CHARACTERISTICS OF USDA UTILITY COW BEEF SUBJECT TO BLADE TENDERIZATION AND HYDRODYNAMIC SHOCK WAVES

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Accepted for Publication March 5, 2003

ABSTRACT

Longissimus lumborum samples were removed 24 h postmortem from six U.S. Utility carcasses to be utilized in determining the effects of tenderness enhancement methods and aging time on quality attributes of beef. Within each sample, sections were randomly assigned to hydrodynamic shock waves (HSW), blade tenderization (BT), a combination of BT and HSW (HSBT), or no treatment (C). Steaks within each treatment (excluding HSW) were aged for 7 and 14 days. Sensory evaluation included subjective ratings for myofibrillar tenderness, connective tissue amount, and overall tenderness. Objective measurements included thaw and cooking losses, shear force, and standard plate count. HSW and HSBT were effective in decreasing (P < 0.05) Warner-Bratzler peak force, total energy, and standard plate count. However, aging time (14 days) was more effective (P < 0.05) in decreasing peak force shear values than BT, HSW, or HSBT. Sensory values, thaw and cooking losses were not affected (P > 0.05) by any treatments.

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INTRODUCTION

Tenderness is the palatability trait with the most effect on consumer acceptability (Savell et al. 1989), and consumers are willing to pay more for increased tenderness (Savell and Shackleford 1992). Consumer reaction to tenderness of products determines if purchases are repeated (Morgan et al. 1991). Therefore, it is important that the beef industry provide consumers with a consistently tender product. Technology to enhance tenderness is economically important to consumers, processors, and producers since increased consumer satisfaction stimulates additional sales and profits. Tenderness enhancement of beef from mature cattle is especially important since increased chronological age is associated with decreased tenderness (Light 1987).

Solomon et al. (1997a, b) and Solomon (1998) demonstrated that hydrodynamic shock waves (HSW) are effective in improving tenderness by 49-72% in fresh and cold-shortened longissimus muscle from U.S. Select beef. However, Marriott et al. (2001) reported that HSW were ineffective in improving the tenderness of U.S. Commercial longissimus lumborum muscle. This difference could be due to HSW’s ability to affect the myofibrillar structure (Zuckerman and Solomon 1998) and its inability to affect the connective tissue component of tenderness that is more inherent in more mature cattle (Marriott et al. 2001).

Blade tenderization (BT) is commercially utilized to increase tenderness by partial severance of both connective tissue and muscle fibers, which leads to reduced shear force and mastication (Miller 1975). Wheeler et al. (1990) reported that BT improves tenderness in Brahman and Hereford beef cattle slaughtered at less than 18 months of age by decreasing shear force values and improving consumers’ sensory response to myofibrillar tenderness and connective tissue amount. Benito-Delgado et al. (1994) reported that BT was effective in decreasing shear values in post rigor longissimus muscle that was harvested from Angus crossbred steers (~18 months) and stored for 7 days but not 3 days. These studies demonstrate BT’s ability to improve tenderness, but this method also results in higher drip losses and reduced shelf-life during storage (Davis et al. 1977).

Presently, no single technique is accepted industry-wide for improving beef (especially mature beef) tenderness due to implementation costs, inefficiency, inconvenience, or adverse effects on other sensory attributes. Although technologies are available to enhance tenderness, problems such as unacceptable variability continue to exist. Due to the ability of BT to partially sever connective tissue, and the potential for HSW to disrupt the myofibrillar structure, the coupling of these two mechanisms may be effective in improving the tenderness of beef from mature cattle.
The objective of this study was to explore the efficacy of coupling HSW and BT to enhance the tenderness of cow beef (U.S. Utility). To evaluate the utility of these methods, each was utilized separately as well as in combination to determine the effects on the physical, sensory, and microbial properties of beef steaks from the longissimus muscle.

MATERIALS AND METHODS

Tenderness Enhancement Methods

Six cull cow carcasses that graded U.S. Utility were harvested at a commercial meat plant in Lynchburg, Virginia. At 24 h postmortem, 36 cm of M. longissimus lumborum (LD) was removed from one carcass side caudal to the 12th/13th thoracic vertebrae and was trimmed to 0.6 cm of external fat. The 6 LD muscles were vacuum packaged (Cryovac Sealed Air, Division of W.R. Grace & Co., Duncan, S.C.) then transferred approximately 160 km (2 h transit time) in an iced cooler to the Virginia Polytechnic Institute & State University Meat Laboratory, and stored at 2-3°C.

