Internal Color and Tenderness of the *Longissimus Thoracis* Are Affected by Cooking Methods and Degree of Doneness

*M.D. Wharton, J.K. Apple, J.W.S. Yancey, J.T. Sawyer, and M.S. Lee*

**Story in Brief**

*Longissimus thoracis* (LT) steaks (*n* = 360) from USDA Select ribeye rolls aged 0 to 35 d at 35.6°F were used to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force (WBSF) and cooked beef color. Steaks were cooked to 3 different endpoint temperatures (150, 160 or 170°F) using: 1) an air-impingement oven (IMP); 2) clam-shell griddle (PANI); 3) forced-air convection oven (BLOD); 4) counter-top electric griddles (GRID); and 5) gas-fired, open-hearth char-grill (CHAR). Cooking steaks to 170°F took longer (*P* < 0.05) than cooking to 150°F, regardless of cookery methods, and, even though cooking losses were similar (*P* = 0.09) among cookery methods, cooking loss percentages for steaks cooked to 170°F were greater (*P* < 0.05) than steaks cooked to 150 and 160°F. The greatest (*P* < 0.05) and least (*P* < 0.05) WBSF values were in steaks cooked to 170 and 150°F, respectively, whereas steaks cooked in the BLOD had lower (*P* < 0.05) shear force values than steaks cooked on CHAR, GRID and PANI. Internal cooked color of LT steaks cooked to 150°F was the reddest (*P* < 0.05), and steaks cooked on CHAR were redder (*P* < 0.05) than steaks cooked on GRID, IMP and PANI. Cooking LT steaks to 150°F produced more tender steaks, with an obviously redder internal cooked color, than cooking to 170°F. Moreover, broiling LT steaks in the BLOD resulted in lower WBSF values, but internal cooked color was intermediate to other cookery methods.

**Introduction**

The *longissimus* muscle (LM) is probably the most studied muscle, especially in meat science, and, because LM steaks are more tender than other steaks from the sirloin and round (Neely et al., 1998; Lorenzen et al., 2003), it is the “gold standard” to which the palatability attributes of other cuts of meat are routinely compared (Savell and Shackelford, 1992). Cookery guidelines for research (AMSA, 1995) specify broiling/grilling steaks to 160°F, based on the finding that most consumers prepare LM steaks by grilling and broiling (Lorenzen et al., 1999). However, Lorenzen et al. (1999) reported that degrees of doneness for LM steaks were equally distributed among “rare to medium rare,” “medium,” “medium well” and “well done,” or greater, by consumers in Chicago, Houston, Philadelphia and San Francisco, whereas Wheeler et al. (1999) noted that 64 to 82% of beef consumers cooked beef between “medium” and “very well done” degrees of doneness. Moreover, research has demonstrated that shear force values increase (Lorenzen et al., 2003), and consumer ratings for tenderness decrease (Neely et al., 1998; Lorenzen et al., 1999) with increasing endpoint temperature.

Although a number of studies have tested the effects of cookery method and/or degree of doneness on the palatability attributes of beef LM steaks, little is known about the internal color changes associated with increasing degrees of doneness from “rare” to “well done” nor is there information concerning cookery method on internal color changes. Therefore, the objective of this research study was to test the effect of various cookery methods and internal endpoint temperature on Warner-Bratzler shear force and cooked beef color of *longissimus thoracis* steaks.

