Internal Color and Tenderness of the Infraspinatus Are Affected by Cooking Method and Degree of Doneness

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

Story in Brief

Infraspinatus (IF) steaks (n = 360) from USDA Select clods 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 loss percentage was greatest (P < 0.05) in steaks cooked to 170°F, and lowest (P < 0.05) in steaks cooked to 150°F, whereas steaks cooked on CHAR and PANI had the highest (P < 0.05) and lowest (P < 0.05) cooking losses, respectively. Steaks cooked in the BLOD to 170°F cooked the longest (P < 0.05), and steaks cooked on the PANI to 150°F had the shortest (P < 0.05) cook time. Steaks cooked to 150 and 170°F had the least (P < 0.05) and greatest (P < 0.05) WBSF, respectively, and steaks cooked on the PANI and in the BLOD had the least (P < 0.05) and greatest (P < 0.05) WBSF values, respectively. Steaks cooked on the PANI to 150°F had the reddest (P < 0.05) internal cooked color, whereas those cooked on the PANI to 170°F were the least (P < 0.05) red internally. Results of this experiment suggest that endpoint temperature has a greater impact on cook losses and mechanical tenderness than cookery method.

Introduction

Different cooking methods and endpoint temperatures have always been used when cooking steaks. According to AMSA (1995) guidelines, broiling is the most common cookery method for steaks. Tenderness of beef tends to decrease as end point temperature increases, and research has shown that the degree of doneness to which beef is cooked varies among U.S. consumers, with 64 to 82% of beef consumers cooking their steaks to “medium” to “very well done” (Wheeler et al., 1999).

When cooking beef from “rare” to “very well done,” obvious changes occur to the internal color of cooked meat. Myoglobin is the primary heme pigment responsible for fresh meat color, and, during cooking, myoglobin is denatured to varying degrees, thereby influencing the appearance of meat color (Gracia-Segovia et al., 2006). Therefore, the objective of this research study was to test the effect of cookery method and internal endpoint temperature on Warner-Bratzler shear force and cooked beef color of the infraspinatus steaks.

Experimental Procedures

USDA Select clods were aged 0, 7, 14, 21, 28, or 35 d at 35.6°F (10 clods/aging period) to develop a wide range in possible tenderness differences. After the aging period, six 1-in-thick infraspinatus (IF) 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, 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, 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

1 Department of Animal Science, Fayetteville

102
model. Least squares means were calculated and separated statistically using pair-wise t-tests (PDIFF option) when a significant (P ≤ 0.05) F-test was identified.

**Results and Discussion**

No interaction existed (P > 0.05) between endpoint temperature and cooking method for WBSF, cooking loss, L* (lightness), or b* (yellowness), whereas cooking time and a* (redness) had interactions (P < 0.05) between endpoint temperature and cooking method.

Steaks cooked to 150°F had longer (P < 0.05) WBSF (Table 1) than those cooked to 160 or 170°F, which were similar (P > 0.05). Wheeler et al. (1999) confirms these results stating that higher endpoint temperatures lead to an increased WBSF and a less tender steak. Cooking method did not affect (P = 0.324) WBSF.

Not surprisingly, steaks cooked to 150°F had the lowest (P < 0.05) cooking losses (Table 1), and those cooked to 170°F had the greatest (P < 0.05). It is generally understood that higher endpoint temperatures result in greater cooking losses. Cooking steaks on the CHAR resulted in the greatest (P < 0.05) cooking loss, and the conduction cooking methods of GRID and PANI resulted in the least amount (P < 0.05) of losses during cooking. Cooking with air, as with the CHAR, BLOD, and IMP, apparently led to greater evaporation of intramuscular moisture.

