, pH enhancement, tenderness

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INTRODUCTION

A major problem facing the beef industry is inconsistency in meat tenderness at the consumer level (Huff-Lonergan et al., 1995). Tenderness is variable among carcasses, muscles, and locations within a muscle. Many processing techniques are used by the industry to aid in the improvement of tenderness. These include electrical stimulation, injection of calcium chloride, blade tenderization, and postmortem aging. Research has shown that postmortem aging of meat results in increased tenderness (Goll et al., 1964).

Postmortem aging is effective in improving the tenderness because of the loss of structural integrity from proteolysis of myofibrillar and cytoskeletal proteins (Koohmaraie et al., 1987; Koohmaraie, 1994; Huff-Lonergan et al., 1996). Although the degradation of the myofibrillar proteins actin and myosin is limited (Koohmaraie, 1994; Huff-Lonergan et al., 1995), the breakdown of the proteins titin and nebulin tend to coincide with the increase in tenderness.

Hamling (2006) reported that beef chuck and round muscles enhanced with a water, ammonium hydroxide, salt, and carbon monoxide solution (patent pending technology from Freezing Machines Inc., Dakota Dunes, SD) are more tender than nonenhanced muscles. In addition, enhanced steaks had less connective tissue, were juicier, and had less off-flavor than nonenhanced steaks, which is consistent with the findings of Nath et al. (2006). The optimal pump level for these muscles was also determined to be 20%. However, research has not been conducted to test the effects of pH enhancement on aging. Therefore, the objectives of this study were to determine whether the benefits of enhancement (tenderness, juiciness, and flavor) of beef chuck and round muscles with ammonium hydroxide and salt would be reduced by aging.

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.

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Experimental Design

The 3 muscles (n = 72 for each muscle) studied were the M. triceps brachii (**TB**), M. biceps femoris (**BF**), and M. rectus femoris (**RF**). Subprimals were randomly assigned to a pump level (0 and 20%), aging period (1, 7, and 14 d post enhancement), and replication (3).

Raw Meat Materials

Subprimals (average Choice or better) containing the TB, BF, and RF, (72 clod hearts, NAMP no. 114E; 72 sirloin caps, NAMP no. 184D; and 72 peeled knuckles, NAMP no. 167A; North American Meat Processors Association, 2007) were obtained from Tyson Foods in Dakota City, Nebraska. Subprimals (2 to 3 d postmortem) were randomly assigned to 1 of 2 pump levels (0 or 20%), 1 of 3 aging periods (1, 7, or 14 d), and 1 of 3 replications. For each muscle there were 24 subprimals per replication (12 per pump level, 4 per aging period). Samples from all 3 subprimal types were prepared and collected at the Beef Products Inc. facility in Dakota City, Nebraska. Preparation and collection of samples were done on one type of subprimal before moving on to the next type of subprimal.

Injection of Samples

For each replication, 12 subprimals assigned to the 0% pump level were unpackaged and cut. Subprimals (12) assigned to the 20% pump level were unpackaged and an initial weight (green weight) was taken. Subprimals were injected with a solution containing 1% sodium chloride and sufficient ammonium hydroxide to make the brine pH 11.4. The solution also contained carbon monoxide formulated so that a 20% pump would result in less than 0.4% of carbon monoxide in the finished product. This is patented technology from Freezing Machines Inc. Subprimals were then injected to the target pump level by a Fomaco injector (model FGM-88SW, Fomaco, Køge, Denmark). Once injected, subprimals were weighed to determine the actual pump level. The second and third replications followed in the same manner.

Cutting Procedures

After a final weight was recorded and the pump level determined, 3 to 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. The RF was cut proximal to distal. Steaks were then trimmed of excess fat and muscle, leaving the muscle of interest (TB, BF, and RF) intact. The first steak from each subprimal was used for Warner-Bratzler shear force (**WBS**) determination. The remaining steaks were used for consumer taste panel evaluations.

Packaging Procedures

Steaks were packaged in a high-oxygen modified-atmosphere package (**MAP**; 80% oxygen, 20% carbon dioxide) on a Ross Jr. A-10 model packaging machine (Ross Industries Inc., Midland, VA) in 3.81-cm trays (no. 10 tray, Jamestown Plastics, Brockton, NY) containing a soaker pad (PL-75, Sealed Air Corp., Duncan, SC). The trays were sealed with the Cryovac lid 1050 film (Sealed Air Corp.). Trays were then placed in boxes and stored overnight at the cooler storage facility at Beef Products Inc. in Dakota City, Nebraska. Boxes were shipped to the Loeffel Meat Laboratory at the University of Nebraska on the following day and stored at 4°C.

Aging

Subprimals were randomly assigned to 1 of 3 aging periods (1, 7, and 14 d post treatment). Steaks were aged in a MAP (80% oxygen, 20% carbon dioxide) at 4°C. At the end of each aging period, steaks were removed from their MAP, vacuum packaged in nylon-polyethylene vacuum pouches (3 mil STD barrier, Prime Sources, St. Louis, MO), and frozen. Steaks were frozen until further analysis of WBS and consumer taste panel evaluations.