**Experimental Procedures**

USDA Select ribeye rolls were aged 0, 7, 14, 21, 28, or 35 d at 35.6°F (10 ribeye rolls/aging period) to develop a wide range in possible tenderness differences. After the aging period, six 1-in-thick *longissimus thoracis* (LT) steaks (*n* = 360) were cut from each primal, labeled, vacuum-packaged, and frozen at -22°F for approximately 60 d before cooking. Then, frozen steaks were randomly assigned to 1 of 15 treatments in a 3 × 5 factorial arrangement, with 3 endpoint temperatures (150, 160 or 170°F) and 5 cookery methods. Steaks were thawed overnight at 35.6°F; removed from vacuum-packages, and weighed. Steaks were then cooked to their assigned endpoint temperature in/on either: 1) an air-impingement oven (IMP); 2) a clam-shell griddle (PANI); 3) electric, counter-top griddles (GRID); 4) forced-air, convection oven (BLOD); or 5) gas-fired, open-hearth char-grill (CHAR). All cookery methods were preheated to 360°F before cooking, and internal temperature was monitored in steaks cooked in PANI, BLOD, GRID and CHAR by placing copper-constantan thermocouples in the geometric-center of each steak. Additionally, LT steaks cooked in the BLOD, PANI and CHAR were turned when the internal temperatures had reached 95, 100, and 105°F for 150, 160 and 170°F endpoint temperatures, respectively, whereas steaks cooked on GRID were turned every 4 min until reaching the appropriate endpoint temperature. Finally, belt speeds of the IMP were set at 20, 25 and 30 min to produce endpoint temperatures of 150, 160 and 170°F, respectively, and endpoint temperature of each IMP-cooked steak was confirmed at the completion with a hand-held thermometer.

Cooking times were recorded for each steak cooked, and, after a 1-h cooling period at room temperature, LT steaks were weighed to calculate cooking loss percentages. Then, each steak was sliced.
perpendicular to the cut surface, and instrumental color (L*, a*, and b* values), as well as reflectance values from 400 to 740 nm, was measured immediately after cutting with a Hunter Miniscan XL, equipped with a 9-mm aperture, and illuminant A. Immediately after cooked color data collection, six 0.5-in-diameter cores were removed parallel with the muscle fiber orientation, and each core was sheared once with a Warner-Bratzler shear force (WBSF) device attached to an Instron Universal Testing machine with a 110-lb compression load cell and a crosshead speed of 200 mm/min. The average peak shear force of the 6 cores was used for statistical analyses.

Data were analyzed as an incomplete block design with subprimal as the block and individual steak as the experimental unit. Analysis of variance was generated with the mixed model procedure of SAS (SAS Inst., Inc., Cary, N.C.), with cookery method, endpoint temperature, and the 2-way interaction included in the model as fixed effects and subprimal as the random effect in the model. Least squares means were calculated and separated statistically using pair-wise t-tests (PDIF option) when a significant \((P \leq 0.05)\) F-test was identified.

**Results and Discussion**

There was no cooking method by endpoint temperature interactive effect on WBSF, cooking loss, L*, a*, and b* values, as well as reflectance values from 630 over 580; however, an interaction existed for cooking time and b* values.

As expected, steaks cooked to 150°F had the lowest \((P < 0.05)\) WBSF, and those cooked to 170°F had the greatest \((P < 0.05)\) WBSF (Table 1). This agrees with Wheeler et al. (1999) and Lorenzen et al. (2003), who reported that increasing endpoint temperature also increases meat toughness. Steaks cooked in the BLOD had lower \((P < 0.05)\) WBSF values than those cooked on the CHAR, GRID, or PANI, whereas those cooked on the IMP were intermediate \((P > 0.05)\). The BLOD and IMP both use convection heating, whereas the GRID and PANI use convection heating and the CHAR uses a combination of convection and conduction, heating by both direct contact with the hot grills and hot air from the gas burners.

Not surprisingly, steaks cooked to 170°F had the greatest \((P < 0.05)\) cooking loss (Table 1); however, those cooked to 160°F had numerically, but not statistically \((P > 0.05)\), greater cooking losses than those cooked to 150°F. Cooking method did not affect \((P > 0.05)\) cooking loss in the LT. The BLOD had the longest \((P < 0.05)\) and the PANI had the shortest \((P < 0.05)\) cooking time at all 3 endpoint temperatures (Figure 1). When cooking to 150°F, steaks cooked on the IMP had longer \((P < 0.05)\) cook times than those cooked on the CHAR, whereas the GRID method was intermediate \((P > 0.05)\). Steaks cooked on the CHAR to 160°F took less time \((P < 0.05)\) than those cooked to 160°F on the GRID, which in turn, took less time \((P < 0.05)\) than those cooked to 160°F on the IMP. When cooking to 170°F, the CHAR and GRID methods had similar \((P > 0.05)\) cooking times, which were shorter \((P < 0.05)\) than cooking to 170°F on the IMP. In the BLOD, cooking to 150 and 170°F had the shortest \((P < 0.05)\) and longest \((P < 0.05)\) cooking times, respectively. Cooking steaks to 150 and 160°F on the CHAR resulted in similar \((P > 0.05)\) cooking times, which were shorter \((P < 0.05)\) than those cooked to 170°F on the CHAR. On the GRID and PANI, cooking steaks to 170°F took longer \((P < 0.05)\) than cooking to 150°F, and cooking to 160°F had intermediate \((P > 0.05)\) cooking times. Using the IMP, cooking to 150°F resulted in a shorter \((P < 0.05)\) cooking time than cooking to 160 or 170°F, which were similar \((P > 0.05)\).