On the second day postmortem, the samples were transferred in an iced cooler approximately 500 km to a USDA research facility (USDA, Beltsville, Md.). Each muscle was cut into 4 sections based on random selection of treatments starting caudal to the 12th/13th thoracic vertebrae. These treatments consisted of the control (C), hydrodynamic shock wave (HSW), blade tenderization (BT), and a combination of the HSW and the BT (HSBT). The randomization was performed so that all regions of the muscle would receive each treatment at least once to account for tenderness variation within each muscle. Each treatment section was aged for 7 and 14 days to determine how aging time affected tenderness enhancement methods and beef quality. Sections were cut to 10.3 cm thickness for every treatment except for HSW. HSW was cut to 5.1 cm due to limitations in total length. These limitations prevented the application of the 14 days treatment to the HSW treated samples. At approximately 48 h postmortem, shock wave treatment was applied using 100 g of binary explosive (ammonium nitrate and nitromethane). Vacuum packaged meat sections for HSW were placed on a 1.3 cm thick 0.40 cm diameter steel plate, which was placed in the bottom of a 98-L plastic container (PEC) (Rubbermaid, Wooster, Ohio). The plastic containers were filled with water and the explosive was placed at a distance of 30.5 cm from the surface of the sample, and the explosive was detonated. Samples treated with BT and HSBT were passed once through a 378 blade manual system (Model MT-M, Lumar Ideal II, Longueil, Québec). Blade tenderization was applied to the HSBW after the hydrodynamic shockwave treatment was applied. The blade tenderizer consisted of 14 rows,
3” deep of blades and 27 columns, 7.38” wide of blades that were thin, flat blades with sharp points. Treated muscles were transported approximately 500 km in a styrofoam cooler packed with ice back to the VPI&SU Meats Laboratory and stored at 2-3C in vacuum packaged bags. At 7 (C, HSW, BT, HSBT) and 14 days (C, BT, HSBT) postmortem, sections were cut into 2.5 cm steaks. Simultaneously, standard plate count (SPC) was obtained for all treatments using a surface swab method. All steaks reserved for sensory and shear value analysis were again vacuum packaged and stored at -29C.

Standard Plate Count

A sterile cotton swab was rubbed over each treatment section of lean meat in 2 similar locations per treatment inside a 10 cm² template. The swab was placed into 10 mL of peptone water, and broken off. This allowed the cotton to soak in the peptone water and created a 10⁶ dilution. Appropriate dilutions were performed, and the solution was plated on Standard Methods Agar. After incubating the plates for 48 h at 35C, they were removed and the colonies were counted. Plates containing between 25 and 250 colony forming units (cfu) were enumerated to determine cfu/cm².

Shear Force Measurements

Frozen LD steaks for each treatment (within a muscle) and each aging time (7 and 14 days) were thawed at 4C for 20 h. Each steak was roasted to an internal temperature of 71C in a 165C Blodgett oven (GCS Service, Richmond, Va.) according to AMSA guidelines (1995). Cooked samples were cooled to approximately 20C (ambient temperature) and 8-10 cores (12.7 mm diameter) were removed parallel to the muscle fiber for each steak. These cores were sheared once with a Warner-Bratzler shear device attached to a computer interfaced Instron (Model 1011, Instron Corp., Canton, Mass.) equipped with a 50-kg load cell with a crosshead speed of 200 mm/min and 10% load range. The means for total energy (kg) and maximum peak force (kg) were calculated for each steak.

Sensory Evaluation

Control (7, 14 days), HSW (7 days), BT (7, 14 days), and HSBT (7, 14 days) LD steaks (2.5 cm thick) were cooked using the same procedure as for shear force determinations in order to evaluate sensory properties. Cooked samples were cut into 1 × 1 × 1 cm cubes and evaluated by an eight-member trained sensory panel. Panelists were trained following AMSA (1995) guidelines. Prepared samples were placed in a zip lock bag (S.C. Johnson & Son, Racine, Wisc.) and held in a 55C water bath until served. Tenderness (myofibrillar and
overall) and connective tissue amount were evaluated in individual booths (under 15 lux red light). Eight point scales $1 = \text{extremely tough}$ and $8 = \text{extremely tender}$ for myofibrillar and overall tenderness; and $1 = \text{abundant}$ and $8 = \text{none}$ for amount of connective tissue were used.