Steaks cooked on the PANI had the shortest (P < 0.05) cook time (Figure 1), regardless of temperature. Surprisingly, when cooked on the PANI, steaks cooked to 150°F had similar (P > 0.05) cook times to those cooked to 170°F, whereas those cooked to 160°F had shorter (P < 0.05) cooking times than those cooked to 170°F. Steaks cooked in the BLOD had longer (P < 0.05) cook times than those cooked on any other cooking method, with the exception of the IMP (P > 0.05). Furthermore, steaks cooked on the IMP were similar (P > 0.05) in cooking time to those cooked on the GRID. The GRID had longer (P < 0.05) cooking times than the CHAR when steaks were cooked to 160 and 170°F; however, when cooking steaks to 150°F, the IMP and GRID were similar (P > 0.05) to CHAR. Within each cooking method, cooking steaks to 170°F took longer (P < 0.05) than cooking to 150 or 160°F, and cooking to 160°F had numerically longer (P < 0.05) cook times than to 150°F, but the differences were only significant for steaks cooked on the GRID (P < 0.05).

Neither cooking method (P = 0.109) nor endpoint temperature (P = 0.461) affected lightness (L* values) of *infraspinatus* steaks (Table 1). When cooking to 150°F, all 5 cooking methods had similar (P < 0.05) redness (a*) values (Figure 2). Moreover, when cooking to 170°F, all cooking methods had similar (P > 0.05) redness (a*) values, and, not surprisingly, the steaks cooked to 150°F were redder (P < 0.05) than those cooked to 170°F for each method. Steaks cooked at a lower temperature tend to have a higher redness (a*) value than those steaks cooked at a higher temperature indicating more myoglobin degradation (Gracía-Segovia et al., 2006). When cooked in the BLOD and on the CHAR, *infraspinatus* steaks cooked to 160°F were similar (P > 0.05) in redness to those cooked to 150°F and were greater (P < 0.05) than those cooked to 170°F. It was interesting that the convection-type cooking methods of BLOD and CHAR had redness values for “medium” steaks that were similar to those of “medium rare.” In contrast, when cooking on the GRID, IMP, or PANI, steaks cooked to 160°F were less red (P < 0.05) than those cooked to 150°F and were similar (P > 0.05) to those cooked to 170°F. These methods produced internal redness in “medium” steaks similar to those of “medium well.” Steaks cooked to 150°F were more yellow (higher b*; P < 0.05) (Table 1) than those cooked to 170°F, whereas those cooked to 160°F were intermediate (P > 0.05). Cooking method did not affect (P > 0.05) yellowness (b*) values.

**Implications**

Even though cooking in a clam-shell grill resulted in *infraspinatus* steaks with the lowest cooking losses and shear force values, information from this study indicates that endpoint temperature has a greater impact on cooking losses, cook time, shear force measured tenderness, and internal color than any cookery method.

**Literature Cited**


---

**Table 1. Main effects of endpoint temperature and cookery method on characteristics of cooked *infraspinatus* steaks.**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Endpoint temperature</th>
<th>Cookery method</th>
<th>SEM</th>
<th>BLOD</th>
<th>CHAR</th>
<th>GRID</th>
<th>IMP</th>
<th>PANI</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150°F</td>
<td>160°F</td>
<td>170°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cook loss, %</td>
<td>26.1c</td>
<td>29.2b</td>
<td>34.4a</td>
<td>0.36</td>
<td>31.0c</td>
<td>33.5b</td>
<td>27.0a</td>
<td>30.5b</td>
<td>27.7c</td>
</tr>
<tr>
<td>WBSF, lb</td>
<td>6.39c</td>
<td>7.10b</td>
<td>7.20a</td>
<td>0.189</td>
<td>6.65</td>
<td>7.06</td>
<td>6.80</td>
<td>7.05</td>
<td>6.93</td>
</tr>
<tr>
<td>L*</td>
<td>53.5</td>
<td>53.6</td>
<td>54.1</td>
<td>0.46</td>
<td>53.1</td>
<td>53.7</td>
<td>53.0</td>
<td>54.8</td>
<td>53.9</td>
</tr>
<tr>
<td>b*</td>
<td>17.1a</td>
<td>16.4b</td>
<td>15.8b</td>
<td>0.37</td>
<td>15.8</td>
<td>17.0</td>
<td>16.0</td>
<td>16.9</td>
<td>16.5</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-Batzler shear force.

3L* = a measure of darkness to lightness (greater number indicates a lighter color) and b* = a measure of yellowness (greater number indicates a more yellow color).

a,b,cWithin 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 *infraspinatus* 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 redness (a* values) of internal cooked color of *infraspinatus* steaks (greater a* values indicates a redder 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).