Cooking Procedure

Steaks to be used for WBS and consumer taste panel evaluations were allowed to thaw for 24 h at 4°C. Steaks were trimmed of excess fat and connective tissue and cooked on Farberware Open-Hearth broilers (Model 455N, Walter Kidde and Co., Bronx, NY) to a final internal temperature of 70°C (American Meat Science Association, 1995). Internal temperatures were monitored by an Omega 450ATT thermometer with a type T thermocouple (Omega Engineering Inc., Stamford, CT). Raw and cooked weights of each individual steak were recorded to determine cooking loss (%).

WBS Analysis

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 Corp., 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.

Consumer Taste Panel Evaluations

Participants ($n \geq 30$) were recruited from University of Nebraska faculty, staff, and students. To participate, individuals had to be at least 19 years of age and not

Table 1. Least squares means for shear force values and percentage of cooking loss for triceps brachii steaks[1]

Item	WBS[2]	SE	Cooking loss, %	SE
Treatment				
Control	4.95[b]	0.20	28.88[a]	0.62
Pump	4.18[a]	0.19	31.09[b]	0.61
Age, d				
1	4.15[x]	0.24	32.16[y]	0.76
7	4.81[y]	0.28	29.08[x]	0.74
14	4.73[y]	0.19	28.72[x]	0.76

[a,b]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[x,y]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Warner-Bratzler shear force is expressed as kilograms of force.

Table 3. Least squares means for shear force values and percentage of cooking loss for rectus femoris beef steaks[1]

Item	WBS[2]	SE	Cooking loss, %	SE
Treatment				
Control	4.76[b]	0.14	28.69[a]	0.47
Pump	3.58[a]	0.14	31.25[b]	0.47
Age, d				
1	4.15	0.17	29.67[y]	0.57
7	4.10	0.17	33.22[z]	0.57
14	4.27	0.17	27.03[x]	0.57

[a,b]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[x–z]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Warner-Bratzler shear force is expressed as kilograms of force.

part of a trained taste panel. Consumers evaluated 6 samples (1 × 2 × 1-cm pieces labeled with a random 3-digit number) on an 8-point hedonic scale for tenderness, juiciness, flavor, and overall acceptability (8 = extremely desirable, 7 = very desirable, 6 = moderately desirable, 5 = slightly desirable, 4 = slightly undesirable, 3 = moderately undesirable, 2 = very undesirable, 1 = extremely undesirable). A single session had 6 samples of the same muscle that represented each treatment—pumped or nonpumped at each of the 3 aging periods (1, 7, and 14 d)—and that were served in random order.

Statistical Analysis

The experiment was arranged in a randomized, complete block design with replication serving as the block. Treatments were allocated in a 2 × 3 factorial with 2 treatments and 3 aging periods. Treatments and aging periods were considered fixed effects, replication was a random effect, and cooking time was used as a covariate.

Data were analyzed by using the GLIMMIX procedure of SAS (2002, version 9.1, Cary, NC). When significance ($P \leq 0.050$) was indicated by ANOVA, separation of means was performed by using the LSMEANS and PDIFF functions of SAS.

RESULTS AND DISCUSSION

WBS and Cooking Loss

For all muscles, WBS values were lower for pump steaks than for control steaks (Tables 1 to 3). Enhanced TB steaks had WBS values of 0.77 kg less than the control steaks. This is comparable to the 0.97-kg difference with the BF and 1.18-kg difference with the RF. Hamling (2006) found the differences between control and pump steaks (22.5% pump level) for these 3 muscles

Table 2. Least squares means for shear force values and percentage of cooking loss for biceps femoris beef steaks[1]

Item	WBS[2]	SE	Cooking loss, % Age, d 1	Cooking loss, % Age, d 7	Cooking loss, % Age, d 14	Cooking loss, % SE
Treatment						
Control	3.87[y]	0.11	30.30[b,x]	28.18[a,x]	28.98[a]	0.80
Pump	2.90[x]	0.11	34.78[b,y]	30.67[a,y]	29.48[a]	0.80
Age, d						
1	3.06[x]	0.14				
7	3.30[x]	0.14				
14	3.80[y]	0.14				

[a,b]Means in the same row that do not have common superscripts differ ($P < 0.050$).
[x,y]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Warner-Bratzler shear force is expressed as kilograms of force.

Table 4. Least squares means for consumer taste panel ratings for triceps brachii beef steaks[1]

	Consumer taste panel[2]			
Item	Tenderness	Juiciness	Off-flavor	Overall acceptability
Treatment				
Control	4.23[a]	4.13[a]	4.10[a]	4.07[a]
Pump	5.40[b]	5.32[b]	4.93[b]	5.11[b]
SE	0.09	0.09	0.10	0.10
Age, d				
1	5.24[y]	5.10[y]	5.15[z]	5.16[z]
7	4.67[x]	4.62[x]	4.57[y]	4.56[y]
14	4.53[x]	4.46[x]	3.84[x]	4.05[x]
SE	0.16	0.13	0.11	0.14

[a,b]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[x–z]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Based on an 8-point scale: 8 = extremely desirable, 1 = extremely undesirable.