**Thaw Loss and Cook Loss**

Percentage thaw and cook losses were determined from samples cooked for shear force determinations. Thaw loss was the percentage of purge in the package after thawing and was calculated based on the difference between whole package weight and the weight of the bag and thawed product. Cooking loss values were calculated based on the weight of samples before and after cooking.

**Statistical Analyses**

A Randomized Complete Block Design with six replications was utilized to test the effects of aging time (7 or 14 days) and treatment (C, BT, HSW, and HSBT) in a $2 \times 4$ factorial design (General Linear Methods Procedure (GLM) Version 8.2, SAS, 1999 Cary, N.C.). Blocking reduced variation among replications caused by inherent tenderness differences among carcasses. Duncan's Multiple Range Test (Version 8.2, SAS, 1999 Cary, N.C.) was utilized to determine differences ($P<0.05$) among treatments.

**RESULTS AND DISCUSSION**

**Warner-Bratzler Shear Force**

Objective shear force measurements (Tables 1, 2) revealed that data from all tenderness enhancement methods did not differ ($P>0.05$) in Warner-Bratzler peak force required for shearing cored samples that were aged for either 7 or 14 days. Although not statistically significant ($P = 0.10$), HSW and HSBT treated samples had numerically lower peak force values than either the control or BT samples. Due to lack of interaction between time and treatments ($P>0.05$), data was pooled across time and are presented in Table 3. These data demonstrate that when aging times are grouped together, coupling blade tenderization with hydrodynamic shock waves was successful in decreasing ($P<0.05$) shear value peak force. These differences probably were not evident at 7 or 14 days due to lack of statistical power present to demonstrate differences. Seven or 14 days having a smaller sample size than when 7 and 14 day data is combined cause this lack of power. Tables 1, 2, and 3 also reveal that Warner-Bratzler total energy was improved at 14 days by HSBT utilization and when 7 and 14 days data were grouped together. The small differences in
objective measurements can be attributed to samples being acceptable in tenderness. Observations of effectiveness due to HSBT (7 and 14 days) and HSW (7 days) treatment were less evident at 16.7 and 19% decrease in peak shear force than those previously reported (Berry et al. 1997; Solomon et al. 1997a, b; Solomon 1998) (49-72%). However, these values were similar to those reported by Marriott et al. (2001) where a 10% decrease in shear value was exhibited.

HSW and HSBT demonstrated the potential to decrease shear value (Tables 1, 2, and 3), however aging for 14 days instead of 7 days also reduced ($P<0.05$) shear values by a similar amount, (0.80 kg; Fig. 1), with a 0.89 kg reduction by HSW, and a 0.71 kg by HSBT. Peak shear force for C, BT, and HSW decreased by 0.66, 0.94, and 0.91 kg, respectively at 14 days when compared to their 7 day counterpart. Greater statistical differences may have been evident in the tenderness enhancement treatments if samples were inherently less tender and if the initial tenderness values of the experimental units were more consistent (data not shown). Magnitude of the response to shock wave treatment varied from animal to animal (data not shown). However, there is no apparent explanation for the pattern observed. One plausible explanation is differences in sample size and acoustical match of samples with water provided variation in treatment response. However, the authors postulate that observed variation is attributed to differences in position and placement of samples in relationship to shock wave orientation.