Internal lightness (L*) values of the cooked steaks was not affected by end-point cooking temperature or cooking method (Table 1). Steaks cooked to 150°F had the reddest (highest a* value; \(P < 0.05\)) internal cooked color, and those cooked to 170°F were the least red \((P < 0.05)\). Steaks cooked on the CHAR were redder \((P < 0.05)\) than those cooked on the GRID, IMP, or PANI, whereas those cooked in the BLOD were intermediate \((P > 0.05)\). Differences in yellowness were significant \((P < 0.05)\) (Figure 2), but were numerically irrelevant as the largest b* difference was just over 4 units. Steaks cooked to 150°F in the BLOD or on the CHAR were more yellow (higher b* values; \(P < 0.05\)) than steaks from any other cooking method and endpoint temperature combination. Steaks cooked to 160 and 170°F had similar \((P > 0.05)\) b* values for all cookery methods, and on the GRID and PANI b* values were similar \((P > 0.05)\) regardless of end-point temperature. When cooked on the IMP, steaks cooked to 150°F were more yellow \((P < 0.05)\) than those cooked to 170°F, and steaks cooked to 160°F were intermediate \((P > 0.05)\).

**Implications**

As expected, shear force values, cooking losses and cook times increased, and internal cooked color became less red, with increasing endpoint temperatures, regardless of cookery method. Moreover, although char-grilling produced steaks with a redder internal cooked color than the other cookery methods, cooking steaks in a forced-air convection oven resulted in more tender steaks, especially when compared to steaks cooked on the char-grill, electric, counter-top griddles, and in the clam-shell griddle.

**Literature Cited**


Table 1. Main effects of endpoint temperature and cookery method on characteristics of cooked longissimus thoracis steaks.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Endpoint temperature</th>
<th>Cookery method¹</th>
<th>Cookery method²</th>
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<tbody>
<tr>
<td></td>
<td>150°F</td>
<td>160°F</td>
<td>170°F</td>
</tr>
<tr>
<td>Cook loss, %</td>
<td>26.2⁶</td>
<td>29.3⁵</td>
<td>35.2⁴</td>
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<td>WBSF, lb.</td>
<td>7.04⁶</td>
<td>7.50⁵</td>
<td>8.2⁴</td>
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<tr>
<td>L*</td>
<td>59.1</td>
<td>58.6</td>
<td>57.7</td>
</tr>
<tr>
<td>a*</td>
<td>20.1⁶</td>
<td>15.1⁵</td>
<td>12.2</td>
</tr>
</tbody>
</table>

¹BLOD = forced-air convection oven; CHAR = gas-fired, open-hearth char-grill; GRID = counter-top electric griddles; IMP = air-impingement oven; and PANI = clam-shell griddle.
²Warner-Bratzler shear force.
³L* = a measure of darkness to lightness (greater number indicates a lighter color); and a* = a measure of redness (greater number indicates a redder color).
⁴⁵⁶Within a row and main effect, least squares means lacking common superscript letters differ (P < 0.05).

Fig. 1. Interactive effect of cookery method and endpoint temperature on cook time of longissimus thoracis steaks. Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).
Fig. 2. Interactive effect of cookery method and endpoint temperature on yellowness (b* values) of internal cooked color of *longissimus thoracis* steaks (larger b* values indicates a more yellow color). Cookery methods were forced-air convection oven (BLOD), open-hearth char-grill (CHAR), counter-top electric griddles (GRID), an air-impingement oven (IMP), and clam-shell griddle (PANI).