Table 5. Least squares means for consumer taste panel ratings for biceps femoris beef steaks[1]

	Consumer taste panel[2]			
Item	Tenderness	Juiciness	Off-flavor	Overall Acceptability
Treatment				
Control	4.62[a]	4.49[a]	4.33[a]	4.32[a]
Pump	6.23[b]	5.74[b]	5.29[b]	5.55[b]
SE	0.13	0.11	0.10	0.09
Age, d				
1	5.71[y]	5.36[y]	5.29[z]	5.38[z]
7	5.41[xy]	5.11[xy]	4.92[y]	5.01[y]
14	5.16[x]	4.87[x]	4.22[x]	4.42[x]
SE	0.15	0.12	0.11	0.11

[a,b]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[x–z]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Based on an 8-point scale: 8 = extremely desirable, 1 = extremely undesirable.

to be approximately 0.80, 1.70, and 1.20 kg for the TB, BF, and RF, respectively.

Interestingly, WBS values increased as aging periods increased. This coincides with the results found by Sorheim et al. (2004). The current study and the one by Sorheim et al. (2004) were both done with the use of a high-oxygen MAP system. Both the TB and RF showed WBS increases of approximately 0.60 to 0.75 kg as the aging periods increased. However, no significant aging effects were observed for the RF. There were no significant interactions between pump and control steaks at the differing aging periods ($P \geq 0.050$).

Significant treatment and aging effects were observed for cooking loss (Tables 1 to 3). Pump TB steaks had 2.21% more cooking loss than control TB steaks. As aging increased in TB steaks, cooking loss decreased significantly. For the BF, a significant treatment × day interaction for cooking loss was noted. For d 1 and 7, the pump BF steaks had significantly greater amounts of cooking loss, whereas there was no difference between treatments on d 14. A similar treatment effect was noted for the RF, in which the pump steaks had significantly greater cooking loss. However, cooking loss increased significantly from d 1 to 7, but then decreased significantly from d 7 to 14.

Consumer Taste Panel Evaluations

Consumer sensory ratings for TB steaks found pump steaks to be significantly ($P \leq 0.050$) more desirable than control steaks for tenderness, juiciness, flavor, and overall acceptability (Table 4). Steaks aged for 1 d post treatment were significantly more desirable than steaks aged for 7 and 14 d for all traits. Those results are likely due to the oxidation and rancidity that occur quickly in a high-oxygen MAP. This portion of the study was done to test the sensory storage life in high-oxygen MAP.

Consumers of BF steaks found pump steaks to be significantly more desirable than control steaks for tenderness, juiciness, flavor, and overall acceptability (Table 5). The pump steaks were rated 1.23 points higher than control steaks for overall acceptability. Steaks aged for 1 d post treatment were always more desirable than steaks aged for 7 and 14 d for all traits.

Consumers rated RF pump steaks 1.45, 1.33, 1.07, and 1.34 points higher than control steaks for tenderness, juiciness, flavor, and overall acceptability, respectively (Table 6). Steaks aged for 1 and 7 d post treatment

Table 6. Least squares means for consumer taste panel ratings for rectus femoris beef steaks[1]

	Consumer taste panel[2]			
Item	Tenderness	Juiciness	Off-flavor	Overall acceptability
Treatment				
Control	3.67[a]	3.61[a]	3.72[a]	3.47[a]
Pump	5.12[b]	4.94[b]	4.79[b]	4.81[b]
SE	0.15	0.11	0.09	0.10
Age, d				
1	4.59[y]	4.62[y]	4.72[z]	4.53[y]
7	4.56[y]	4.36[y]	4.37[y]	4.27[y]
14	4.04[x]	3.85[x]	3.67[x]	3.62[x]
SE	0.17	0.19	0.15	0.17

[a,b]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[x–z]Means in the same column that do not have common superscripts differ ($P < 0.050$).
[1]Beef steaks randomly assigned to a control or pump treatment and then aged for 1, 7, or 14 d post-treatment.
[2]Based on an 8-point scale: 8 = extremely desirable, 1 = extremely undesirable.

were always more desirable ($P \leq 0.050$) than steaks aged for 14 d. There were no differences between d 1 and 7 post treatment except that steaks aged for 1 d had a more desirable flavor. For all steaks, there were no significant interactions between treatment (pump, control) and aging period.

Tenderness of beef chuck and round muscles improves when injected with a solution containing ammonium hydroxide and salt. Data indicate that the tenderness benefits of enhancement are not reduced by aging. However, as aging increased in a high-oxygen MAP, all steaks were less desirable for tenderness, juiciness, flavor, and overall acceptability. In addition, as the aging period increased, WBS values increased for TB and RF steaks. Further research may be needed to explore the effects of aging in a low-oxygen MAP with this enhancement system.

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