Sensory Evaluation

Sensory scores for myofibrillar tenderness, overall tenderness, and connective tissue amount did not differ ($P<0.05$) among treatments (Table 1, 2, and 3). These results differ from those of Marriott et al. (2001) who found an 11.6% improvement ($P<0.05$) in the tenderness of commercial grade beef *longissimus* muscle, and from those reported by Berry et al. (1997) and Solomon (1998), who reported that shock wave treatment improved beef tenderness in select beef *longissimus* muscle. Our results may have differed slightly from these researchers due to utilization of U.S. Utility beef. Therefore, when utilizing beef that is inherently tender, use of HSW and/or BT is not able to improve beef tenderness. The lack of effectiveness of shock waves on connective tissue is in general agreement with other tenderness enhancement techniques, which tend to affect myofibrillar components more than stromal proteins. More studies on effects of HSW and HSBT are warranted, but it will be crucial to screen samples to assure they are not tender.
TABLE 1.
WARNER-BRATZLER SHEAR FORCE, SENSORY CHARACTERISTICS, PURGE LOSS, AND COOKING LOSS OF BLADE AND HYDRODYNAMIC SHOCK WAVE TREATED LONGISSIMUS MUSCLE
(at 7 day storage)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>Blade (BT)</th>
<th>Hydrodynamic Shockwave</th>
<th>Hydrodynamic Shockwave+ Blade</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>WARNER-BRATZLER SHEAR FORCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak force (kg)</td>
<td>4.59</td>
<td>4.54</td>
<td>3.70</td>
<td>4.05</td>
<td>0.29</td>
</tr>
<tr>
<td>Total energy (kg\times cm)</td>
<td>37.2</td>
<td>34.7</td>
<td>32.3</td>
<td>34.3</td>
<td>2.33</td>
</tr>
<tr>
<td>SENSORY EVALUATION(^c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myofibrillar Tenderness</td>
<td>5.58</td>
<td>5.76</td>
<td>5.86</td>
<td>5.79</td>
<td>0.20</td>
</tr>
<tr>
<td>Connective Tissue Amount</td>
<td>4.95</td>
<td>5.17</td>
<td>5.02</td>
<td>5.24</td>
<td>0.21</td>
</tr>
<tr>
<td>Overall Tenderness</td>
<td>5.29</td>
<td>5.57</td>
<td>5.62</td>
<td>5.52</td>
<td>0.21</td>
</tr>
<tr>
<td>PURGE LOSS (%)</td>
<td>1.48</td>
<td>1.50</td>
<td>2.15</td>
<td>1.94</td>
<td>0.26</td>
</tr>
<tr>
<td>COOKING LOSS (%)</td>
<td>19.7</td>
<td>20.5</td>
<td>19.8</td>
<td>18.4</td>
<td>1.07</td>
</tr>
<tr>
<td>STANDARD PLATE COUNT, (log(_{10}) g)</td>
<td>6.29(^a)</td>
<td>6.15(^ab)</td>
<td>5.94(^bc)</td>
<td>5.83(^bc)</td>
<td>0.13</td>
</tr>
</tbody>
</table>

\(^{a,b,c}\) Means bearing unlike superscripts within the same row are significant (\(P<0.05\))

Sensory scale:
Myofibrillar Tenderness: 8 = extremely tender, 1 = extremely tough
Connective Tissue Amount: 8 = none, 1 = abundant
Overall Tenderness: 8 = extremely tender, 1 = extremely tough
### TABLE 2.
WARNER-BRATZLER SHEAR FORCE, SENSORY CHARACTERISTICS, PURGE LOSS, AND COOKING LOSS OF BLADE AND HYDRODYNAMIC SHOCK WAVE TREATED LONGISSIMUS MUSCLE
(at 14 day storage)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>Blade (BT)</th>
<th>Hydrodynamic Shockwave + Blade</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>WARNER-BRATZLER SHEAR FORCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak force (kg)</td>
<td>3.93</td>
<td>3.60</td>
<td>3.14</td>
<td>0.31</td>
</tr>
<tr>
<td>Total energy (kg*cm)</td>
<td>32.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.93</td>
</tr>
<tr>
<td>SENSORY EVALUATION&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myofibrillar Tenderness</td>
<td>5.55</td>
<td>5.79</td>
<td>5.64</td>
<td>0.27</td>
</tr>
<tr>
<td>Connective Tissue Amount</td>
<td>5.21</td>
<td>4.69</td>
<td>5.00</td>
<td>0.16</td>
</tr>
<tr>
<td>Overall Tenderness</td>
<td>5.60</td>
<td>5.33</td>
<td>5.38</td>
<td>0.20</td>
</tr>
<tr>
<td>PURGE LOSS (%)</td>
<td>2.63</td>
<td>2.80</td>
<td>3.09</td>
<td>0.32</td>
</tr>
<tr>
<td>COOKING LOSS (%)</td>
<td>21.0</td>
<td>21.8</td>
<td>21.5</td>
<td>1.08</td>
</tr>
<tr>
<td>STANDARD PLATE COUNT, (log_{10}/g)</td>
<td>6.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.07</td>
</tr>
</tbody>
</table>

<sup>a</sup> Means bearing unlike superscripts within the same row are significant ($P < 0.05$)

<sup>c</sup> Sensory scale:
- Myofibrillar Tenderness: 8 = extremely tender, 1 = extremely tough
- Connective Tissue Amount: 8 = none, 1 = abundant
- Overall Tenderness: 8 = extremely tender, 1 = extremely tough
### TABLE 3.
WARNER-BRATZLER SHEAR FORCE, SENSORY CHARACTERISTICS, PURGE LOSS, AND COOKING LOSS OF BLADE AND HYDRODYNAMIC SHOCK WAVE TREATED LONGISSIMUS MUSCLE
(Based on the data of 7 day and 14 day storage across treatments)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>Blade (BT)</th>
<th>Hydrodynamic Shockwave+ Blade</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WARNER-BRATZLER SHEAR FORCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak force (kg)</td>
<td>4.26b</td>
<td>4.10b</td>
<td>3.55a</td>
<td>0.23</td>
</tr>
<tr>
<td>Total energy (kg*cm)</td>
<td>34.7b</td>
<td>32.7b</td>
<td>28.9a</td>
<td>1.59</td>
</tr>
<tr>
<td><strong>SENSORY EVALUATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myofibrillar Tenderness</td>
<td>5.67</td>
<td>5.65</td>
<td>5.71</td>
<td>0.12</td>
</tr>
<tr>
<td>Connective Tissue Amount</td>
<td>5.08</td>
<td>4.93</td>
<td>5.12</td>
<td>0.11</td>
</tr>
<tr>
<td>Overall Tenderness</td>
<td>5.44</td>
<td>5.45</td>
<td>5.45</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>PURGE LOSS (%)</strong></td>
<td>2.21</td>
<td>2.02</td>
<td>2.51</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>COOKING LOSS (%)</strong></td>
<td>20.7</td>
<td>21.1</td>
<td>20.3</td>
<td>0.67</td>
</tr>
<tr>
<td><strong>STANDARD PLATE COUNT, (log_{10}/g)</strong></td>
<td>6.41a</td>
<td>6.39a</td>
<td>5.99b</td>
<td>0.07</td>
</tr>
</tbody>
</table>

\[a, b\] Means bearing unlike superscripts within the same row are significant \(P<0.05\)

\[c\] Sensory scale:
Myofibrillar Tenderness: 8 = extremely tender, 1 = extremely tough
Connective Tissue Amount: 8 = none, 1 = abundant
Overall Tenderness: 8 = extremely tender, 1 = extremely tough
FIG. 1. EFFECTS OF AGING TIME (ACROSS TREATMENTS) ON WARNER-BRATZLER PEAK FORCE VALUES (kg) OF BEEF THAT WAS TREATED WITH THE CONTROL, HYDRODYNAMIC SHOCK WAVES, BLADE TENDERIZATION, AND A COMBINATION OF BLADE TENDERIZATION AND HYDRODYNAMIC SHOCK WAVES

Standard error bars are included for each treatment.
Standard Plate Count, Thaw Loss, and Cooking Loss

Data in Tables 1, 2, and 3 indicate that both HSW and HSBT were effective ($P<0.05$) in decreasing SPC. These results may be attributable to the high pressure causing membrane damage of the bacteria (Raloff 1998), and the possibility of the HSW causing surface bacteria to move towards the interior of the steak (Lorca et al. 2002). BT did not affect ($P>0.05$) SPC. This result is consistent with those of Benito-Delgado (1994), who also reported that BT did not affect SPC. Davis et al. (1977) demonstrated that BT did not affect psychrotrophic plate counts, but may cause decreased shelf-life through increasing the surface area of the meat and allowing the microorganisms to penetrate into the previously intact meat structure. Coupling BT with HSW may decrease SPC by increasing surface area from BT and causing membrane damage of the microorganisms from HSW. This decrease in SPC may lead to extended shelf-life, and if high enough pressure fronts were created, SPC could be decreased further leading to even longer shelf-life. Thaw loss and cooking loss were not affected $(P>0.05)$ by HSW, BT, or HSBT (Tables 1, 2, and 3). These observations seem reasonable since the treatment method applied should have a minimal effect on these traits (Solomon et al. 1997a, b).

CONCLUSIONS

Hydrodynamic shock waves (HSW) and the combination of hydrodynamic shock waves with blade tenderization (HSBT) slightly improved the instrumental tenderness and decreased the microbial counts of U.S. Utility cow beef. These effects were not consistently evident since some controls already exhibited acceptable shear force values. Aging for 14 days over 7 days tended to improve instrumental tenderness values more effectively than HSW and HSBT.

REFERENCES


